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Subsurface Layer Investigation Using The Vertical Electrical Sounding (VES) in Muara Batu and Dewantara Sub-districts

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ABSTRACT
Research has been carried out that aims to determine the structure of the subsurface layers in the Muara Batu and Dewantara sub-districts using the Schlumberger array Vertical Electrical Sounding method. This research was conducted at 3 location points with a track length at each point of 600 m. The data in this study were measured using the SuperSting R8/IP resistivity meter and processed using the Ip2win software. The results obtained show that the subsurface layer at point VES1 consists of alluvium with a very low resistivity value (1.2 – 5.1 Ωm), VES2 consists of top soil, clays, gravels, tuffaceous, limestones, sandstones, and calcareous mudstones with a resistivity value of 4.8 – 39.0 Ωm, and VES3 consists of clays, gravels, silty clay, sandy silty clays, tuffaceous, silt, sand, calcareous mudstones and hard rocks with a resistivity value of 8.0 – 18.7 Ωm. The subsurface of VES1 is a layer that is saturated with water and is not dense so it has liquefaction potential. While VES2 and VES3 are dense layers so that buildings built in this area will be safer against earthquakes.

Keywords: *Vertical Electrical Sounding, Subsurface layer, Muara Batu, Dewantara*

1. INTRODUCTION

Muara Batu is the sub-district where Malikussaleh University was founded. Over time, the rapid development of the campus has had an impact on development in the surrounding area. This can be seen from the construction of housing complexes in the Dewantara sub-district. Both of these sub-districts are administratively located in the North Aceh district and geomorphologically are hills and coastal plains consisting of alluvium. These conditions can cause coastal areas to potentially experience seawater intrusion and liquefaction. On the other hand, Aceh, which is an area traversed by the Sumatra fault, results in frequent earthquakes [1]. The impact of this earthquake will certainly be very dangerous for buildings built on soft rock. Several earthquake events can be seen that have caused very serious damage to buildings, such as the earthquake in the districts of Benar Meriah and Central Aceh (3 July 2013), Pidie Jaya (7 December 2016), and Cianjur (21 November 2022).

Generally, before tall buildings are built, drilling is often carried out to determine the hardness of the soil. But only at shallow depths, because it takes a long time so it costs a lot. Therefore research on deeper subsurface structures needs to be done to provide an overview of the subsurface rock conditions. This investigation can be carried out using a geophysical survey, one of which is the Vertical Electrical Sounding method. In this method what is measured is the electrical properties of the rock by passing an electric current that has a high voltage into the ground. The results of the rock resistivity values obtained can be modeled in 1D to provide information on the resistivity of rock layers concerning depth. Where this information can be useful in planning earthquake-resistant buildings, determining the depth of the foundation, the depth of hard layers, and the depth of groundwater.

The VES method is generally applied in geophysical exploration activities to determine the identification of aquifer layers [2], [3]. The VES method is also often integrated with borehole data such as in research to characterize sediment processes in Krueng Aceh [4], geotechnical investigations [5], and so on. The VES method with the Schlumberger array arrangement can provide an overview of the resistivity values of subsurface rocks [6]

1.1. Geology of Muara Batu and Dewantara Sub-district

The research area based on the geology of the Lhokseumawe quadrangle is included in the Alluvium (Qh) and Idi Formation (Qpi). The Alluvium consists of gravels, sands, and clays, while the Idi Formation consists of several areas, namely Samalanga, Peudada, Lhokseumawe, and Krueng Jambo Aye. The Lhokseumawe area consists of reefal limestones, gravels, sandstones, and calcareous mudstones. The Julu Rayeu Formation (QTjr) in the research area can be below the Idi Formation [7].

