Geophysical Investigation of Groundwater Within Nnamdi Azikiwe University, Awka, and Environ Using Electrical Resistivity Method

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ABSTRACT

Using vertical electrical sounding (VES) of the electrical resistivity method, the aquifer potential, and electrical variations of lithologic units, investigation was conducted within and around Nnamdi Azikiwe University in Awka, Anambra State, Nigeria. Latitude 6⁰ 12' N to 6⁰ 17' N and Longitude 7⁰ 5'E to 7⁰ 10'E define the boundaries of this study area. This research was carried out due to the difficulty associated with accessing underground water in the area, as the precise depths of the aquifer are still very unknown. Hence, this study is significant. Twelve (12) VES Stations were acquired using the Schlumberger Array. The data was interpreted using MS Excel and Interpex. This work reveals that the study area has 3-5 geo-electric layers, indicating the predominance of Shale, an impermeable layer with an appreciable amount of Sandstone. The depth and thickness of the aquiferous units were unknown since the base of some geo-electric layers was not reached with an average resistivity of 1460.95 ohm-m.

Keywords: *Groundwater, Aquifer, Resistivity, Geo-electric, Awka.*

INTRODUCTION

When surface water is impractical for a specific task, groundwater might be a helpful substitute. It is crucial to conduct a site investigation or pre-construction study to determine the quantity and quality of groundwater accessible to guarantee the efficient and sustainable use of groundwater resources (Al-garni, 2009; Venkata et al 2014).

Combining geophysics and hydrogeology has provided valuable tools for studying and managing groundwater resources (Rubin *et al*., 2005). A significant challenge is the complexity of subsurface environments, which can lead to difficulties in accurately interpreting geophysical data and making predictions about subsurface hydrological properties. The lack of adequate observational data and limited accessibility to subsurface environments also pose challenges to hydrogeophysics (Hubbard & Rubin, 2002).

This work aims to use the electrical resistivity method to provide valuable information on the aquifer depth, apparent resistivity and inferred lithology in the area to ensure a sustainable water supply.

Location and Physiography

Nnamdi Azikiwe University is situated at Awka South Local Government Area in Anambra State, Nigeria (Fig 1). Awka is the capital of Anambra State, and the Nnamdi Azikiwe University is located along the Enugu – Onitsha Express Road. It is bounded by Latitude N 06⁰ 12' to 06⁰ 17' and Longitude E007⁰ 5' to 007⁰ 10'. The average elevation of Awka is 95 meters (312 feet), and it lies in a valley on the Mamu River plains. The climate is tropical.

The Nnamdi Azikiwe University's permanent location is in the highlands of a low, asymmetrical ridge known as a Cuesta in the Awka-Orlu Uplands' northern area. Most of the site's low-lying areas are wet, indicating that the underlying soil (aquiclude) has low permeability. The surface water flows toward the northeast (Aghamelu *et al.*, 2011).

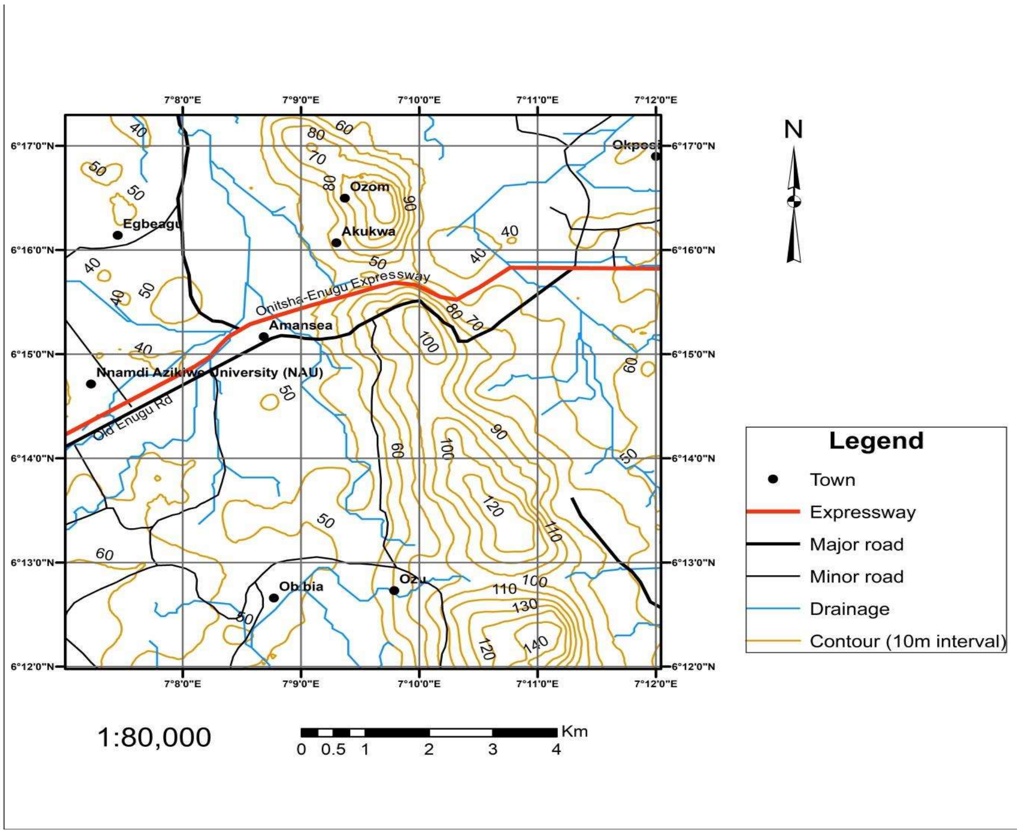


Figure 1: Location map of the study area.

