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3D Resistivity Modeling of Aquifers Based on Geoelectrical Data in Parungmulya Village, Karawang, West Java

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Abstract: Water supply provision in Parungmulya Village, Karawang Regency, West Java, faces challenges in accessing clean water. This study aims to identify groundwater potential in the area using the resistivity geoelectric method. Measurements were conducted along six survey lines using the Schlumberger configuration to analyze subsurface layer characteristics and aquifer potential. The results indicate that a sandstone layer with high porosity and permeability has the potential to serve as a groundwater source for the local community. The resistivity values for this sandstone range from 306 to 2675 Ohm.m, with a maximum volume of 7,178.1 m^3. This layer demonstrates a significant capacity for storing and transmitting groundwater. Additionally with a resistivity range of 306 to 2,675 ohm·m and an estimated volume of 7,178.1 m^3. In addition, the tuffaceous sandstone layer is the most extensive aquifer in the study area, with resistivity ranging from 408 to 1,488 ohm·m and a total volume of 28,892 m^3. The findings of this study are expected to serve as a foundation for groundwater exploration planning to mitigate the water shortage problem in Parungmulya Village.

Keywords: Karawang, Resistivity, Geoelectrical, Schlumberger Configuration.

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INTRODUCTION

Groundwater is water located beneath the Earth's surface or within rock layers. It originates from rainwater that infiltrates the soil and accumulates in aquifer layers. An aquifer is a subsurface layer capable of absorbing and transmitting fluids, consisting of porous sedimentary rocks such as sand, gravel, and limestone, as well as fractured crystalline rocks such as granite, which allow water to flow toward wells or springs **[1]**. Based on the impermeability of the rock layers surrounding the aquifer, there are several types of aquifers: confined aquifer, semi-confined aquifer, semi-unconfined aquifer, and unconfined aquifer **[2]**.

One of the commonly used methods for detecting groundwater presence is the geoelectric resistivity method. This method operates by injecting an electric current into the ground through a pair of electrodes and then measuring the voltage formed on the surface **[3]**. Several configurations of the geoelectric resistivity method include Wenner, Schlumberger, Wenner-Schlumberger, Dipole-Dipole, Pole-Pole, and Wenner-Alpha configurations **[4]**. In this study, the applied geoelectric method is the Schlumberger configuration. This method is widely used to address various groundwater-related issues, such as determining the thickness, depth, and boundaries of groundwater layers, identifying potential groundwater zones, and assessing groundwater quality **[5]**.

Parungmulya Village is located in Ciampel District, Karawang Regency, West Java Province. Most of the residents of Parungmulya Village rely on well water, both dug wells and bore wells, to meet their daily needs. Based on observations, the local community faces challenges in accessing clean water. Given the rapid development of industrial, agricultural, and urbanization sectors in this area, the demand for clean water has become a pressing issue. Identifying groundwater sources is crucial to helping the residents of Parungmulya Village determine well-digging locations that can provide high-quality clean water while supporting sustainable development in the region.

Based on the explanation above, this study aims to identify aquifer layers and determine the potential groundwater sources in Parungmulya Village using the Schlumberger configuration geoelectric method. The data obtained will be preliminarily analyzed and presented in the form of two-dimensional and three-dimensional models. Although previous studies in this basin have generally used one-dimensional geoelectric methods to estimate groundwater depth, these techniques are often unable to capture the complex variations of the Subang Formation. This formation consists of layers of claystone and local glonkonitic tuff sandstone that exhibit abrupt facies changes, making it difficult to determine aquifer continuity. By processing and analyzing the data through integrated one-dimensional and three-dimensional volumetric inversion, this study offers new insights into the structure of subsurface fluid pathways. This spatial modeling represents an advanced approach that is crucial for accurately characterizing the geometry of productive aquifers, while also reducing the risk of drilling failure in the complex geological environment of Parungmulya.

METHODS

The research method used in this study is the resistivity geoelectric method, one of the geoelectric techniques aimed at examining the resistivity properties of subsurface rock layers. This method works by injecting an electric current into the ground using two current electrodes placed at a certain distance. Then, the potential difference that arises is measured using two potential electrodes also placed on the surface **[6]**. Data collection was conducted around Parangmulya Village, Karawang Regency, West Java, on November 16-17, 2024.

