



Delineation of Groundwater Aquifer Systems Using Vertical Electrical Sounding (VES) in Sesela Village, West Lombok, Indonesia

Melinda Dwi Erintina^{1,*}, Aji Syailendra Ubaidillah², Kusnadi³, Uraihan Azhari⁴, Andi Faesal⁵, ZA Munarfan Putra⁶

^{1,2,3,4} Universitas Muhammadiyah Mataram / Engineering Faculty / D3 Teknik Pertambangan, Mataram, Lombok, Indonesia.

^{5,6} Universitas Muhammadiyah Mataram / Engineering Faculty / Teknik Geologi, Mataram, Lombok, Indonesia.

* Corresponding author : melindadwie2@gmail.coms

Tel.:+81-72-867-1686

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Abstract

The expansion of residential areas in Sesela Village, West Lombok, has led to increased groundwater demand, while subsurface hydrogeological information remains limited. This study aims to delineate aquifer systems and characterize subsurface conditions to support preliminary groundwater assessment in the study area. The investigation was conducted using the resistivity method through Vertical Electrical Sounding (VES) with a Schlumberger configuration. Two VES points, spaced approximately 30 m apart, were acquired and interpreted using one-dimensional inversion to obtain resistivity values and layer thicknesses. The results from both VES points indicate a consistent subsurface structure consisting of seven layers. The interpreted lithology include topsoil, sand and gravel, volcanic breccia, lapilli tuff, and sandy tuff. Based on resistivity characteristics, three aquifer systems were identified. A shallow unconfined aquifer occurs at depths of 1.5–5 m, with resistivity values ranging from 10 to 25.4 Ωm , associated with sand and gravel deposits. An intermediate semi-confined aquifer is identified at depths of 9–26 m, with resistivity values between 23 and 29.3 Ωm , corresponding to lapilli tuff. A deeper confined aquifer is observed at depths of 57–116 m, with resistivity values ranging from 18.9 to 22.5 Ωm , interpreted as sandy tuff. These aquifer layers are separated by volcanic breccia layers characterized by relatively high resistivity values (131–671 Ωm), which act as aquitards. The similarity of resistivity patterns between the two VES points suggests relatively consistent vertical layering, although minor variations in depth are observed. The results provide preliminary information on aquifer distribution and subsurface conditions, which may serve as a basis for further hydrogeological investigation and groundwater resource assessment in Sesela Village.

Keywords: Vertical Electrical Sounding (VES), Schlumberger Configuration, Aquifer, Groundwater, West Lombok

1. Introduction

Sesela Village, located in West Lombok Regency, has undergone rapid residential expansion in recent years, as reflected by the increasing development of housing and supporting infrastructure (Erintina, 2025). This land-use change is typically associated with population growth and a consequent rise in water demand. In many developing regions, such expansion often occurs without adequate development of water supply systems, leading to increased reliance on groundwater as a primary source of freshwater (Mishra, 2023).

Groundwater plays a critical role in fulfilling domestic water demand, particularly in areas where centralized supply systems are limited (Foster, 2022). Increasing population density and settlement development in Sesela Village are expected to intensify groundwater abstraction. If not properly managed, excessive groundwater withdrawal may disrupt the natural balance of aquifer systems, potentially resulting in

groundwater level decline and reduced well productivity (Rizvi et al., 2025). Therefore, understanding the occurrence and distribution of groundwater is essential for sustainable resource management (Jia et al., 2019).

However, hydrogeological information in the study area remains limited. Currently, there is no detailed characterization of aquifer geometry, including depth, thickness, and spatial distribution, nor adequate information on the subsurface lithological conditions controlling groundwater occurrence. In such data-limited settings, groundwater exploration is often conducted using empirical approaches, which may lead to uncertainty in well placement and inefficient resource utilization (Díaz-Alcaide et al., 2019). It highlights the need for a systematic and scientifically based subsurface investigation.

Geophysical methods, particularly electrical resistivity techniques, are widely applied in groundwater

exploration due to their effectiveness in delineating subsurface structures (Alao et al., 2025). Vertical Electrical Sounding (VES) using the Schlumberger configuration is commonly employed to investigate vertical variations in resistivity (Erintina, 2022), which can be interpreted in terms of lithology and water saturation. This method enables the identification of potential aquifer zones and estimation of their depth and thickness (Kadar et al., 2024).