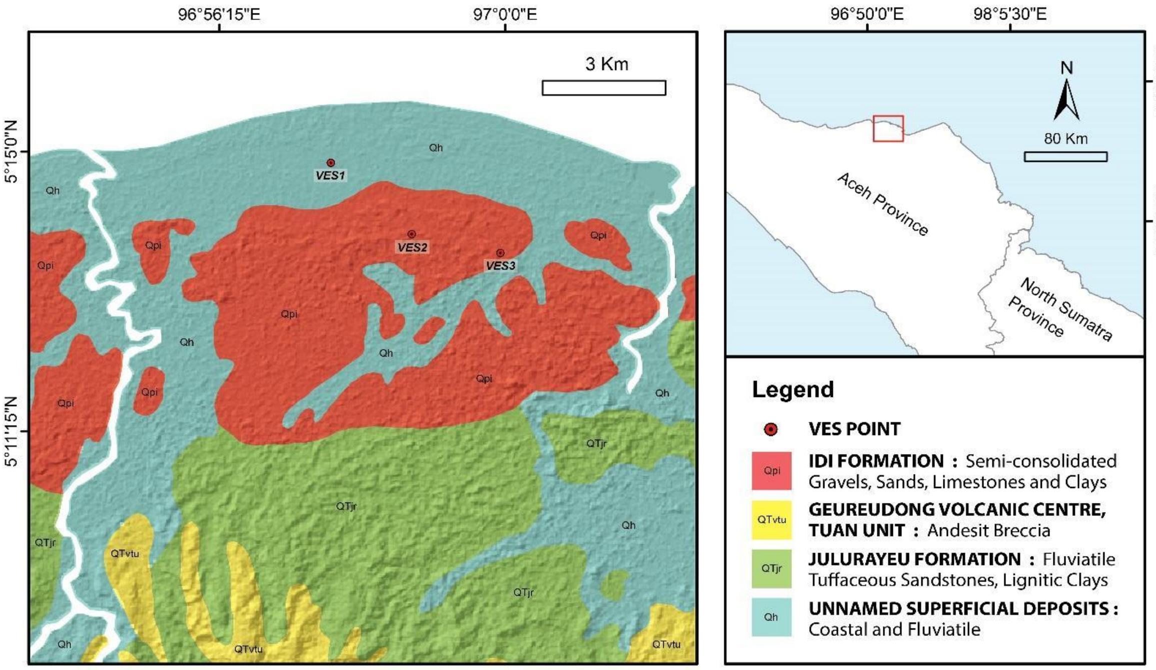

Figure 1. The geological map of the research area shows that in general, it consists of sedimentary rocks

1.2. Resistivity of Rocks and Minerals

The resistivity values obtained usually overlap between one rock and another. This is because the resistivity of rocks is influenced by many factors such as porosity, water saturation level, and dissolved salt concentration. Sedimentary rocks generally have a lower resistivity value than igneous and metamorphic rocks because they are more porous and contain a lot of water. Resistivity values in sedimentary rocks depend on porosity and salinity. Meanwhile, resistivity values in igneous and metamorphic rocks depend more on fractures and the percentage of water that fills the fractures [8].

Table 1. Resistivities of various rocks, sediments, and minerals [9].

Rock Type	Resistivity Range (Ωm)
Clays	1-100
Unconsolidated wet clay	20
Sandstones	$1\text{-}6.4 \times 10^8$
Limestone	$50\text{-}10^7$
Surface waters (sediments)	10-100
Surface waters (igneous rocks)	$0.1\text{-}3 \times 10^3$
Natural waters (sediments)	1-100
Natural waters (igneous rocks)	0.-150
Sea water	0.2

