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Article

Aquifer Identification Using the Schlumberger Vertical Electrical Sounding (VES) Method in Mulyojati Village, Metro Barat Subdistrict, Metro City

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Abstract. Groundwater is ideally expected to be available in a sustainable manner and managed based on adequate subsurface hydrogeological information. However, conditions in Mulyojati Village, Metro Barat Subdistrict, Metro City indicate a lack of site-specific data on aquifer characteristics, despite increasing groundwater demand driven by population growth and socio-economic activities. This limitation may lead to uncertainty in well drilling planning and groundwater utilization. Therefore, an effective preliminary exploration method is required to identify groundwater-bearing layers. This study applies the Vertical Electrical Sounding (VES) method using the Schlumberger configuration to investigate subsurface resistivity variations related to lithology and groundwater saturation. The urgency of this research arises from the absence of previous geophysical investigations in the area, particularly within the heterogeneous Qpt Formation, which is considered a potentially productive aquifer. The objective of this study is to characterize subsurface resistivity and delineate potential aquifer zones in Mulyojati Village. The results are expected to provide essential baseline information for groundwater development planning and support sustainable groundwater resource management in the Metro City area.

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1. Introduction

The major source of clean and safe water accessed globally for multi-purpose uses is groundwater [1]. Groundwater plays a vital role as a primary source of clean water, particularly in areas where surface water availability is limited [2]. The occurrence of groundwater is closely controlled by geological conditions [3], lithology, and subsurface structures, making site specific investigations essential using geophysical and hydrogeological methods for effective groundwater resource planning [4]. To estimate subsurface formations, it is necessary to carry out investigations to determine the presence or absence of a groundwater-bearing layer, commonly known as an aquifer [5].

Mulyojati Village, located in Metro Barat Subdistrict, Metro City, has experienced increasing population growth and socio and economic development, leading to higher demand for reliable groundwater sources [6-7]. Despite this demand, information on local groundwater potential remains limited, resulting in uncertainty in borehole placement and groundwater development planning. This condition highlights the need for a subsurface investigation that can provide preliminary insight into groundwater bearing layers. To date, there have been no published studies that specifically apply geoelectric methods to investigate aquifer characteristics in Mulyojati Village. The measurement points for this study are located within the Qpt formation, which generally consists of Quaternary volcanic and pyroclastic deposits. This type of formation often exhibits heterogeneous subsurface properties, which can potentially affect groundwater distribution. However, there is drilling data located in Karangrejo Village with the same formation as the research site.

The Vertical Electrical Sounding (VES) method with Schlumberger configuration is a geophysical technique commonly used for preliminary groundwater exploration, as it allows the identification of subsurface resistivity variations related to lithology and groundwater saturation [8]. By analyzing resistivity responses, this method provides valuable information about subsurface layers and potential aquifer zones [9]. Therefore, this study aims to investigate the subsurface resistivity characteristics in Mulyojati Village using the VES method to identify potential aquifer layers in the Qpt formation. The results are expected to provide essential basic information for groundwater development planning and contribute to the understanding of site-specific hydrogeology in the Metro City area.

2. Research Method

2.1. Research Location

This research was conducted in Mulyojati Village, Metro Barat Subdistrict, Metro City, Lampung Province. The geoelectrical data used in this study were acquired by the Center for Groundwater and Environmental Geology (Pusat Air Tanah dan Geologi Tata Lingkungan). The study area was selected due to the increasing demand for groundwater resources and the limited availability of site-specific subsurface information to support groundwater development planning. Data acquisition was carried out at five (5) Vertical Electrical Sounding (VES) measurement points, as shown in Figure 1.