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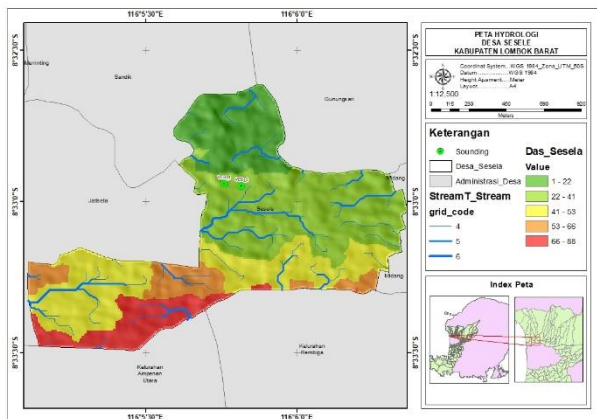
2. Research Method

Study Area

The study was conducted in Sesela Village, West Lombok Regency, Indonesia, an area currently undergoing rapid residential development. This expansion has implications for increasing groundwater demand. Regionally, the area is influenced by volcanic and associated sedimentary deposits, which may function as groundwater-bearing formations. However, the subsurface hydrogeological framework of the study area has not been adequately characterized, necessitating a geophysical investigation.

Data Acquisition

A geoelectrical resistivity survey was conducted using the Vertical Electrical Sounding (VES) method with a Schlumberger configuration, which is suitable for resolving vertical variations in subsurface resistivity (Obasi et al., 2022). Measurements were acquired at **two VES stations** within the study area. The selection of these locations was based on site accessibility and their ability to represent the general subsurface conditions of the area. Although limited in number, the VES points were positioned to provide an initial characterization of vertical subsurface layering related to groundwater occurrence.



Picture 1. Geological Map and VES point position

At each VES station, the current electrode spacing (AB) was progressively expanded to increase the depth of investigation, while the potential electrode spacing (MN) was adjusted as required to maintain measurable potential differences. The maximum electrode spacing (AB/2) was determined based on field conditions and the targeted investigation depth.

During data acquisition, electrical current was injected into the ground through the current electrodes, and the resulting potential difference was measured across the

potential electrodes. Based on these considerations, this study aims to characterize the subsurface conditions and delineate potential aquifer layers in Sesela Village using the VES method with Schlumberger configuration. The results are expected to provide a scientific basis for assessing groundwater potential and to support more effective and sustainable groundwater resource management in the study area.

The apparent resistivity (ρ_a) values were calculated using the Schlumberger geometric factor:

$$\rho_a = K \frac{\Delta V}{I}$$

Where K is the geometric factor, ΔV is the measured potential difference, and I is the injected current (Telford, 1990).

Data Processing and Interpretation

Apparent resistivity data were plotted against half-current electrode spacing (AB/2) on logarithmic scales to generate sounding curves. These curves were used to infer the vertical variation of subsurface resistivity.

Quantitative interpretation was performed through 1D inversion using an iterative least-squares approach to obtain true resistivity values and layer thicknesses (Ghari et al., 2020). The inversion process aimed to minimize the misfit between observed and calculated apparent resistivity data, typically expressed as the root mean square (RMS) error (Hidayah et al., 2023). The resulting models represent simplified layered subsurface conditions consistent with the measured data.

Aquifer Delineation

Subsurface layers were interpreted by integrating inverted resistivity values with established resistivity ranges for common lithologies and their hydrogeological characteristics. Layers exhibiting relatively low to moderate resistivity values were interpreted as potential aquifer layers, depending on the inferred lithology and degree of saturation (Ige et al., 2022).

Correlation between VES stations was conducted to evaluate lateral continuity of the identified layers and to delineate aquifer geometry. The interpreted parameters, including depth and thickness of aquifer layers, were subsequently used to assess groundwater potential within the study area.