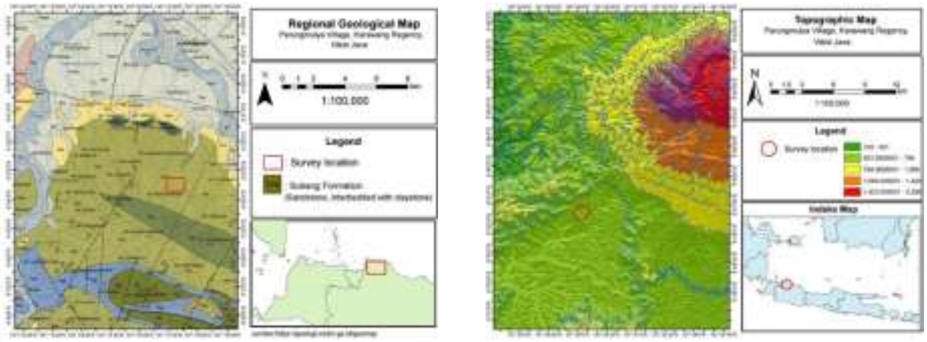


Figure. 1 (a) Regional Geological Map of Parungmulya Village, Karawang, West Java
(b) Topographic Map of Parungmulya Village, Karawang, West Java

The area of Parungmulya Village, Karawang Regency, belongs to the Subang Formation, which consists of conglomerate sandstone deposits, siltstone, tuffaceous sandstone, and deposits from floodplains and young rivers. The underlying layer is composed of layered gray marl, which then transitions into clay with thin sand intercalations. In the middle section, there is conchoidal clay rich in concretions, while the upper part is dominated by greenish-gray clay with tuffaceous sandstone intercalations containing glauconite. Additionally, planktonic fossils such as *Globorotalia tumida, Globorotalia lenguangensis*, and *Globorotalia pleisiotumida* are found in the Subang Formation, indicating that this formation dates to N17 or the Late Miocene **[7]**. Topographically, this area is at an elevation of 46 to 176 meters above sea level, indicating a landscape of lowlands to hilly terrain. This study conducted six measurement traverses using the Schlumberger electrode configuration.

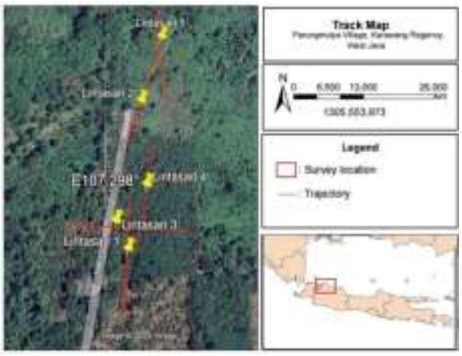


Figure. 2 Track Map

Table 1. Geolectric Track Design

Track	Track Length (m)
Track 1	100
Track 2	100
Track 3	100
Track 4	100
Track 5	200
Track 6	200

The Schlumberger configuration in the resistivity geoelectric method uses four electrodes, consisting of two current electrodes (A and B) and two potential electrodes (M and N) arranged in a straight line **[8]**.

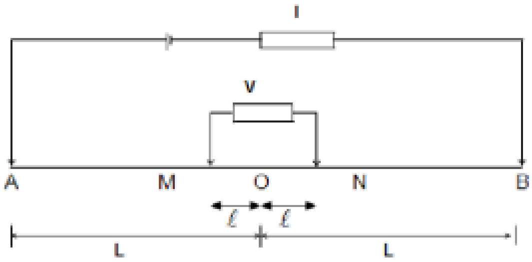


Figure. 3 Schlumberger Configuration Circuit

The resistivity obtained from these measurements is apparent resistivity (ρa), which is the resistivity derived from the assumption that the Earth has homogeneous layers **[9].** This apparent resistivity (ρa) value can be expressed by the following equation: **[10]**

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

With the Schlumberger Configuration geometric factor:

$$k = \pi \frac{(L^2 - l^2)}{2l} \quad (2)$$

The geoelectric survey was conducted using the main equipment, including 1 set of Irys Syscal Junior Resistivitymeter, 4 cable reels of 200 meters each, 4 yellow cables (2 for current and 2 for potential), 4 measuring tapes of 100 meters each, and 10 metal electrodes. Supporting equipment included 3 handy talkies, GPS, 4 hammers, and a location map.

