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Aquifer Assessment in the Capit Urang Tourist Area, Metro City: A Vertical Electrical Sounding Approach

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ABSTRACT

This study was conducted in the Capit Urang Tourist Area, Metro City, which is surrounded by rivers and faces problems with turbid well water that cannot be directly used. The research aims to identify subsurface conditions, especially aquifer thickness and depth, and to evaluate the possibility of deeper aquifers with better water quality. The Vertical Electrical Sounding (VES) method with a Schlumberger array was applied at six sounding points with a maximum AB/2 spacing of 100 m. Data were acquired using a Naniura resistivity meter, processed into apparent resistivity, and inverted with IPI2Win software. The results indicate four main subsurface layers with a resistivity pattern of $\rho_1 < \rho_2 > \rho_3 < \rho_4$. The first layer has a resistivity of 50–150 Ωm and is interpreted as topsoil with a thickness of less than 1.5 m. The second layer has a resistivity of 300–400 Ωm and is interpreted as gravel to a depth of about 6 m. The third layer, with resistivity of 40–70 Ωm, is interpreted as sandstone functioning as an aquifer with a thickness of 10–13 m to a depth of roughly 16 m. The fourth layer, with resistivity of 160–650 Ωm, is interpreted as impermeable bedrock. The aquifer is influenced by river infiltration, leading to turbid groundwater, while the limited electrode span prevented detection of deeper aquifers. Based on lithological interpretation, the aquifer system is classified as an unconfined to semi-unconfined aquifer. These findings provide a scientific basis for groundwater management and for future hydrogeophysical and hydrochemical investigations to improve water-supply sustainability in the Capit Urang Tourist Area.

Keywords: aquifer, groundwater management, Metro City, schlumberger array, tourist area, vertical electrical sounding

INTRODUCTION

The Capit Urang Tourist Area is a natural tourist destination located in Metro City, Lampung Province. Surrounded by rivers, the area offers a unique natural landscape that enhances its attractiveness to visitors. However, a significant problem arises in the area related to groundwater availability. Shallow well water (approximately 6–7 m deep) is not suitable for direct use by residents or tourists due to its cloudy appearance, similar to river water. This condition suggests that the groundwater in the area originates from a shallow aquifer that is directly recharged by the surrounding river. Because the river water is consistently turbid, the quality of shallow groundwater in the area has also deteriorated.

This issue is crucial to investigate, considering that the availability of clean water is a basic necessity for the community and a key factor in supporting tourism activities. Identifying the hydrogeological conditions in the Capit Urang Tourist Area can provide insight into whether other aquifers exist beneath the layers directly connected to the river. If the presence of deeper aquifers can be confirmed, they may serve as a potential source of cleaner and more potable groundwater.

Previous studies have demonstrated that the geoelectrical method, particularly Vertical Electrical Sounding (VES), is effective for identifying subsurface conditions, including aquifer thickness and depth [1-3]. This method has been widely applied in various regions of Indonesia, such as volcanic areas in Bandung, West Java [4], the Sidoarjo area in East Java [5], Tarakan City in North Kalimantan [6], Beach Ridge environments in Simeulue, Aceh [7], Dendam Lake area in Bengkulu City [8], and Palopo City in South Sulawesi [9].

In the Lampung region, VES-based studies have been conducted in Central Lampung [10], Pesawaran [11, 12], Bandar Lampung City [13-15], and extensively in South Lampung [16-20]. Those studies have successfully provided detailed information on the characteristics of local aquifers. However, research employing a similar approach in Metro City remains limited, with only a single study conducted in the Imopuro area [21], located approximately 9 km from the Capit Urang tourist area.

Using the VES method, the objective of this study is to identify the thickness of the aquifer suspected to be recharged by the river in the Capit Urang Tourist Area and to evaluate the potential for deeper aquifers with better water quality. The results are expected to provide a scientific basis for groundwater management planning and to support the sustainable utilization of natural tourism resources in Metro City.

METHODS

The basic concept of the Vertical Electrical Sounding (VES) method is to measure variations in subsurface resistivity with depth by gradually increasing the distance between the current electrodes (AB). This principle makes it possible to identify subsurface rock layers based on contrasts in their electrical resistivity [22-24]. In this study, the Schlumberger configuration (FIGURE 1) was employed because it provides advantages in terms of stronger signal strength, higher vertical resolution and sensitivity, as well as a greater depth of investigation compared to other arrays such as the Wenner or dipole–dipole configuration [25].