RESULT AND DISCUSSION

The interpretation of Vertical Electrical Sounding (VES) data at the two measurement points reveals a layered subsurface structure characterized by variations in resistivity values. The inversion results indicate that the subsurface in the study area can generally be represented by a multi-layer model, reflecting differences in lithology and degree of water saturation (Memon et al., 2025).

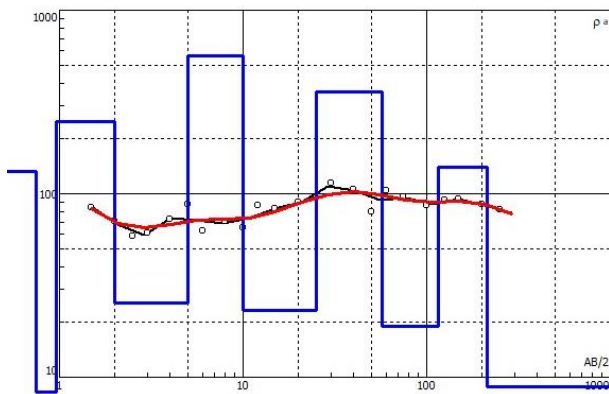


Figure 2. The resistivity sounding curve VES 1 (the relationship between apparent resistivity (ρ_a) and half electrode spacing ($AB/2$))

The resistivity sounding curve at VES 1 (figure 2) illustrates the relationship between half-current electrode spacing ($AB/2$) and apparent resistivity (ρ_a), presented on a logarithmic scale. This curve reflects changes in subsurface resistivity with increasing depth of investigation as electrode spacing expands. At smaller $AB/2$ values, the curve represents near-surface materials with relatively low resistivity, associated with topsoil and unconsolidated deposits. As the spacing increases, variations in the curve indicate contrasts between more resistive and more conductive layers.

The interpretation of resistivity data at VES 1 indicates a vertically heterogeneous subsurface composed of seven geoelectrical layers (Figure 3). These layers are distinguished based on contrasts in resistivity values and subsequently interpreted in terms of lithological and hydrogeological characteristics.

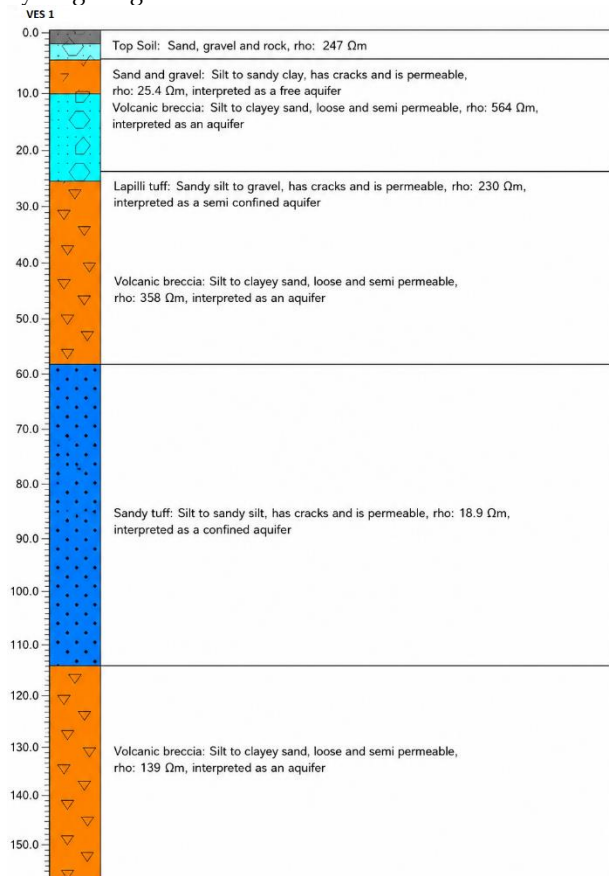


Figure 3. Log Resistivity of VES 1

The uppermost layer, extending from the surface to a depth of approximately 2 m, exhibits relatively low resistivity and is interpreted as topsoil or unconsolidated overburden. This layer reflects near-surface conditions influenced by weathering processes and variable moisture content.

At depths of approximately 2–5 m, a layer with a resistivity value of about 25.4 Ω m is identified. This layer is interpreted as a mixture of sand and gravel with silt fractions, characterized by relatively high porosity and permeability. Based on these properties, the layer is classified as an unconfined aquifer, which likely contributes to shallow groundwater occurrence.