3. METHODS

The research was conducted at 3 location points in Muara Batu and Dewantara Sub-districts. These points are VES1 (Ulee Madon), VES2 (Pulo Rungkoem) and VES3 (Reuleut Timue). Data collection was carried out using the Vertical Electrical Sounding method with the Schlumberger array. In this Schlumberger array measurement, four electrodes are used, namely 2 electrodes as current electrodes (A and B) and 2 electrodes (M and N) as potential electrodes. Apparent resistivity ρ_a ρ_a is calculated based on current I and potential difference ΔV with geometric factor K [10] :

$$\rho_a = K \frac{\Delta V_{MN}}{I_{AB}} \rho_a = K \frac{\Delta V_{MN}}{I_{AB}}$$

$$K = \frac{2\pi}{\frac{1}{r_{AM}} - \frac{1}{r_{AN}} - \frac{1}{r_{BM}} + \frac{1}{r_{BN}}} K = \frac{2\pi}{\frac{1}{r_{AM}} - \frac{1}{r_{AN}} - \frac{1}{r_{BM}} + \frac{1}{r_{BN}}}$$

(2)

The length of each measuring point line is 600 m. The data acquisition process was carried out using a SuperSting R8/IP Resistivitymeter and data processing using the Ipi2win software to obtain a 1D resistivity cross-section. Subsurface resistivity data is also correlated with existing drill data as an approach to subsurface interpretation.

4. RESULT AND DISCUSSION

The subsurface lithology is interpreted based on the subsurface resistivity values obtained and associated with geological conditions at each data measurement point.

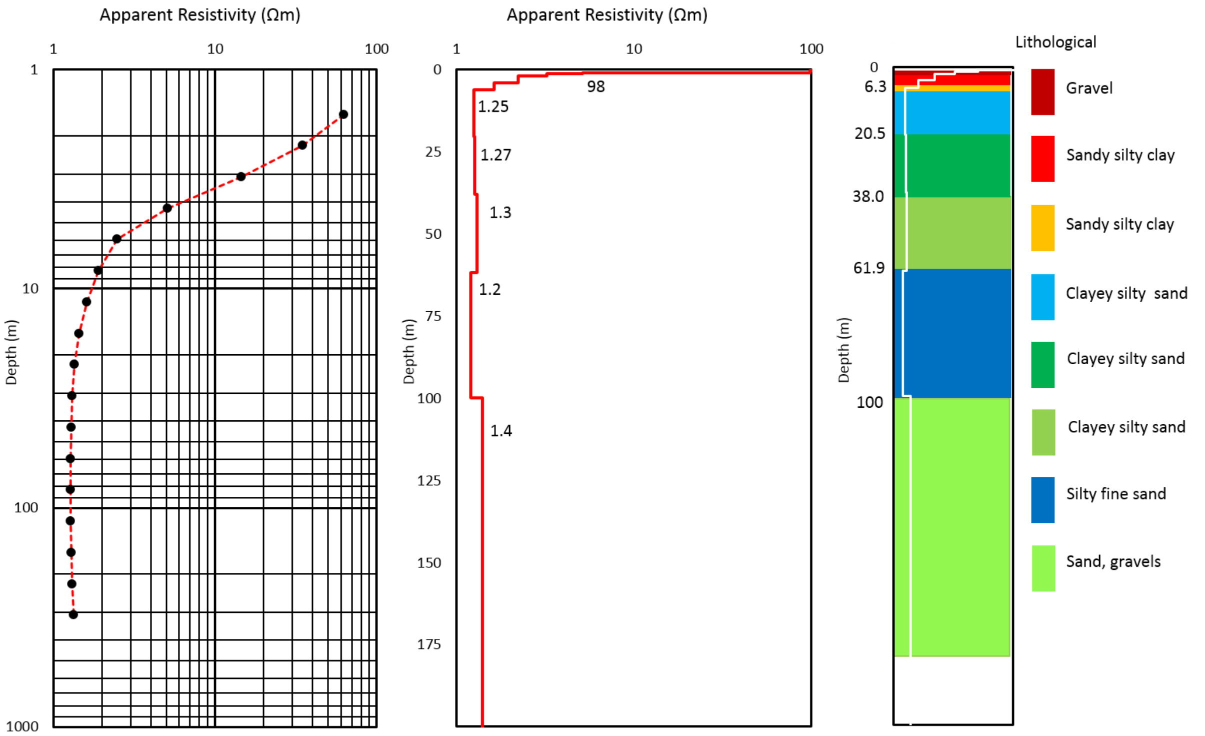

Figure 2. Apparent resistivity curve model and lithological interpretation (VES1).