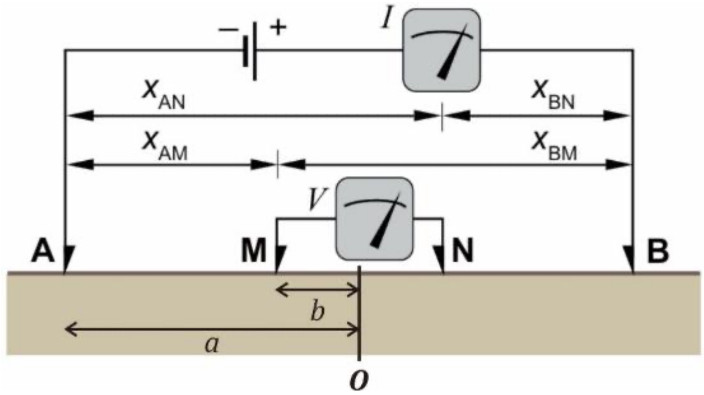


FIGURE 1. The electrode configuration using the Schlumberger array (modified from Dentith and Mudge [24]).

Measurements were carried out at six sounding points distributed across the study area, as shown in the measurement location map (FIGURE 2). The geographic coordinates of each sounding point are provided in TABLE 1. The survey was conducted in May 2025, corresponding to the dry season, to minimize the influence of soil moisture variability on resistivity measurements. The survey employed a maximum AB/2 spacing of 100 meters, corresponding to a total current electrode spacing (AB) of 200 meters. In VES surveys, the adequate depth of investigation is approximately 10–30% of the AB spacing [26], this configuration is expected to achieve an investigation depth of about 40 meters or greater.

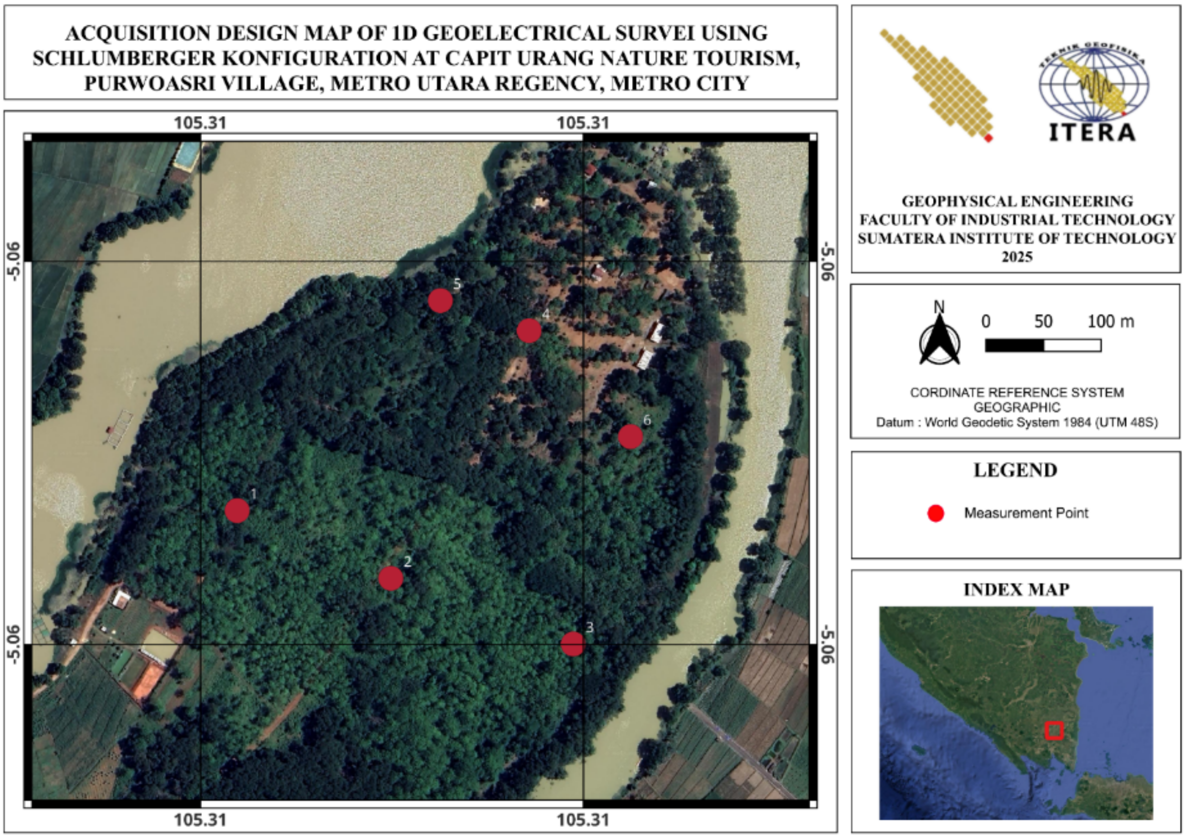


FIGURE 2. VES measurement location map of the study area.