A pronounced increase in resistivity is observed at depths between 5 and 10 m, with values reaching approximately 564 Ω m. This layer is interpreted as volcanic breccia composed of coarse-grained materials. The high resistivity suggests low water saturation, and the layer is therefore classified as an aquitard, which restricts vertical groundwater flow.

At depths of 10–25 m, a relatively conductive layer with a resistivity of approximately 23 Ω m is identified. This layer is interpreted as lapilli tuff composed of sand- to gravel-sized particles with fractured porosity. The relatively low resistivity indicates higher water saturation, and the layer is classified as a semi-confined aquifer, representing an intermediate groundwater-bearing zone.

Between 25 and 57 m depth, resistivity values increase to approximately 358 Ω m, corresponding to another volcanic breccia layer. Similar to the overlying resistive layer, this layer is interpreted as an aquitard, limiting vertical groundwater movement due to its relatively low permeability.

A deeper conductive layer is identified at depths of 57–116 m, with a resistivity value of approximately 18.9 Ω m. This layer is interpreted as sandy tuff composed of silt- to sand-sized materials with relatively good permeability. The low resistivity indicates significant water saturation, and the layer is classified as a **confined** aquifer, representing the most prospective groundwater-bearing formation at this location.

The deepest layer, extending from 116 to 160 m, exhibits moderate resistivity values of approximately 139 Ω m and is interpreted as volcanic breccia. This layer is classified as an aquitard, forming the lower boundary of the identified aquifer system.

The resistivity sounding curve at VES 2 (figure 4) illustrates the relationship between half-current electrode spacing ($AB/2$) and apparent resistivity (ρ_a), presented on a logarithmic scale. This curve reflects changes in subsurface resistivity with increasing depth of investigation as electrode spacing expands.

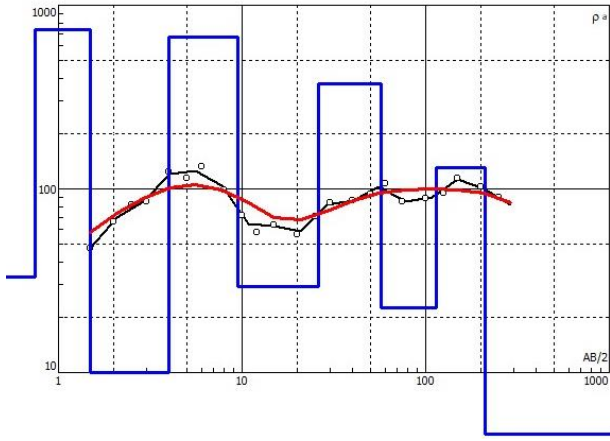


Figure 4. The resistivity sounding curve VES 2 (the relationship between apparent resistivity (ρ_a) and half electrode spacing ($AB/2$))

The resistivity interpretation at VES 2 (figure 5) reveals a seven-layer subsurface model characterized by alternating conductive and resistive layers. The identified layers reflect variations in lithology and groundwater saturation.