Field data acquisition was carried out following the procedures established based on the following flowchart:

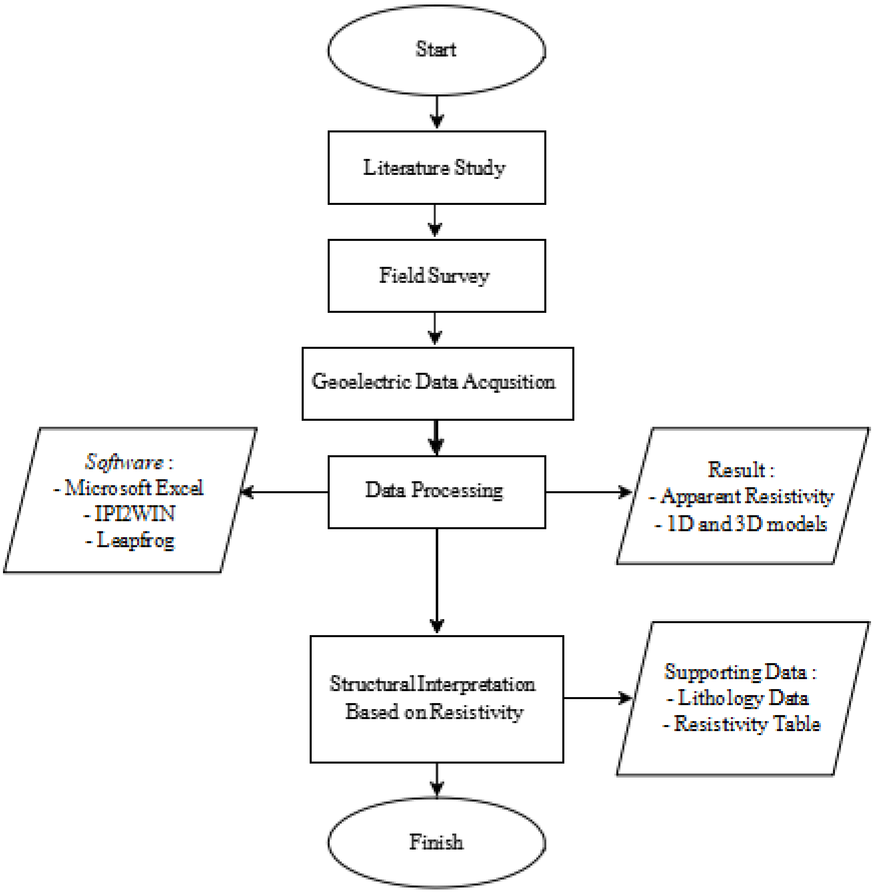


Figure. 3 Research Flowchart

RESULTS AND DISCUSSION

Based on the interpretation of resistivity data, six main lithological layers were identified across five 1D model transects. These layers exhibit varying resistivity characteristics, reflecting differences in their compositional components. The interpretation results refer to the resistivity values table by Telford (1990), identifying geological structures such as clay layers, hard rock formations, and potential groundwater zones.