TABLE 1. Coordinates of the sounding points in the study area.

Sounding Point	Coordinate		Elevation (m)
	Horizontal	Vertical	
Point 1	-5.0599576	105.3102445	53
Point 2	-5.0603860	105.3114867	53
Point 3	-5.0610690	105.3130773	52
Point 4	-5.0586143	105.3125599	52
Point 5	-5.0583628	105.3118639	52
Point 6	-5.0592836	105.3133247	52

TABLE 2. Electrode intervals of AB/2 and MN/2.

No.	AB/2 (m)	MN/2 (m)	No.	AB/2 (m)	MN/2 (m)
1	2.0	0.5	10	15.0	2.0
2	2.5	0.5	11	20.0	2.0
3	3.0	0.5	12	25.0	2.0
4	4.0	0.5	13	30.0	2.0
5	5.0	0.5	14	50.0	2.0
6	6.0	0.5	15	50.0	10.0
7	8.0	0.5	16	60.0	10.0
8	8.0	2.0	17	80.0	10.0
9	10.0	2.0	18	100.0	10.0

Field data were acquired using a Naniura geoelectrical instrument, which offers good sensitivity for VES surveys. During data acquisition, the injected current ranged from 20 mA to 550 mA, with each measurement stacked three times and subsequently averaged to improve data reliability. The acquisition process involved planting current electrodes (A and B) and potential electrodes (M and N) at specific intervals, followed by a gradual widening of the AB spacing while the MN spacing was kept constant or adjusted as needed to maintain resolution [25]. Details of the AB/2 and MN/2 electrode spacings applied at each sounding point are summarized in TABLE 2. The average adequate acquisition time per sounding point was approximately 1.5 hours, excluding instrument setup and equipment mobilization.

The study area is characterized by relatively gentle topography and a ground surface consisting of reddish-brown soil with dense vegetation. Visual inspection indicated good electrode–ground contact for both current and potential electrodes, suggesting efficient current flow through the AB electrodes and reliable potential responses recorded at the MN electrodes.

The apparent resistivity (ρ_a) values were calculated using the fundamental relationship between potential difference (ΔV), current strength (I), and electrode-geometry factors (k), as expressed in EQUATION (1) and (2), where