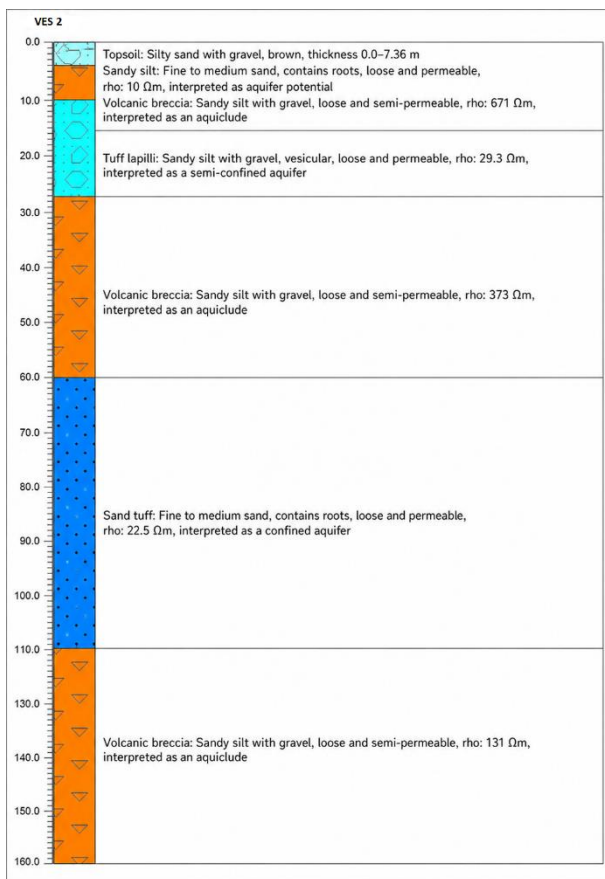


Figure 5. Log Resistivity of VES 2

The uppermost layer, extending from the surface to a depth of approximately 1.5 m, is interpreted as unconsolidated overburden or topsoil. This layer is influenced by surface weathering and moisture conditions and does not significantly contribute to groundwater storage.

At depths of 1.5–4 m, a conductive layer with a resistivity value of approximately 10 Ωm is identified. This layer is interpreted as a mixture of sand and gravel with silt fractions, exhibiting relatively high porosity and permeability. Based on these characteristics, the layer is classified as an unconfined aquifer, representing a shallow groundwater zone.

A marked increase in resistivity (approximately 671 Ωm) occurs at depths of 4–9.5 m, corresponding to a volcanic breccia layer composed of coarse materials. The high resistivity indicates low water saturation, and this layer is interpreted as an aquitard, which may restrict vertical groundwater flow.

At depths of 9.5–26 m, a relatively low resistivity layer (approximately 29.3 Ωm) is identified and interpreted as lapilli tuff. The fractured and permeable nature of this layer suggests its role as a semi-confined aquifer, capable of storing and transmitting groundwater.

Another resistive unit is observed between 26 and 57 m, with a resistivity value of approximately 373 Ωm . This layer is interpreted as volcanic breccia and is classified as an aquitard, separating the overlying and underlying aquifer systems.

A deeper conductive layer is present at depths of 57–114 m, with a resistivity value of approximately 22.5 Ωm . This layer is interpreted as sandy tuff with relatively good permeability and high water saturation. Accordingly, it is classified as a confined aquifer, representing the main groundwater-bearing formation at this location.

The deepest layer, extending from 114 to 160 m, shows a moderate resistivity value of approximately 131 Ωm and is interpreted as volcanic breccia. This layer is considered an aquitard, forming the lower boundary of the identified aquifer system.

The results obtained from two VES measurements, located approximately 30 m apart, indicate a relatively consistent subsurface layering pattern. The similarity in geoelectrical response suggests lateral continuity of subsurface units, while minor differences in aquifer depth are likely associated with local elevation variations and natural heterogeneity.