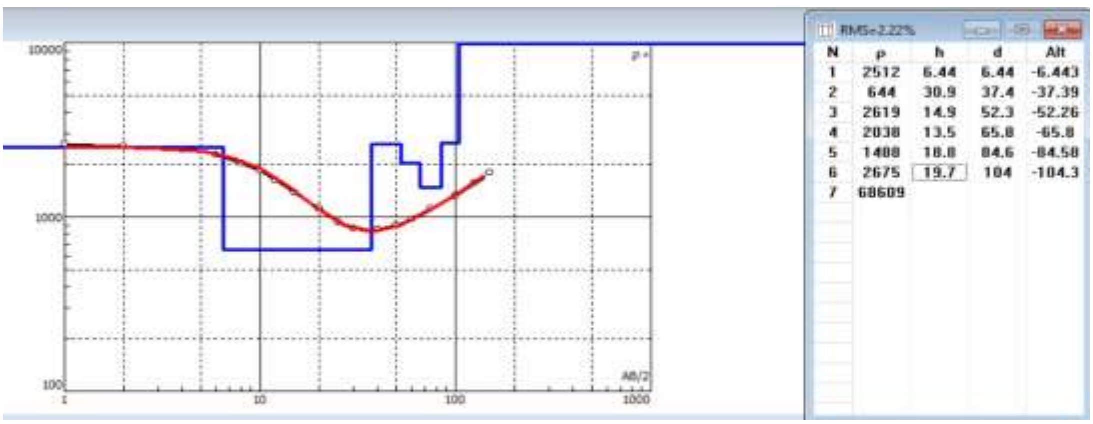


Figure. 4 The First 1D Track Model

The data processing results for transect 1 reveal six distinct soil layers at the surface. From a depth of 0 to 2.02 meters, topsoil is present. Between 2.02 and 9.82 meters, sandstone is found, which has pores that allow water to pass through, indicating the potential for an unconfined aquifer. From 9.82 to 23.6 meters, limestone with low porosity is present, making it less effective at storing water. Between 23.6 and 42.9 meters, clay limestone is identified, which has slightly better water retention due to its low porosity. From 42.9 to 68.6 meters, tuff sandstone is present, where water flows through its pores, suggesting the presence of a localized aquifer. Finally, at depths of 68.6 to 100 meters, compact and dense sandstone is found, which is not easily able to store water.

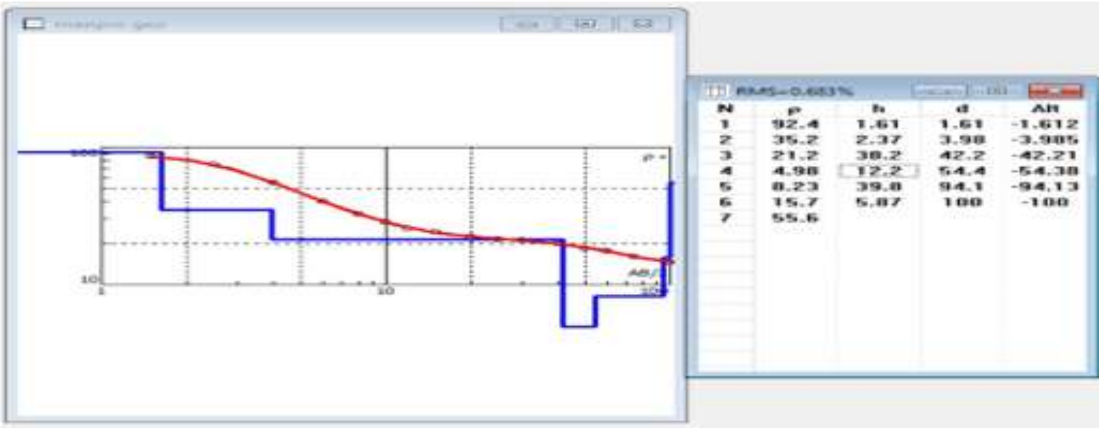


Figure. 5 The Second 1D Track Model

The data processing results for transect 3 reveal five distinct soil layers at the surface. From a depth of 0 to 3.07 meters, topsoil is present. Between 3.07 and 15.7 meters, clay sand is identified as a potential unconfined aquifer due to the dominance of sand, allowing water to pass through. From 15.7 to 37 meters, sand is present, serving as a potential aquifer due to its high porosity and moderate to high permeability, which enables it to store and transmit water effectively. Between 37 and 60.8 meters, claystone is found, which is not easily permeable to water. Finally, from 60.8 to 100 meters, sand claystone is present, acting as a potential localized aquifer.