$$\rho_a = k\frac{\Delta V}{I}, \tag{1}$$

with

$$k = \pi\left(\frac{a^2 - b^2}{2b}\right). \tag{2}$$

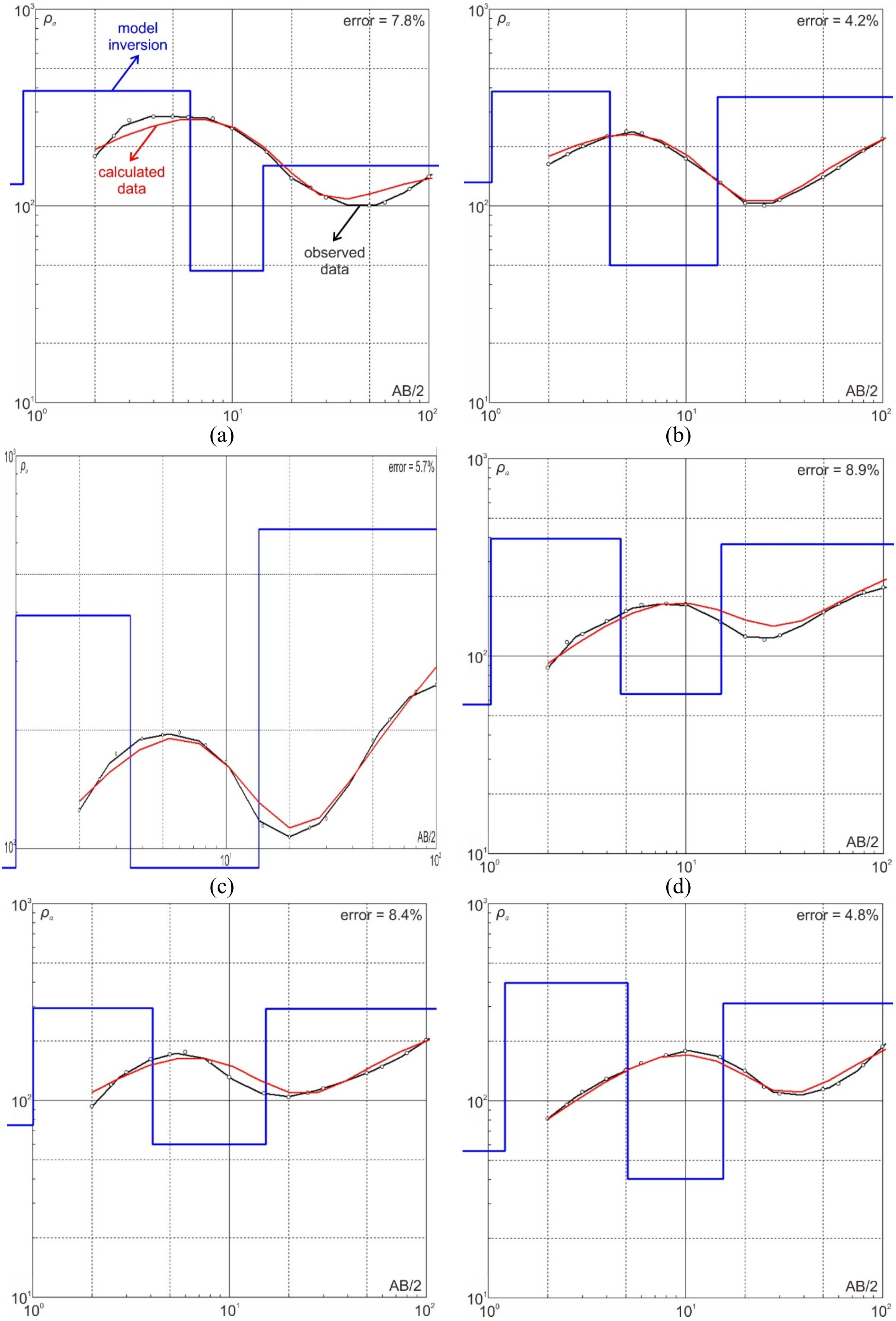
The apparent resistivity data were subsequently analyzed using the IPI2Win software to perform an inversion process. The inversion aims to obtain the most representative resistivity distribution with depth at each sounding point, indicated by a minimum error value.

Interpretation of the inversion results was conducted with reference to regional geological data, particularly the Terbanggi Formation [27], which is present in the Metro City area, as well as previous studies in the same region with the same method [21]. The Terbanggi Formation is dominantly composed of sandstone and intercalations of claystone. By incorporating this geological framework, the interpretation not only provides a quantitative description of subsurface resistivity distribution but also enables correlation with lithology and assessment of aquifer potential beneath the Capit Urang Tourist Area.

RESULTS AND DISCUSSIONS

In general, the measurement results at six sounding points show a relatively similar curve trend (FIGURE 3). The curve pattern indicates the presence of four main layers with a resistivity sequence corresponding to the model of the Lowrie [22], namely $\rho_1 < \rho_2 > \rho_3 < \rho_4$. The inversion results (TABLE 3 and 4) reveal that the first layer has a resistivity of more than 50 Ωm to less than 150 Ωm, the second layer between 300 Ωm and 400 Ωm, the third layer ranges from 40 Ωm to 70 Ωm, and the fourth layer shows very high resistivity in the range of 160–650 Ωm, acting as a half-space. In the resistivity curves, three plots are displayed: the observed data, the calculated data, and the inversion model. The fitness between the observed and calculated curves, indicated by the low error value, demonstrates that the inversion model is reliable. Overall, the modeling results are considered reliable, with error values ranging from 4% to 9%.