Data on the resistivity cross-section of point VES1 obtained very low resistivity values starting from a depth of 1 m (1.2 – 5.1 Ωm). Shows that the subsurface layer at point VES1 is generally a water-saturated rock layer. The resistivity value which continues to decrease as the depth gets deeper gives an illustration that the subsurface rock layer is weak. Areas like this have liquefaction potential. In general, the subsurface layer of VES1 can be interpreted to consist of layers of gravels as the top layer from a depth of 0 – 1 m (98.3 – 161 Ωm), sandy silty clays from a depth of 1-6.3 m, clayey silty clay from a depth of 6.3 – 20.5 m, Silty Fine sand from a depth of 61.9 - 100 m, and sand with gravel from a depth of 100 – 150 m. This interpretation is based on the VES1 geological point approach, namely Alluvium (coastal and fluviatile) [7]. Alluvium is a rock that is difficult to distinguish, but generally sedimentary rocks which are more porous and filled with water have a lower resistivity value. However, if the sedimentary rock is denser, the resistivity value is slightly higher. Therefore at this point, the hard layer is identified as being at a depth of 100 m, where at that depth the resistivity value increases slightly higher (1.4 Ωm)

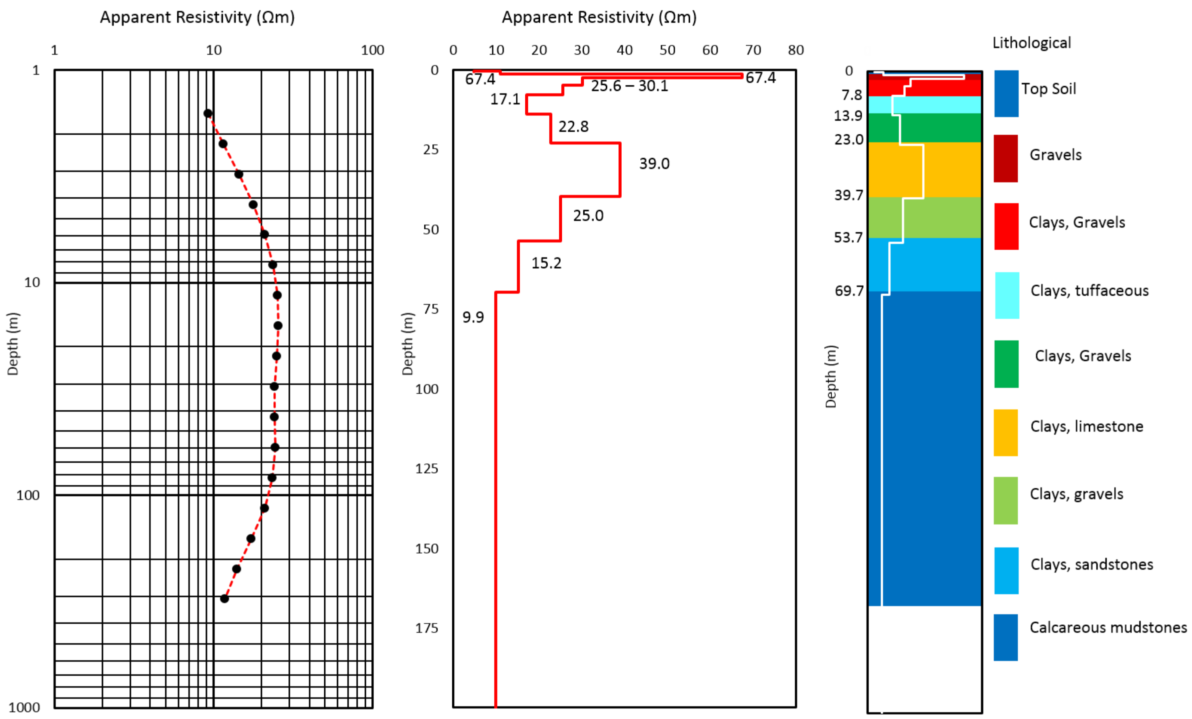

Figure 3. Apparent resistivity curve model and lithological interpretation (VES2).