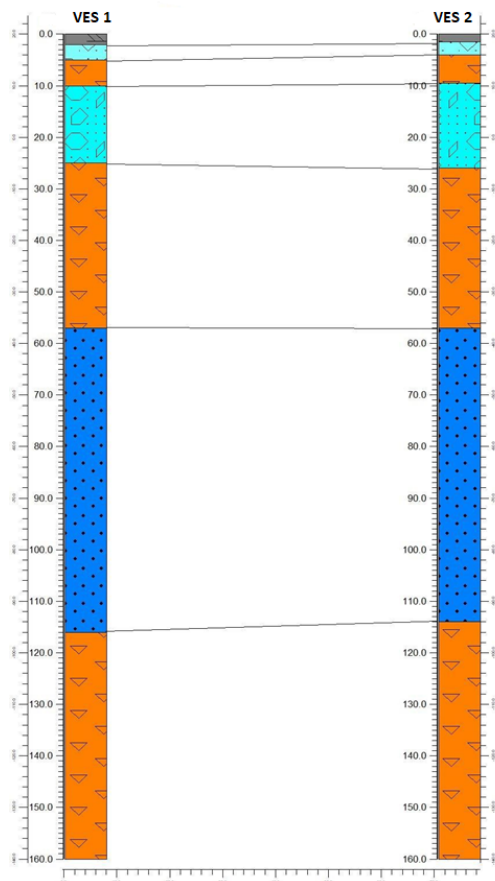


Figure 6. Correlation between VES 1 and VES 2

Based on resistivity analysis, five lithological layers are identified: topsoil (overburden), sand and gravel deposits, volcanic breccia, lapilli tuff, and sandy tuff. The interpretation of these layers is supported by their characteristic resistivity ranges. Sand and gravel deposits, as well as tuff layers, generally exhibit lower resistivity values, indicating higher porosity and groundwater saturation. In contrast, volcanic breccia is characterized by higher resistivity values, reflecting relatively compact material with lower water content, and is therefore interpreted as an aquitard.

The hydrogeological structure derived from both VES points shows a consistent vertical distribution of aquifer systems. A shallow unconfined aquifer is identified at depths of approximately 2–5 m at VES-01 and 1.5–4 m at VES-02. This aquifer is associated with sand and gravel deposits and is suitable for shallow groundwater extraction, such as dug wells.

An intermediate semi-confined aquifer is identified at depths of approximately 10–25 m at VES 1 and 9.5–26 m at VES 2. This unit corresponds to lapilli tuff and exhibits moderate groundwater potential, likely controlled by partial confinement and lithological variability.

A deeper confined aquifer is consistently identified at depths of approximately 57–116 m at VES 1 and 57–114 m at VES 2. This layer, interpreted as sandy tuff, is characterized by relatively low resistivity values, indicating significant water saturation. The presence of overlying high-resistivity breccia layers suggests that this aquifer is well confined and hydraulically protected.

Although geoelectrical cross-sections commonly represent subsurface layering using color gradation, the delineation of groundwater potential is fundamentally controlled by contrasts in resistivity values rather than graphical representation. In resistivity-based interpretation, low-resistivity zones are generally associated with water-saturated and relatively permeable formations, whereas high-resistivity zones correspond to more consolidated, less permeable lithologies that may act as aquitards.

The correlation of VES 1 and VES2 results indicates a laterally consistent, stratified aquifer system characterized by alternating conductive and resistive layers. In particular, the deeper conductive horizon, interpreted as a confined aquifer, represents the most prospective groundwater-bearing formation within the study area. However, this interpretation should be regarded as preliminary due to the limited spatial coverage provided by only two VES measurements. Further investigation, including additional geophysical surveys or borehole data, is required to better constrain the lateral continuity and hydrogeological properties of the identified aquifer system.

CONCLUSION

This study delineated the subsurface aquifer system in Sesela Village, West Lombok, using the Vertical Electrical Sounding (VES) method with Schlumberger configuration. The interpretation of resistivity data from two closely spaced VES points reveals a consistent stratified subsurface composed of alternating conductive and resistive layers associated with volcanic lithologies. Three hydrostratigraphic units were identified, comprising a shallow unconfined aquifer (1.5–5 m), an intermediate semi-confined aquifer (9–26 m), and a deeper confined aquifer (57–116 m). These aquifer systems are hydraulically separated by volcanic breccia layers characterized by high resistivity values, which function as aquitards controlling vertical groundwater movement.

The integration of both VES datasets indicates a laterally continuous aquifer system, suggesting that groundwater occurrence is primarily governed by lithological variations within volcanic deposits. Among the identified aquifers, the deeper confined aquifer exhibits the most favorable characteristics for groundwater development due to its greater thickness, lower

resistivity signature, and confinement by overlying resistive units. However, the interpretation is constrained by limited spatial data coverage and should be regarded as a preliminary hydrogeophysical model. Further investigations involving additional geophysical profiling and borehole validation are required to enhance the reliability of aquifer characterization and support sustainable groundwater resource development in the study area.