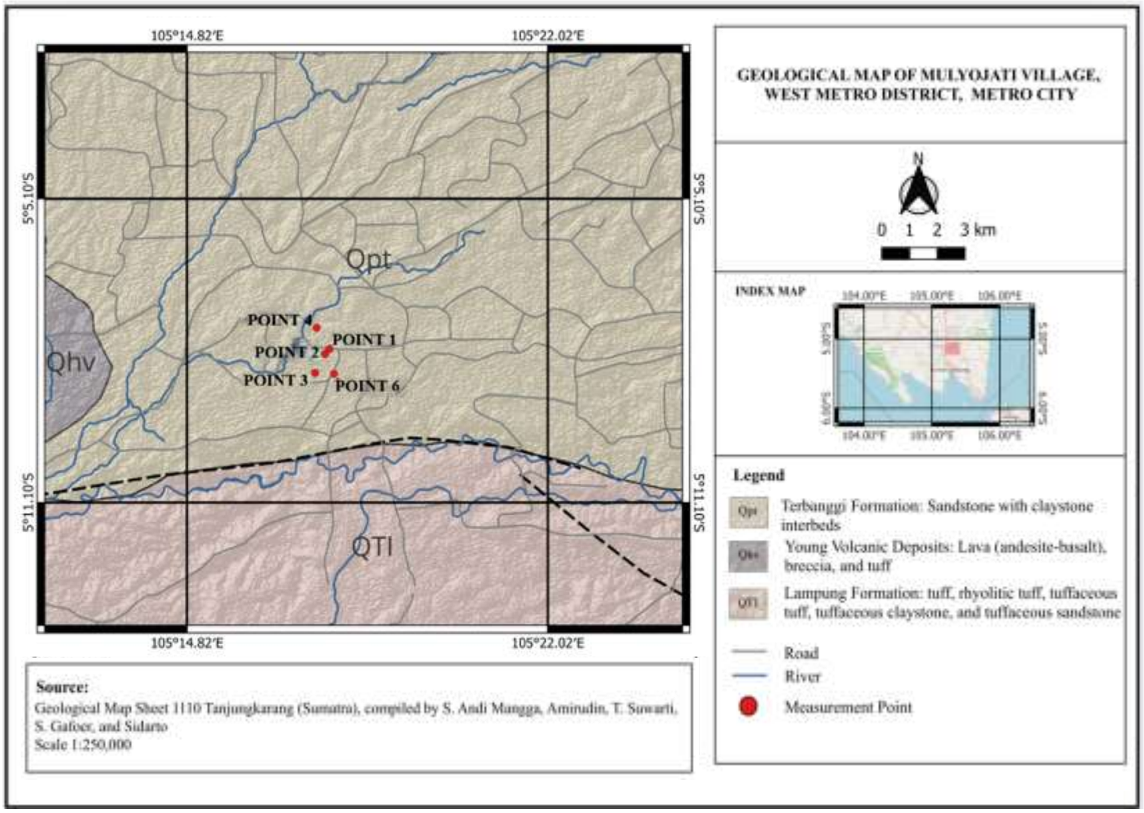


Figure 1. Geological map of measurement points (modified from the geological map of the Tanjungkarang sheet, Sumatra)

Based on the geological map (Figure 1), all measurement points are located within the Qpt formation (Terbanggi Formation), which generally consists of sandstone with claystone intercalations. This formation is bordered by Qhv (young volcanic deposits) and QTi (Lampung Formation). The coordinates of the five measurement points are presented in Table 1.

Tabel 1. Measurement Point Coordinates

No	Geoelectrical Sounding Point	Coordinate		Elevation (masl)
		Longitude (°)	Latitude (°)	
1.	Point 1	105.2944	-5.13446	52.245 masl
2.	Point 2	105.2928	-5.13615	48.684 masl
3.	Point 3	105.2896	-5.14232	46.728 masl
4.	Point 4	105.2902	-5.12752	50.764 masl
6.	Point 6	105.2959	-5.14262	48.206 masl

Regionally, the Qpt formation is classified as a productive aquifer with wide distribution, characterized by relatively permeable lithologies such as sandstone and sandy layers capable of storing and transmitting groundwater. The surrounding formations are interpreted as moderately productive aquifers. This classification is based on regional hydrogeological and geological references. However, detailed site specific subsurface aquifer characteristics in Mulyojati Village have not been previously investigated (Figure 2).