The VES2 point has a resistivity value that varies with each depth. The range of resistivity values at that point is generally moderate (4.8 – 39.0 Ωm). Based on the resistivity section model (Figure 3) the subsurface layer is identified as consisting of a thin layer of topsoil from a depth of 0 - 0.5 m, gravels from a depth of 0.5 - 1.5 m, clay and gravels from a depth 1.5 – 7.8 m, clays, and tuffaceous from depth 7.8 – 13.9 m, clays and gravels from depth 13.9 – 23.0 m, clay and limestones from 23.0 – 39.7 m, clays and gravels from 39.7– 53.7, clay and sandstones from 53.7 - 69.7 m, and calcareous mudstones from 69.7 -150 m. The results of the resistivity section on the interpretation of subsurface lithology at this point can be said in general to be a hard layer starting from a depth of 7.8 m. The existence of groundwater has only been identified at a depth of 53.7 m in a layer of sandstone mixed with clay. The lithology interpretation above is supported by the lithology results from drill data around the location. Drill results show that from a depth of 0 – 4.9 m it consists of topsoil, sandy clays, and gravel below the surface. Then from a depth of 4.9 – 12 m which consists of clays and tuffaceous.

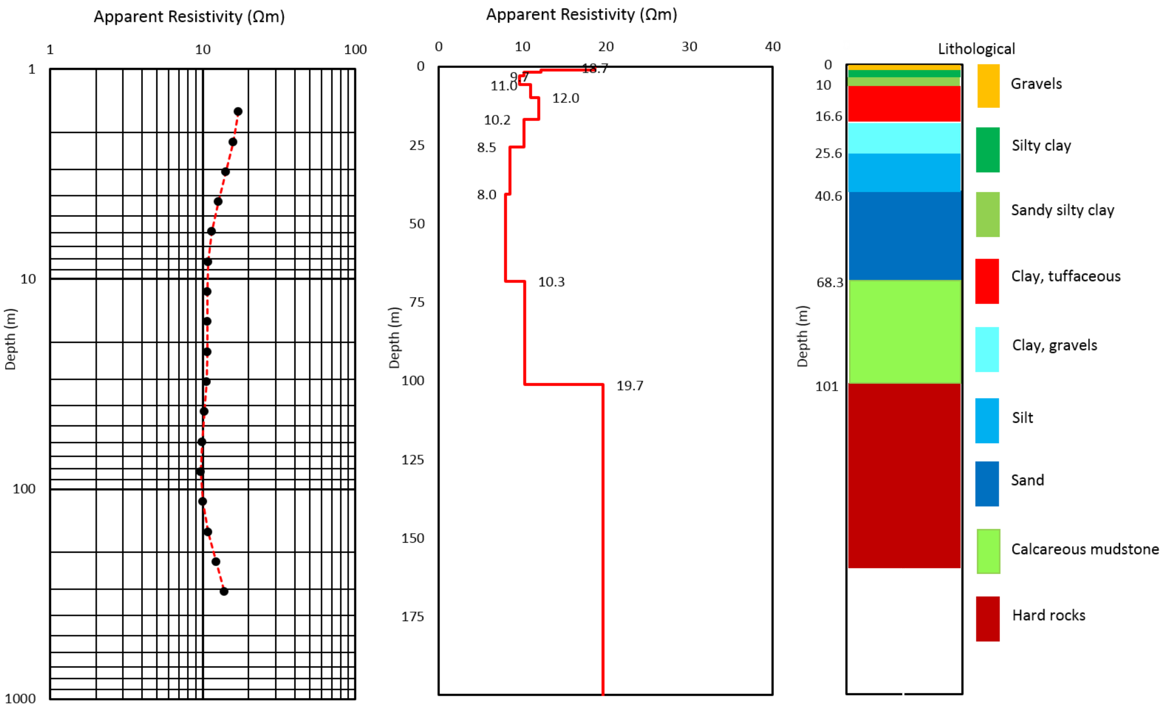

Figure 4. Apparent resistivity curve model and lithological interpretation (VES3)

The range of resistivity values at the VES3 point is generally also moderate (8.0 – 18.7 Ωm). Based on the resistivity value, the subsurface layer of the VES3 point is like a homogeneous layer of rock. The resistivity section model (Figure 4) of the subsurface layer of the point consists of gravels from a depth of 0 – 1 m (12.2 – 18.7 Ωm), silty clay from a depth of 1.2 – 5.9 m, sandy silty clay from a depth of 5.9 – 10 m, clay and tuffaceous from 10 – 16.6 m depth, clay and gravels from 16.6 - 25.6 m depth, silt from 25.6 – 40.6 m depth, sand from 40.6 – 68.3 m depth, calcareous mudstones 68.3 – 101 m, and hard rocks from 101 – 150 m depth. Even though it is in the same Idi Formation as VES2, there is no limestone layer at this point. The aquifer is indicated to be in a layer of sand with a resistivity value of 8 Ωm.