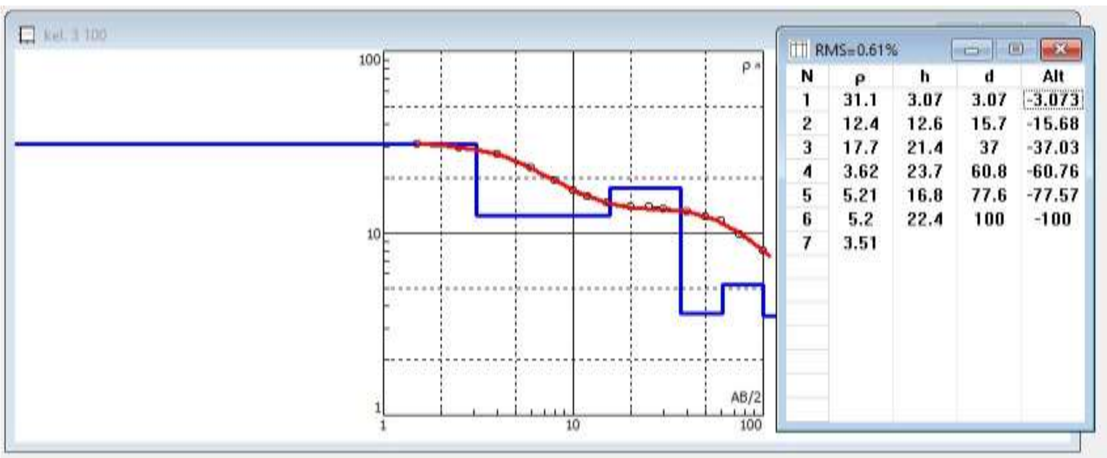


Figure. 6 The Third 1D Track Model

The data processing results for transect 3 reveal five distinct soil layers at the surface. From a depth of 0 to 3.07 meters, topsoil is present. Between 3.07 and 15.7 meters, clay sand is identified as a potential unconfined aquifer due to the dominance of sand, allowing water to pass through. From 15.7 to 37 meters, sand is present, serving as a potential aquifer due to its high porosity and moderate to high permeability, which enables it to store and transmit water effectively. Between 37 and 60.8 meters, claystone is found, which is not easily permeable to water. Finally, from 60.8 to 100 meters, sand claystone is present, acting as a potential localized aquifer.

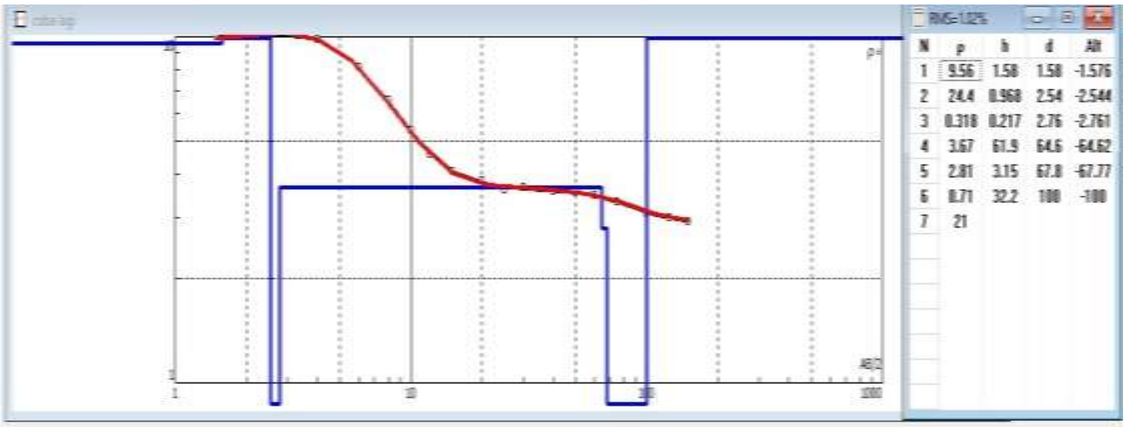


Figure. 7 The Fourth 1D Track Model

The data processing results for transect 4 reveal five distinct soil layers at the surface. From a depth of 0 to 1.43 meters, topsoil is present. Between 1.43 and 2.51 meters, clay sand is identified as a potential unconfined aquifer. From 2.51 to 2.72 meters, claystone is found, which cannot store water due to its low porosity. Between 2.72 and 47.4 meters, sand claystone is present, serving as a potential localized aquifer. Finally, from 47.4 to 100 meters claystone is identified.