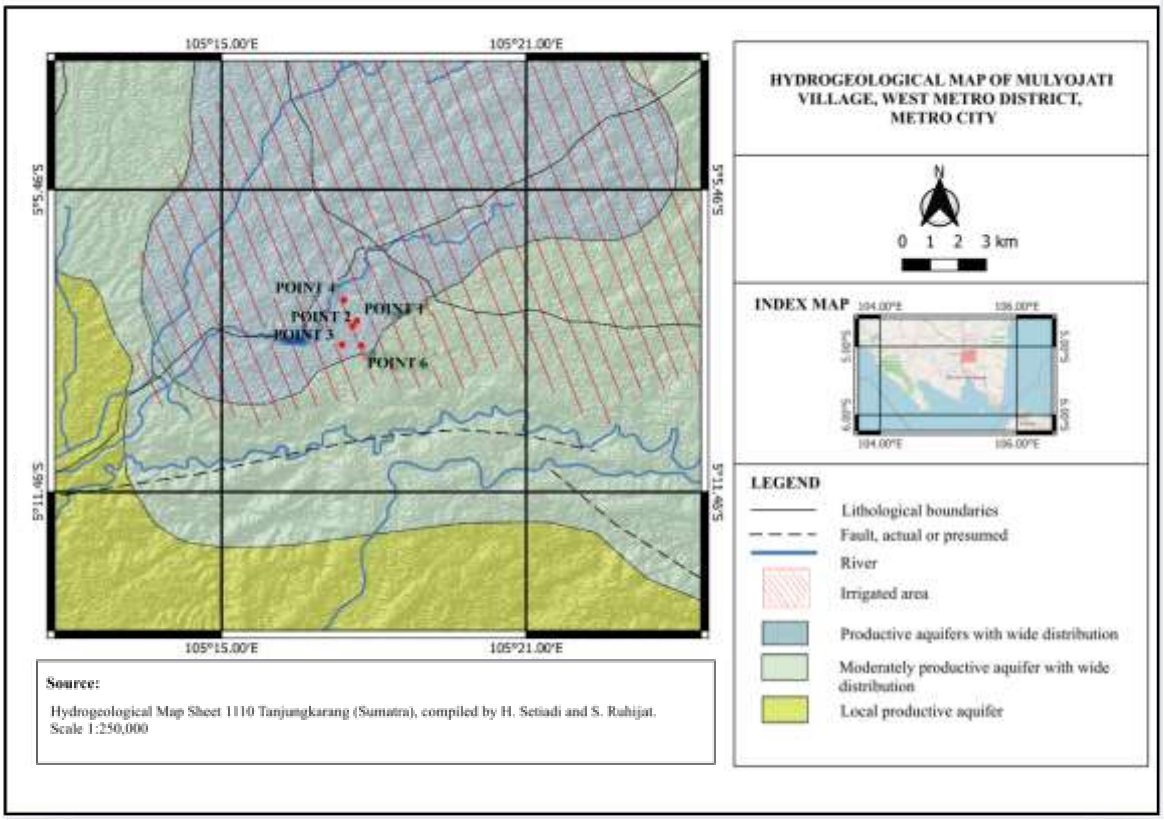
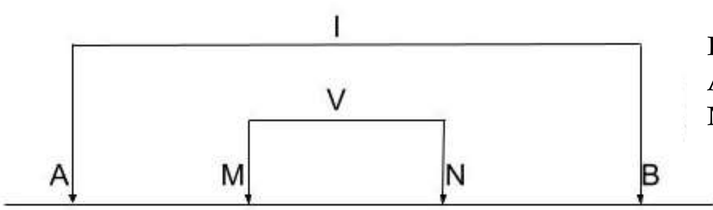


Figure 2. Hydrogeological map of measurement points (modified from the hydrogeological map of the Tanjungkarang sheet, Sumatra)

2.2. Schlumberger Configuration Vertical Electrical Sounding (VES) Method

The geoelectric resistivity method is an active geophysical technique that applies the distribution of electric current beneath the Earth's surface [10]. In geoelectrical methods, vertical electrical sounding (VES), also known as geosounding, is the most commonly used technique in groundwater investigations [11]. The configuration used in the study was Schlumberger (Figure 3). For Schlumberger array of current electrodes (C1 and C2 or A and B), and potential electrodes (P1 and P2 or M and N) [12].