Relatively moderate resistivity values (VES3) from 0 - 150 m depth give a solid subsurface picture. On the other hand, a relatively high resistivity value, such as in the gravels (VES2) layer, indicates that the layer is not dense and easily eroded if the topsoil is removed.

The lithology estimation of subsurface rock layers as aquifer layers is supported by drilled well data near the measurement location. At the VES2 point, the depth of the drilled well is at a depth of ±65 m. Whereas at VES3 point the depth of the drilled well is 51 m. However, at a depth of > 60 m, the water is found in calcareous water.

The subsurface model at two points, namely VES2 and VES3, can be concluded as a dense and hard layer. So that buildings built in this area will be safer against earthquakes. Whereas at point VES1 is a weak layer that has the liquefaction potential.The interpretation of the subsurface lithology at the three VES measurement points is described in table 4.2.

Table 2. Interpretasi data VES

No.	VES Point	Coordinate		Alt. (m)	Layers (n)	Resistivity (Ωm)	Depth (m)	Lithology Interpretation
		Lat.	Long.					
1.	ES1	)5°14’53.01”N	96°57’44.12”E	4	1	98.3 - 161	1	Gravels
					2	2.2 – 5.1	1-4	Sandy silty clay
					3	1.3-1.6	4 – 6.3	Sandy silty Clay
					4	1.25	6.3 - 20.5	Clayey silty sand
					5	1.27	20.5 - 38	Clayey silty sand

					6	1.3	38 – 61.9	Clayey silty sand
					7	1.2	61.9 - 100	Silty fine sand
					8	1.4	100 -150	Sand (aquifer), gravels
2.	ES2	05°13’55.48”N	96°58’48.23”E	38	1	4.8 – 11	0.5	Topsoil
					2	67.4	0.5 - 1.5	Gravels
					3	25.6 – 30.1	1.5 – 7.8	Clays, gravels
					4	17.1	7.8 – 13.9	Clays, tuffaceous
					5	22.8	13.9 – 23.0	Clays, gravels
					6	39.0	23.0 – 39.7	Clays, limestone
					7	25.0	39.7– 53.7	Clays, gravels
					8	15.2	53.7 - 69. 7	Clays, sandstones (aquifer)
					9	9.9	69.7-150	Calcareous mudstones
3.	ES3	05°13’40.44”N	96°59’58.37”E	23	1	12.2 – 18.7	1.2	Gravels
					2	9.7 -12.2	1.2 – 5.9	Silty clay
					3	11	5.9 - 10	Sandy silty clay
					4	12	10 – 16.6	Clays, tuffaceous
					5	10,2	16.6 - 25.6	Clay, gravels
					6	8.5	25.6 – 40.6	Silt
					7	8	40.6 – 68.3	Sand (aquifer)
					8	10.3	68.3 - 101	Calcareous mudstones
					9	19.7	101 - 150	Hard rocks