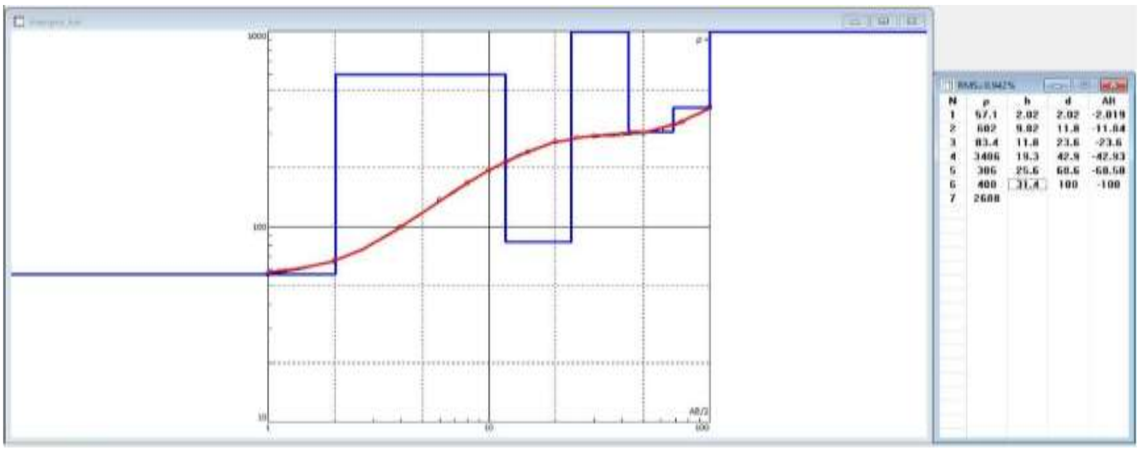
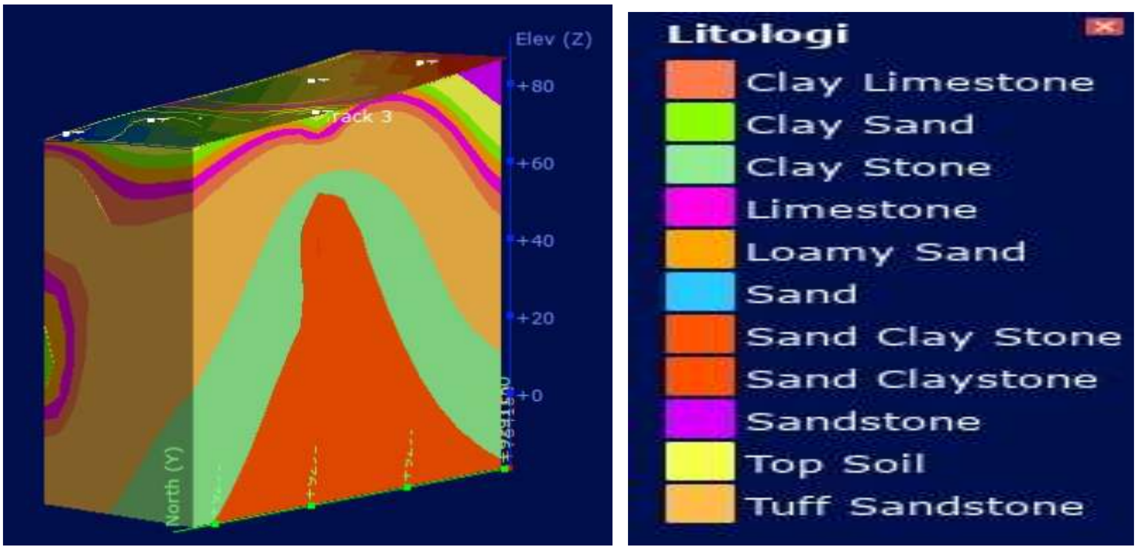