Description:
AB : Electrode current
MN : Electrode potential

Figure 3. Schlumberger Configuration

The data acquisition parameters used in this study were as follows initial half-current electrode spacing (AB/2): 1.5, maximum half-current electrode spacing (AB/2): 500 m, potential electrode spacing (MN): adjusted incrementally according to signal strength, and primary measured parameter: apparent resistivity (ρa)

Field measurements were conducted using a digital resistivity meter, stainless steel electrodes, insulated cables, a measuring tape, and a GPS device for coordinate positioning [13-14]. Data acquisition was performed under dry weather conditions with relatively flat to gently undulating topography, minimizing the influence of surface conditions on resistivity measurements. To ensure that the best data were acquired, each measurement was stacked, and the standard deviation was maintained below 5% [15]. Aquifer identification was based on interpreted resistivity values integrated with geological information [16]. In general, low to moderate resistivity values are commonly associated with saturated sandstone or sandy layers, whereas higher resistivity values indicate compact or dry materials.

2.3 Data Processing

The VES field data obtained from the five measurement points were processed using IPI2Win software to generate one dimensional subsurface resistivity models. Data processing involved converting field measurements into apparent resistivity curves and performing iterative inversion to estimate true resistivity values and layer thicknesses [17-18]. Interpretation was performed by analyzing resistivity patterns and modelings them with drill log data that had known lithological characteristics from the Qpt formation. The interpretation results were then compared with available regional geological [19] and hydrogeological data to improve the reliability of the interpretation [20] (Figure 4).

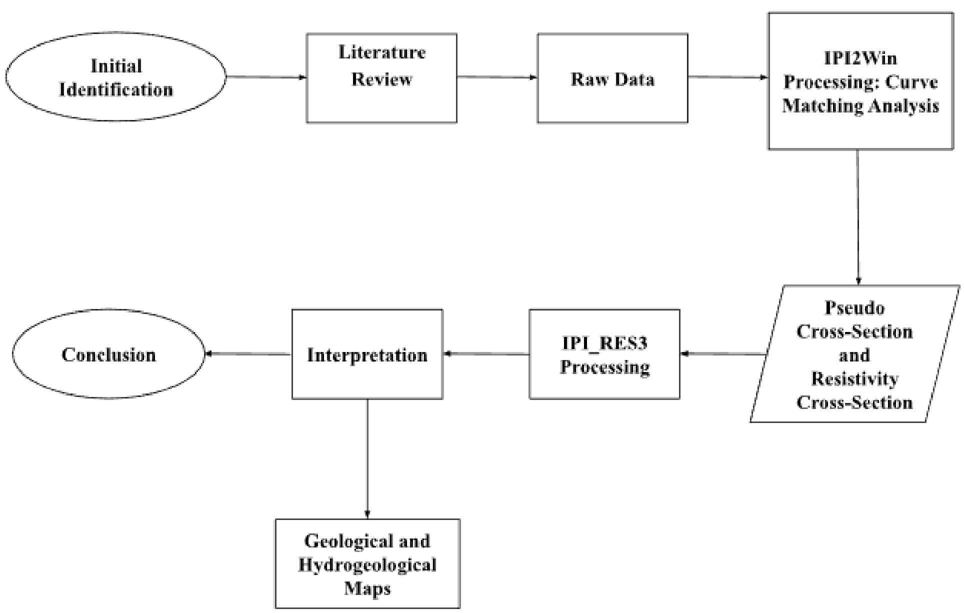


Figure 4. Data Processing Flowchart

3. Results and Discussion

Based on the spatial distribution of the measurement points, the study area was divided into two resistivity cross sections. Cross section 1 consists of measurement points 1, 2, and 3, while cross section 2 consists of points 4, 2, and 5, as shown in Figures 5 until 10. This division was made to represent subsurface variations along two dominant structural directions and to facilitate comparative interpretation between different parts of the study area.