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References

- Alao, J. O., & Abubakar, F. (2025). Groundwater exploration, management strategies and sustainability: geophysical approaches. *Geosystems and Geoenvironment*, 4(3), 100395. <https://doi.org/10.1016/j.geogeo.2025.100395>
- Díaz-Alcaide, S., & Martínez-Santos, P. (2019). Advances in groundwater potential mapping. *Hydrogeology Journal*, 27(7), 2307–2324. <https://doi.org/10.1007/s10040-019-02001-3>
- Erintina, M. D., Ubaidillah, A. S., Faesal, A., & Kurniawan, A. (2022). Identifikasi lapisan akuifer menggunakan resistivity method 1-dimensi di Dusun Karang Bayan, Parampuan, Kabupaten Lombok Barat. *Jurnal Ilmiah Giga*, 25(2), 60–66. <https://doi.org/10.47313/jig.v25i2.1932>
- Erintina, M. D., Sismanto, S., Ubaidillah, A. S., Hidayat, S., Faesal, A., Munarfan, Z., Hermansyah, W., Syarbini, K., Dermawan, I., Anggraeni, J. D., & Gunawan, H. (2025). Identifikasi lapisan akuifer air tanah menggunakan metode resistivitas di Dusun Puarangan, Desa Pelangan, Lombok Barat. *Jurnal Ilmiah Giga*, 28(1), 50–56. <https://doi.org/10.47313/jig.v28i1.4241>
- Foster, S. (2022). The key role for groundwater in urban water-supply security. *Journal of Water and Climate Change*, 13(10), 3566–3577. <https://doi.org/10.2166/wcc.2022.174>
- Ghari, H. A., Voge, M., Bastani, M., Pfaffhuber, A. A., & Oskooi, B. (2020). Comparing resistivity models from 2D and 1D inversion of frequency domain HEM data over rough terrains: Case study from Iran and Norway. *Exploration Geophysics*, 51(1), 45–65.
- Hidayah, A. B., Sadri, M. I., Rafli, M., & Puspita, A. I. D. (2023). Design and implementation of a composite array resistivity data logger for high-resolution 2D inversion modeling. *Journal of Geoscience, Engineering, Environment, and Technology*, 8(1), 44–55. <https://doi.org/10.25299/jgeet.2023.8.1.10875>
- Ige, O. O., Adunbarin, O. O., & Olaleye, I. M. (2022). Groundwater potential and aquifer characterization within Unilorin campus, Ilorin, Southwestern Nigeria, using integrated electrical parameters. *International Journal of Energy and Water Resources*, 6(3), 353–370. <https://doi.org/10.1007/s42108-021-00160-2>
- Jia, X., O'Connor, D., Hou, D., Jin, Y., Li, G., Zheng, C., ... & Luo, J. (2019). Groundwater depletion and contamination: Spatial distribution of groundwater resources sustainability in China. *Science of the Total Environment*, 672, 551–562. <https://doi.org/10.1016/j.scitotenv.2019.03.457>
- Kadar, M. I., & Amir, M. K. (2024). Potensi akuifer menggunakan metode geolistrik di Desa Sambalagi, Kabupaten Morowali. *Mining Science and Technology Journal*, 3(3), 177–186. <https://doi.org/10.54297/minitech-journal.v3i3.886>
- Memon, F. A., Li, H., Hussain, M., Yuan, P., & Beshr, A. M. (2025). Technical advancements of laterally constrained inversion for geophysical datasets. *IEEE Access*. <https://doi.org/10.1109/ACCESS.2025.3608240>
- Mishra, R. K. (2023). Fresh water availability and its global challenge. *British Journal of Multidisciplinary and Advanced Studies*, 4(3), 1–78. <https://doi.org/10.37745/bjmas.2022.0207>
- Obasi, P., Ekinya, A., Akpa, C., & Edene, E. (2022). Characterization of subsurface lithology and aquifer parameters using vertical electrical sounding (VES) for groundwater development in Igbo-Imabana, Southern Nigeria. *Advances in Geological and Geotechnical Engineering Research*, 4(3), 12–31. <https://doi.org/10.30564/agger.v4i3.4939>
- Rizvi, S. F., Izhar, S. K., Shahab, A., Kuddus, M., & Roohi, R. (2025). Comprehensive review on groundwater exploitation, depletion, and its management: sustainable approach toward agricultural productivity in India. *Environmental Quality Management*, 34(4), e70092.
- Telford, W. M. (1990). Applied geophysics. *Nature*, 127(3212), 783–785. <https://doi.org/10.1038/127783a0>