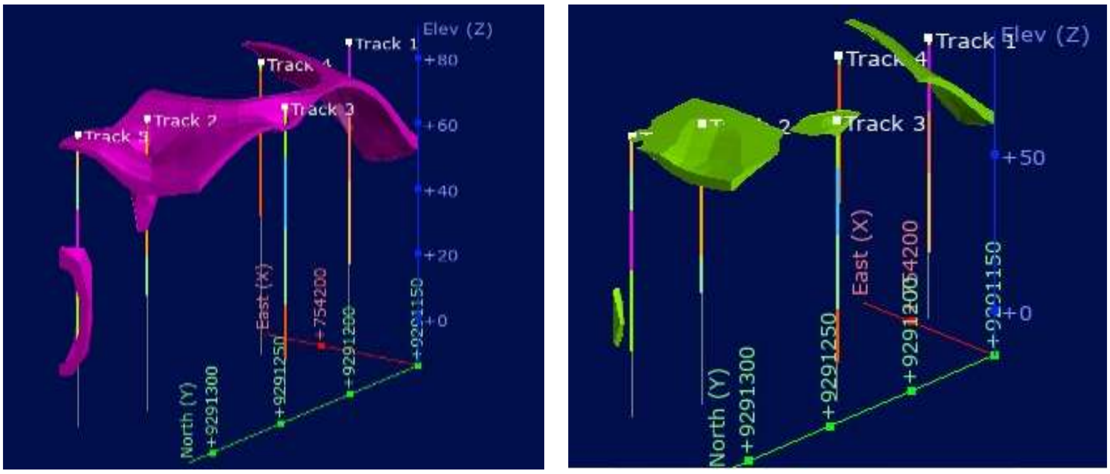
Figure. 8 The Fifth 1D Track Model

The data processing results for transect 5 reveal six distinct soil layers at the surface. From a depth of 0 to 2.02 meters topsoil is present. Between 2.02 and 11.8 meters, tuff sandstone is identified as a potential unconfined aquifer. From 11.8 to 23.6 meters, claystone is found, which is impermeable due to its low permeability. Between 23.6 and 42.9 meters, limestone with low porosity is present, preventing water from passing through. From 42.9 to 68.6 meters, sandstone serves as an aquifer due to its high porosity and permeability, allowing it to store and transmit water effectively. Finally, from 68.6 to 100 meters, tuff sandstone is present as a potential localized aquifer. This is due to increasing depth, which leads to higher pressure and potential mineralization **[11]**, causing a decrease in resistivity compared to shallower tuff sandstone.

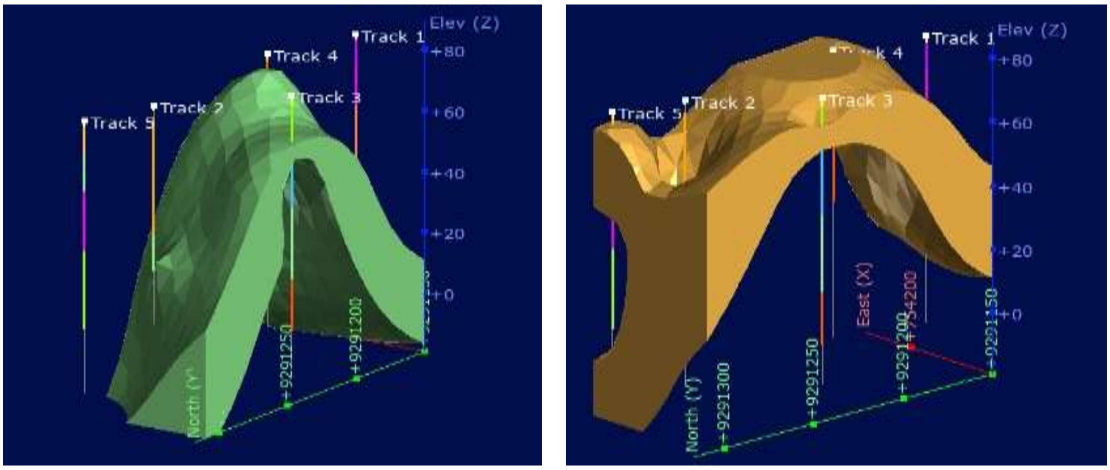


(a) (b)

Figure. 9 ((a) 3D Model of the Southeast Direction
(b) 3D Lithology Model



(a) (b)



(c) (d)

Figure. 10 3D Litology (a) Sandstone (b) Clay Sand (c) Claystone (d) Tuff Sandstone

The 3D aquifer modeling based on resistivity data and rock volume illustrates the distribution of various geological structures that can form aquifers. It highlights distinct properties that indicate variations in subsurface electrical conductivity.

Topsoil exhibits highly variable resistivity, ranging from 9.56 to 2512 Ωm, reflecting differences in water content, mineral composition, and organic matter. Higher resistivity indicates drier or more compact soil, while lower resistivity suggests higher water content and organic material. Sandstone, with a resistivity range of 306 to 2675 Ωm, is highly permeable and serves as a potential aquifer. A resistivity of 644 Ωm indicates the aquifer's ability to store a significant amount of water, with higher resistivity values suggesting areas of lower porosity or reduced water content. Limestone layers, with resistivity values between 2038 and 3486 Ωm, exhibit low permeability and the potential to retain groundwater, as denser and less porous limestone acts as a barrier to groundwater flow. In contrast, claystone, with a resistivity range of 0.318 to 83.4 Ωm, has very low permeability, serving as a barrier to groundwater movement while retaining a substantial amount of water. Clay sandstone, with resistivity values ranging from 2.81 to 5.21 Ωm, has good water retention properties but lower hydraulic conductivity compared to sandstone.