CROSS SECTION 1

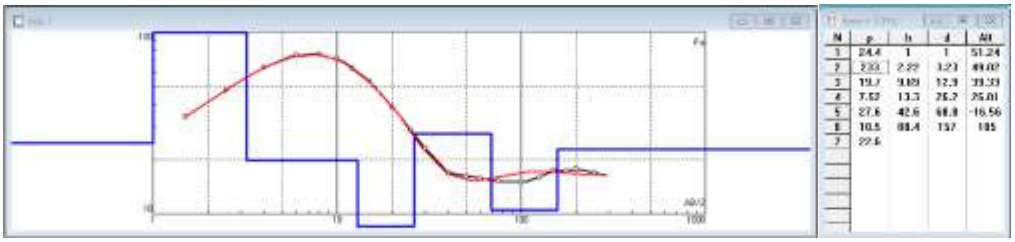


Figure 5. IPI2WIN processing curve and table, point 1

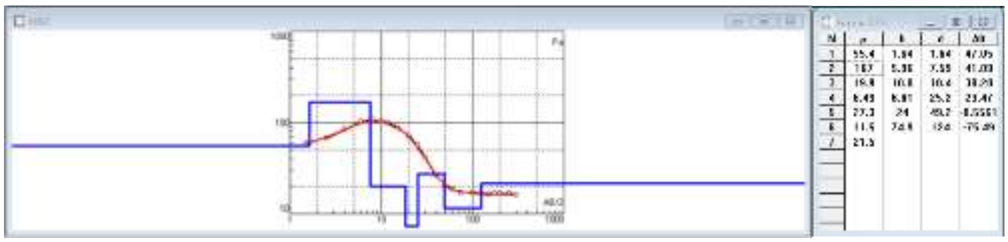


Figure 6. IPI2WIN processing curve and table, point 2

Figure 7. IPI2WIN processing curve and table, point 3

CROSS SECTION 2

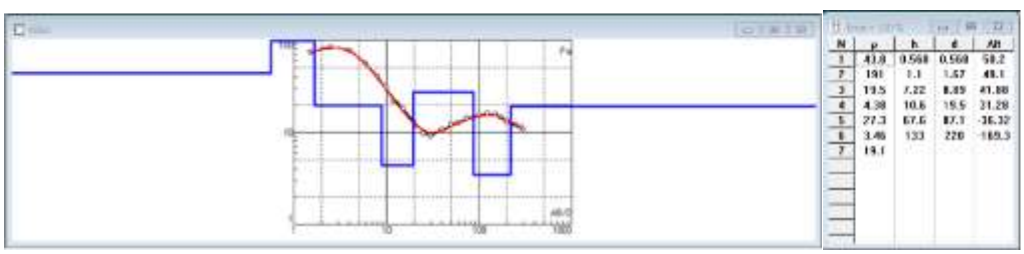


Figure 8. IPI2WIN processing curve and table, point 4

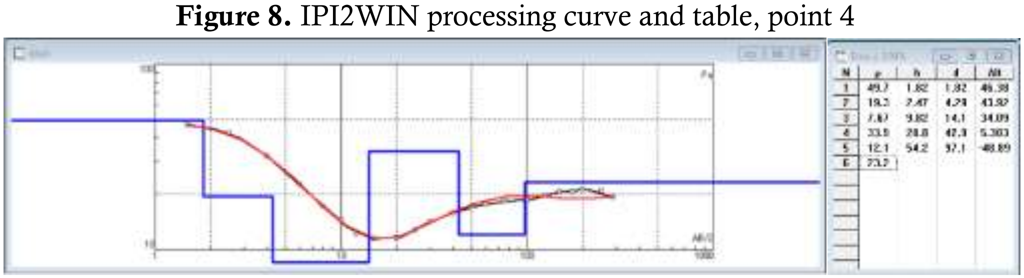


Figure 10. IPI2WIN processing curve and table, point 6

Interpretation of subsurface resistivity values obtained from the VES measurements was supported by comparison with lithological information from an existing drill log located in Karangrejo Village, Metro City, situated at coordinates 105.3324° E and 5.08367° S with an elevation of approximately 68 m above sea level (masl), as shown in Figure 11. Although the drill log is not located exactly at the measurement points, its proximity and similar geological setting within the same regional formation allow it to be used as a qualitative reference for resistivity interpretation [21].