5. CONCLUSION

The subsurface layer of the VES1 point consists of alluvium with a very low resistivity value (1.2 – 5.1 Ωm), VES2 consists of top soil, clays, gravels, tuffaceous, limestones, sandstones, and calcareous mudstones with a resistivity value of 4.8 – 39.0 Ωm, and VES3 point consists of clays, gravels, silty clay, sandy silty clays, tuffaceous, silt, sand, calcareous mudstones and hard rocks with resistivity values of 8.0 – 18.7 Ωm. The subsurface of VES2 and VES3 is a dense layer so that buildings built in this area will be safer against earthquakes, while the subsurface of VES1 is a layer that is saturated with water and is not dense so it has the potential for liquefaction

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REFERENCES

[1] D. H. Natawidjaja and W. Triyoso, ‘The Sumatran Fault Zone — From Source To Hazard’, vol. 1, no. 1, pp. 21–47, 2007.

[2] R. Stanly, S. Yasala, R. Vaishali, and K. Words, ‘Hydrological Subsurface Investigation Using Geophysical Electrical and Magnetic Methods In and Around Valliyar River Basin , India’, *Results Geophys. Sci.*, vol. 7, no. June, p. 100022, 2021, doi: 10.1016/j.ringps.2021.100022.

[3] Syafrizal, D. Darisma, A. H. Pramana, N. Aflah, M. Sayuti, and N. Novita, ‘Identification of the Aquifer Layer using the Geoelectrical Method in Teupin Batee Village, Aceh Besar’, vol. 3, no. 1, pp. 40–46, 2022, doi: 10.25008/bcsee.v3i1.1155.

[4] I. Rusydy *et al.*, ‘Integration of Borehole and Vertical Electrical Sounding Data to Characterise the

Sedimentation Process and Groundwater in Krueng Aceh Basin, Indonesia', *Groundw. Sustain. Dev.*, vol. 10, no. 7, p. 100372, 2020, doi: 10.1016/j.gsd.2020.100372.

[5] M. Yanis *et al.*, 'Geophysical and Geotechnical Approaches in Developing Subsurface Model for Gas Power Plant Foundation', *Indian Geotech. J.*, vol. 52, no. 1, pp. 237–247, 2022, doi: 10.1007/s40098-021-00559-y.

[6] U. Hamzah, A. R. Samsudin, and E. P. Malim, 'Groundwater investigation in Kuala Selangor using vertical electrical sounding (VES) surveys', *Environ. Geol.*, vol. 51, no. 8, pp. 1349–1359, 2007, doi: 10.1007/s00254-006-0433-8.

[7] W. Keats *et al.*, 'The Geology of The Lhokseumawe Quadrangle', Bandung, 1981.

[8] M. H. Loke, 'Tutorial: 2D and 3D Electrical Imaging Surveys', no. October, 2015, [Online]. Available: http://www.geotomosoft.com/coursenotes.zip.

[9] W. M. Telford, L. P. Geldart, and R. E. Sheriff, *Applied Geophysics Second Edition*. 1990.

[10] Y. Ait Bahammou, A. Benamara, A. Ammar, D. Hrittta, I. Dakir, and H. Bouikbane, 'Application of vertical electrical sounding resistivity technique to explore groundwater in the Errachidia basin, Morocco', *Groundw. Sustain. Dev.*, vol. 15, no. June, p. 100648, 2021, doi: 10.1016/j.gsd.2021.100648.