Clay sand layers are a mixture of sand and clay with resistivity ranging from 12.4 to 46.854 Ωm and moderate permeability. The sand content allows water to flow, while the clay content restricts water movement, especially in areas with lower resistivity. Sand, with resistivity values between 17.7 and 35.2 Ωm, facilitates groundwater flow, while lower resistivity indicates higher water content and finer grain sizes. Tuff sandstone , with resistivity ranging from 408 to 1488 Ωm, exhibits potential as an aquifer. A resistivity of 408 Ωm reflects the aquifer's ability to store a significant amount of water, whereas higher resistivity values indicate areas with lower porosity or reduced water content.

The largest volume, approximately 7,178.1 m^3, consists of sandstone, which functions as a non-injected local aquifer with high porosity and permeability, allowing it to store and transport groundwater in significant volumes. Limestone, with a volume of 1,894.2 m^3, exhibits varying properties depending on the degree of fracturing and dissolution. When karstification occurs, it acts as a groundwater reservoir, but in larger quantities, it serves as an impermeable rock.Sandstone, with a volume of 28,892 m^3, acts as a local unconfined aquifer, with its aquifer properties varying depending on pore structure. Sandy clay, with a volume of 197.12 m^3, serves as a transitional layer with moderate permeability, allowing limited water movement. The remaining clay sand, with a volume of 180.89 m^3, functions either as an aquifer or an impermeable layer, depending on its sand composition. Sand claystone, with a volume of 3,369.1 m^3, is widely distributed and controls groundwater flow, but the presence of clay restricts water movement. Claystone, with a volume of 125.25 m^3, and another claystone layer of 158.37 m^3 act as impermeable layers that limit both lateral and vertical groundwater movement. Sand, with a volume of 142.4 m^3, functions as a non-injected local aquifer, facilitating groundwater movement and storage. Finally, for clayey limestone with a volume of 185.1 m^3, its material composition determines whether it functions as an aquifer or an impermeable rock.

Overall, the 3D modeling shows that the main groundwater resources in Parungmulya Village are primarily stored in a porous sandstone layer (7,178.1 m^3) and a tuffaceous sandstone layer (28,892 m^3), which act as the largest regional reservoirs. Meanwhile, the dense claystone unit functions as a watertight aquiclude that structurally seals off and controls groundwater movement. These findings are consistent with the hydrogeological framework published in Applied Hydrogeology by Fetter (2001), which states that groundwater storage and flow within sedimentary rock successions are directly controlled by the primary porosity and intergranular permeability of each lithology **[12]**. Furthermore, these results align with the classic model by Freeze and Cherry (1979), which explains that aquifer systems develop preferentially within highly porous clastic rock matrices beneath a supporting structural seal **[13]**. This finding reinforces the results of the study.

CONCLUSION

This research focuses on 3D resistivity modeling of the aquifer in Parungmulya Village, Karawang, West Java, using the Schlumberger configuration geoelectric method with the aim of identifying aquifer layers and evaluating groundwater potential. Geoelectric data was collected with six measurement passes and analyzed using Microsoft Excel, IPI2Win, and Leapfrog 5.0 software to produce 1D and 3D models.

The research results show that the sandstone layer with high porosity and permeability functions as the main aquifer. The resistivity value for sandstone ranges from 306 to 2675 Ohm.m, with the largest volume reaching 7,178.1 m^3. This layer has the ability to store and drain large amounts of ground water. In addition, the tuff sandstone layer shows potential aquifers with resistivity values between 408 to 1488 Ohm.m and a volume of 28,892 m^3. The clay layer, with a resistivity value between 0.318 to 83.4 Ohm.m, acts as a waterproof layer that limits groundwater flow. This layer has varying volumes, such as clay stone with a volume of 125.25 m^3 and sandy clay stone with a volume of 3369.1 m^3. Clay-sand and clay-sand layers were also found with resistivity values ranging from 2.81 to 46,854 Ohm.m, which have good water retention properties but with lower hydraulic conductivity. Overall, the results of identifying the main aquifer layers are located in the sandstone, tuff sandstone, clay sand and sand layers.

It is hoped that further research will carry out continuous monitoring of the quality and quantity of groundwater, as well as exploring the potential of aquifers in other areas, to ensure sustainability and more effective management of water resources in the future.

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