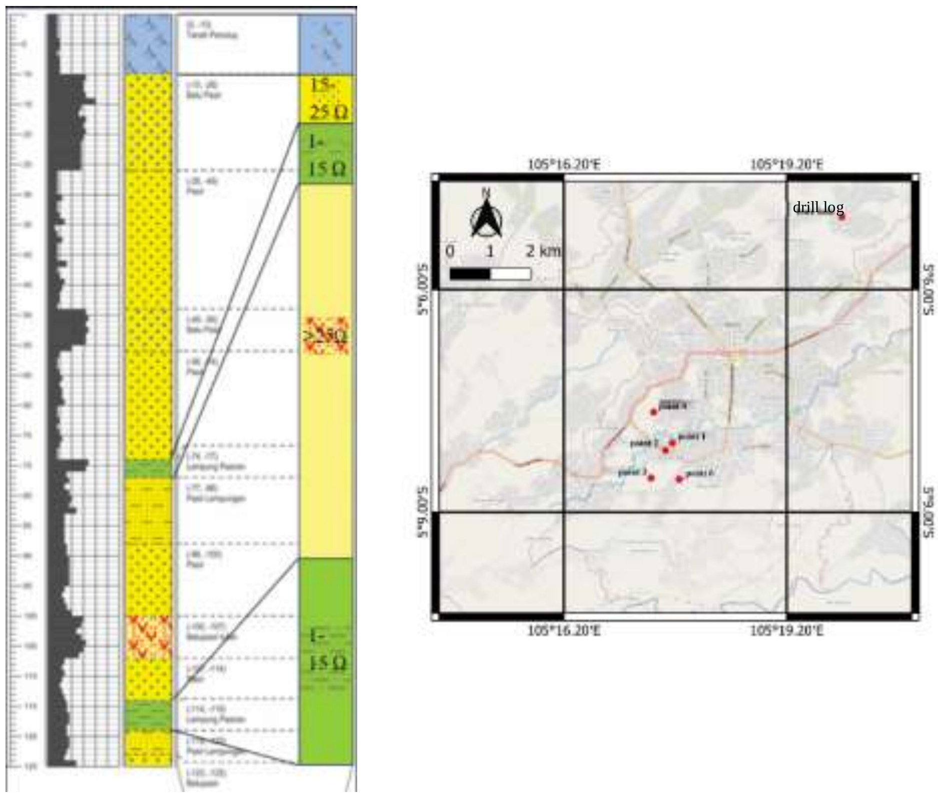


Figure 11. correlation between drill log and research points

Based on the drill log, subsurface layers are dominated by sandstone, sandy clay, clayey sand, and clay intercalations, which correspond well with the resistivity ranges identified from the geoelectrical data. Layers with resistivity values ranging from 1–15 Ωm are interpreted as clay or sandy clay units, which are consistent with low-permeability layers observed in the drill log. Meanwhile, resistivity values of 15–25 Ωm are associated with sandstone or clayey sandstone layers, which have moderate porosity and are interpreted as potential aquifer zones. Higher resistivity values of >25 Ωm are interpreted as relatively dry or compact sandstone layers, consistent with coarser lithology observed at greater depths in the drill log (Table 2).

Table 2. Resistivity values in rocks

Lithology	Resistivity (Ωm)
Sandy clay	1-15 Ωm
Sand, Sandstone	15-25Ωm
Tuff sandstone	>25 Ωm

The modelings between resistivity interpretation and drill log strengthens the reliability of aquifer identification in the study area [22]. However, it should be noted that the absence of direct drilling log data at the measurement points is a limitation of this study. Therefore, resistivity values were modeled using drill log that were still in the same geological formation.