The first layer with a resistivity of 50–150 Ωm is interpreted as topsoil with a thickness of less than 1.5 meters. The second layer, with a resistivity of 300–400 Ωm, corresponds to gravel (referring to Rolia [21]) extending to a depth of approximately 6 meters. The third layer with a resistivity of 40–70 Ωm is interpreted as an aquifer reaching a depth of about 16 meters. This interpretation is supported by its much lower resistivity compared to the overlying gravel, indicating water saturation. The relatively low resistivity is most likely influenced by river water infiltration, suggesting that the layer consists of sandstone (consistent with the geological map [27]) functioning as an aquifer. For clarity, the distribution of aquifers in this area can be seen in FIGURE 4. The fourth layer with a resistivity of 160–650 Ωm is interpreted as bedrock (referring to Rolia [21]). Its high resistivity and half-space character indicate an impermeable unit that confines groundwater within the overlying aquifer.



(a) (b)

(c) (d)

(e) (f)

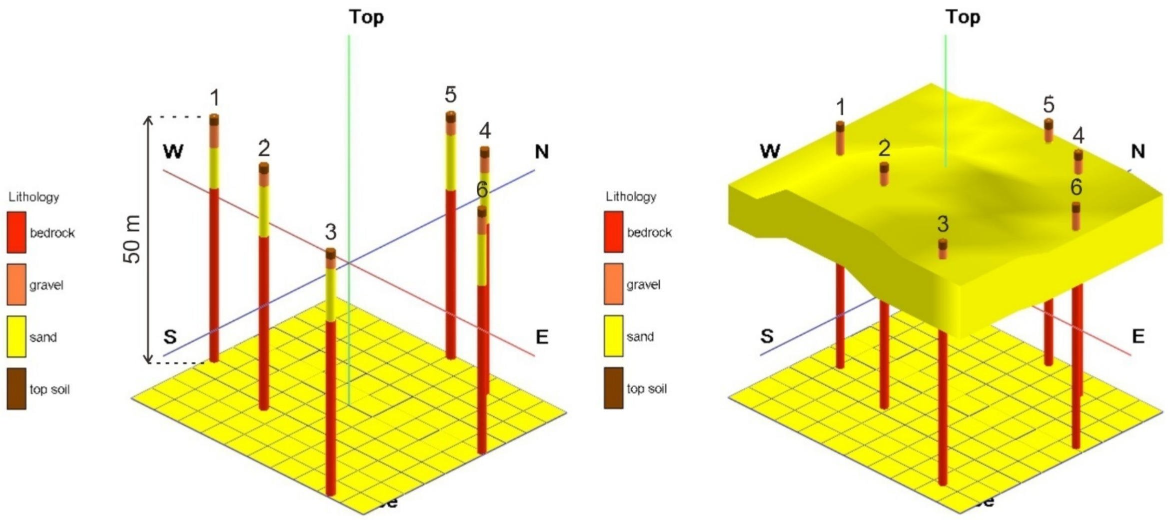
FIGURE 3. VES curves from points 1 to 6, shown in sequence (a–f).

TABLE 3. Inversion results and rock layer interpretation for points 1–3.

Layer	Point 1		Point 2		Point 3		Interpretation
	resistivity (Ωm)	depth (m)	resistivity (Ωm)	depth (m)	resistivity (Ωm)	depth (m)	
1	129	0–0.9	132	0–1.0	88	0–1.0	top soil
2	385	0.9–6.1	383	1.0–4.1	392	1.0–3.5	gravel
3	47	6.1–14.4	50	4.1–14.5	55	3.5–14.3	sandstone (aquifer)
4	160	>14.4	358	>14.5	650	>14.3	bedrock

TABLE 4. Inversion results and rock layer interpretation for points 4–6.

Layer	Point 4		Point 5		Point 6		Interpretation
	resistivity (Ωm)	depth (m)	resistivity (Ωm)	depth (m)	resistivity (Ωm)	depth (m)	
1	57	0–1.0	75	0–1.0	56	0–1.2	top soil
2	393	1.0–4.7	294	1.0–4.1	396	1.2–5.1	gravel
3	64	4.7–15.1	60	4.1–15.4	40	5.1–15.6	sandstone (aquifer)
4	358	>15.1	292	>15.4	312	>15.6	bedrock



(a) (b)

FIGURE 4. Distribution of the aquifer-bearing sandstone layer in the study area: (a) vertical log view, (b) interpolated spatial map.