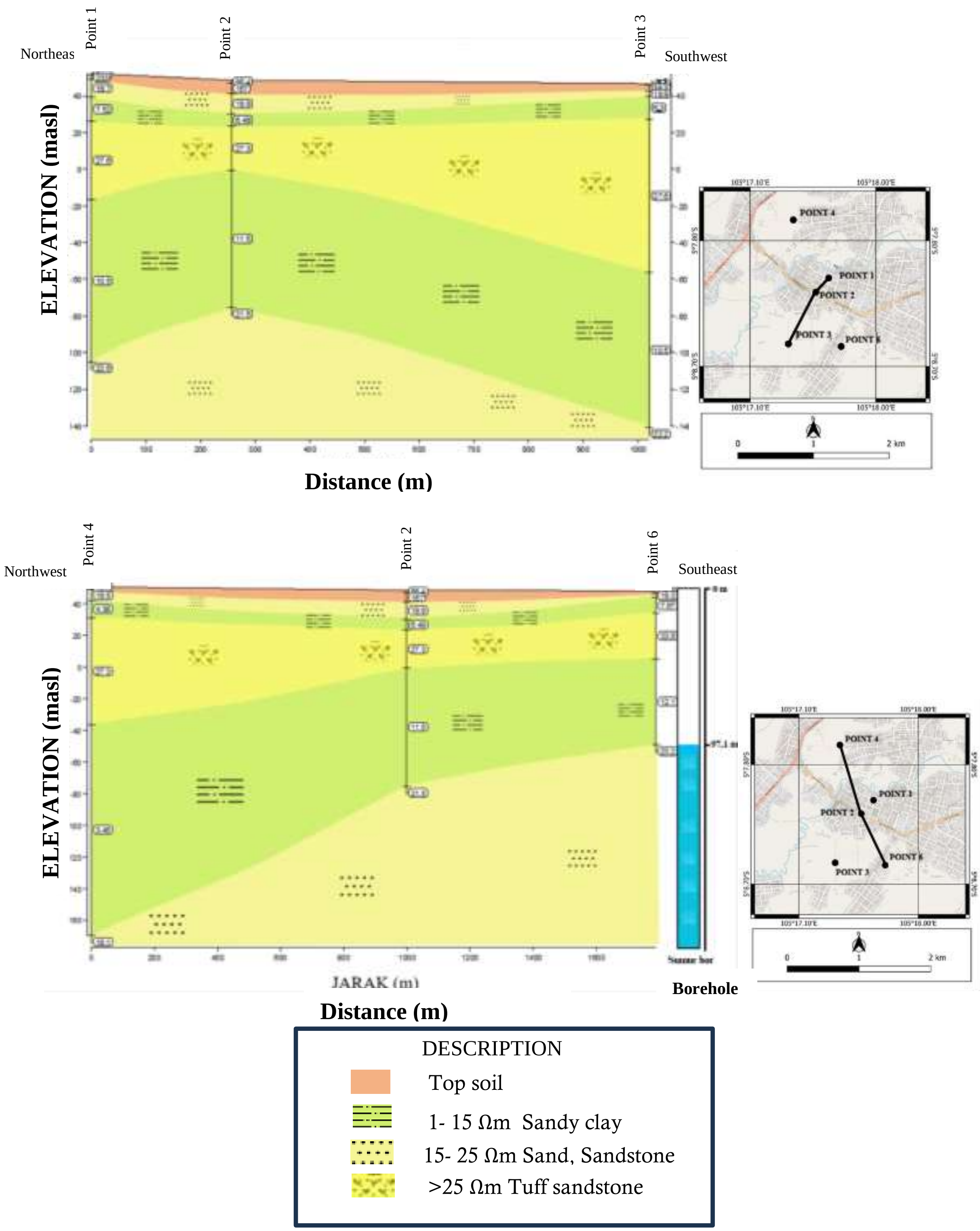


Figure 12. Results of Cross-Sections 1 and 2

In cross section 1 (points 1–2–3), the uppermost layer is identified as topsoil with relatively high resistivity values. Beneath this layer lies a unit with resistivity values ranging from 15–25 Ωm, interpreted as sand and sandstone. Which based on the interpretation of the VES data, the sand layer is identified as an aquifer [23-24]. This interpretation is supported by previous studies in Indonesia where saturated sand materials have good porosity and permeability [25]. The thickness of this aquifer layer varies laterally along the cross section, indicating spatial heterogeneity in groundwater storage potential.

Below the unconfined aquifer, a layer with resistivity values of 1–15 Ωm is interpreted as sandy clay, which acts as an aquitard due to its relatively low permeability [26-27]. This layer limits vertical groundwater flow and plays an important role in maintaining groundwater storage within the overlying aquifer. A deeper layer with resistivity values exceeding 25 Ωm, interpreted as tuffaceous sandstone, is considered a compact unit that serves as the base of the aquifer system. Similar stratigraphic arrangements have been observed in groundwater studies conducted in volcanic terrains of Java and Sumatra, where tuffaceous units often function as impermeable or semi impermeable boundaries [28-29].

In cross section 2 (points 4–2–6), a comparable stratigraphic pattern is observed. However, the thickness of the sand and sandstone layer increases toward point 6 as a a confined aquifer. This variation suggests improved groundwater storage potential in this part of the study area. These geological units significantly influence groundwater flow and storage, as indicated on the geological map, affecting the permeability and characteristics of aquifers in the region [30]. Resistivity values may overlap between different lithologies, particularly in volcanic-derived sediments where clay content, water saturation, and pore water salinity can significantly influence resistivity responses. In addition, the one dimensional nature of VES inversion limits lateral resolution, which may result in uncertainty in defining exact layer boundaries.

To reduce interpretation bias, resistivity values were interpreted by integrating regional geological information and drill log data for the Karangrejo area. However, the absence of drill log data at the research site is a limitation of this study, and the results should be considered as an initial subsurface model.

The determination of the recommended drilling location is based on a quantitative comparison of the thickness and depth of the aquifer at five measurement points, as shown in Figure 13. Among these measurement points, point 6 shows the thickest layer of sand and sandstone, with an aquifer found at a depth of approximately 97.1 m, covered by a layer of low porosity. This configuration indicates favorable groundwater accumulation and protection from surface contamination. Therefore, point 6 is identified as the most suitable location for well development compared to other measurement points.

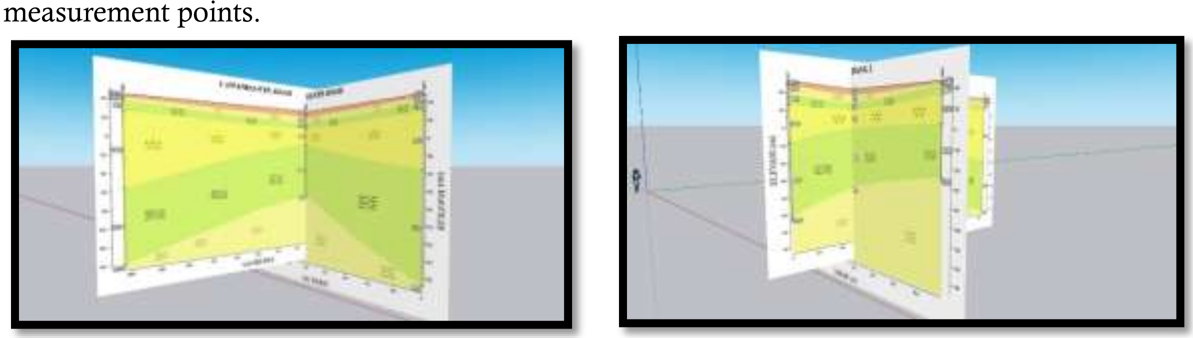


Figure 12. 3D cross-section results

4. Conclusion

The geoelectrical results indicate a consistent subsurface stratigraphy consisting of topsoil, an unconfined aquifer, an aquitard, and a compact basal layer. The unconfined aquifer is represented by sand and sandstone with resistivity values of 15–25 Ωm, while sandy clay with lower resistivity (1–15

Ωm) acts as an aquitard. High resistivity values (>25 Ωm) correspond to compact tuffaceous sandstone forming the base of the aquifer system.

Spatial variations in aquifer thickness suggest heterogeneous groundwater potential across the study area. Based on the comparison of aquifer depth and thickness at the measurement points, point 6 shows the most favorable groundwater potential, characterized by a relatively thick sand–sandstone aquifer at depth and overlain by low permeability material. Therefore, point 6 as a confined aquifer is considered the most suitable location for groundwater drilling, although the results remain preliminary.

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