Overall, the resistivity distribution up to the third layer shows a relatively consistent pattern across all sounding points, supporting the proposed interpretation. The resistivity ranges of the second and third layers remain within narrow intervals, namely 300–400 Ωm for the gravel layer and 40–70 Ωm for the aquifer layer, respectively, indicating laterally uniform subsurface conditions. In contrast, the first layer exhibits a wider resistivity range (50–150 Ωm), which is reasonably interpreted as topsoil. Such variability is expected, as the topsoil represents the shallowest layer and is strongly influenced by surface conditions, including differences in compaction, moisture content, and near-surface heterogeneity, all of which can significantly affect resistivity values.

The interpretation of the deepest layer is relatively more ambiguous, as its resistivity range is also relatively wide (160–650 Ωm). Due to the limited availability of previous studies in the same geological formation and study area, the interpretation relies primarily on Rolia [21]. Accordingly, this layer is interpreted as bedrock; however, when compared to the overlying gravel layer (300–400 Ωm), the inferred bedrock's resistivity range appears partially overlapping and, in some cases, lower than expected. From a lithological perspective, bedrock is generally more compact than gravel and typically exhibits higher resistivity. This discrepancy suggests that the bedrock interpretation should be treated cautiously and may reflect lithological heterogeneity, weathering effects, or variations in saturation conditions within the basal unit.

Because the elevation at each sounding point is nearly uniform, the identified aquifer exhibits a relatively consistent lateral distribution, as illustrated by the inverse distance–weighted interpolation of aquifer properties in FIGURE 4(b). This consistency is reflected in the slight variations in resistivity values and comparable aquifer thickness across all sounding points. Consequently, the calculated transverse resistance values are also similar, resulting in transmissivity values of 0.222 ± 0.037 S, which indicate laterally uniform aquifer transmissivity [1, 28] and suggest hydraulic continuity along the direction of the adjacent river flow. Furthermore, based on the lithological interpretation of each layer, the aquifer system in the study area can be classified as an unconfined to semi-unconfined aquifer. The topsoil and gravel layers act as semi-permeable to permeable units, while the underlying impermeable bedrock forms the basal confining boundary.

Overall, the identified aquifer has a thickness of approximately 10–13 m. Field observations indicate that the groundwater table occurs at depths of about 4–5 m (with the well between 6 and 7 m) below the ground surface, supporting the interpretation that the nearby river system strongly influences groundwater recharge. This is consistent with rivers' hydrogeological role as a primary source of groundwater recharge [29]. Accordingly, these results highlight a close hydraulic connection between surface water and groundwater within the Capit Urang Tourism Area.

Nevertheless, this study has limitations. Because the last identified layer acts as a half-space, the existence of deeper aquifers cannot be confirmed. Further investigation with longer electrode spreads or integrated methods (e.g., 2D resistivity imaging, pumping tests, and/or sample coring) is recommended to validate the subsurface structure.

CONCLUSION

Based on geoelectrical measurements using the Vertical Electrical Sounding (VES) method with a Schlumberger configuration, the subsurface layering beneath the Capit Urang Tourist Area, Metro City, was successfully identified, and the aquifer thickness was estimated. Four main subsurface layers were delineated, characterized by resistivity values: $\rho_1 < \rho_2 > \rho_3 <$

ρ_4. The first layer has a resistivity between 50 Ωm and 150 Ωm, interpreted as topsoil with a thickness of less than 1.5 meters. The second layer has a resistivity of 300–400 Ωm interpreted as a gravel layer extending to a depth of approximately 6 meters. The third layer, with a resistivity of 40–70 Ωm, is interpreted as sandstone that functions as an aquifer with a thickness of 10–13 meters to a depth of around 16 meters. The fourth layer, with a resistivity of 160–650 Ωm, is interpreted as an impermeable bedrock (half-space).

The identified aquifer appears to be recharged by the river surrounding the study area. This is indicated by the low resistivity values in the third layer, which reflect the presence of turbid groundwater similar in quality to the river water. Consequently, even if wells are deepened to penetrate the entire aquifer, the groundwater quality remains unsuitable for direct use.

Furthermore, this study was unable to confirm the presence of deeper aquifers due to the maximum electrode spacing limit (AB/2 = 100 m). Future investigations employing larger electrode spreads are therefore required to explore greater depths. From a practical perspective, the results of this study provide a basis for designing appropriate groundwater wells, including decisions regarding well depth and screen placement. In addition, detailed hydrochemical analyses are strongly recommended to evaluate groundwater quality, determine suitable treatment methods, and ensure safe and sustainable utilization of groundwater resources to support the long-term development of the Capit Urang Tourist Area.

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