Geology of Study Area

Awka is underlain by four geological formations: Alluvial Plain Sands, Ogwashi-Asaba Formation, Ameki/Nanka Sands, and Imo Shale. A narrow N-S trending belt of Alluvial plain sand deposited by the River Niger at an average topographic height of 25m above sea level. The Imo Shale formation, of which shale is the predominant rock type, is the top layer upon which the Nnamdi Azikiwe University, Awka location is situated; this lies within the Anambra sedimentary basin. At different depths (0.0 to 3.5m), other rock types, including siltstone, sandstone, and laterite, are also present and cover the shale. According to Odoh *et al*. (2012), the hue of the fresh shale sample ranges from bluish to black, while the siltstone and sandstone are milky to brownish, and the laterite is dark brownish to reddish. Given the site's height and the terrain's undulations toward the southeast, this is a frequent problem on the university campus, particularly in the Science Village area of the University.

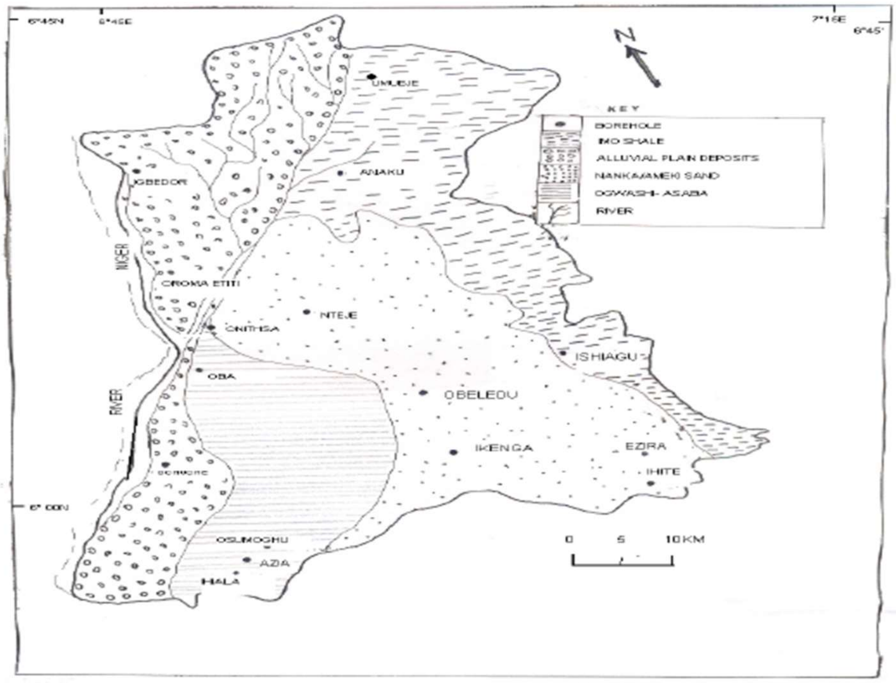


Figure 2: Map showing the spatial distribution of geologic units across Anambra state (Nfor *et al.,* 2010).

DATA COLLECTION OF THE VERTICAL ELECTRICAL SOUNDING USING SCHLUMBERGER ARRAY AND INTERPRETATION

Twelve vertical electrical soundings (VES) data were collected using a maximum current electrode separation of 2m (minimum) and 300 m (maximum). Apparent resistivity was obtained automatically by converting the ground's resistance (R) values. The survey was carried out using a straight pathway for a comprehensive survey spread. In the field, the survey equipment was arranged as necessary. Four electrodes were used: two current electrodes and two potential electrodes. The aid cables connect the four electrodes to their respective points in the resistivity meter.

To find the apparent resistivities and thicknesses of different layers penetrated, the apparent resistivity values from the experiment were plotted against half the current electrode separation on a bi-logarithmic graph. Anakwuba et al (2014), Ezeh (2011), and several researchers have successfully used this approach while exploring groundwater. Matching short parts of the field curves with the associated auxiliary and two-layer model curves allowed for a quantitative interpretation of the resistivity curves. The resistivity data were manually evaluated.

1. DISCUSSION OF RESULTS

Quantitative interpretation

Vertical electrical sounding data were obtained at the 12 geo-electric sounding stations represented as VES 1–12 in this work, and Fig 3 below is the VES map.

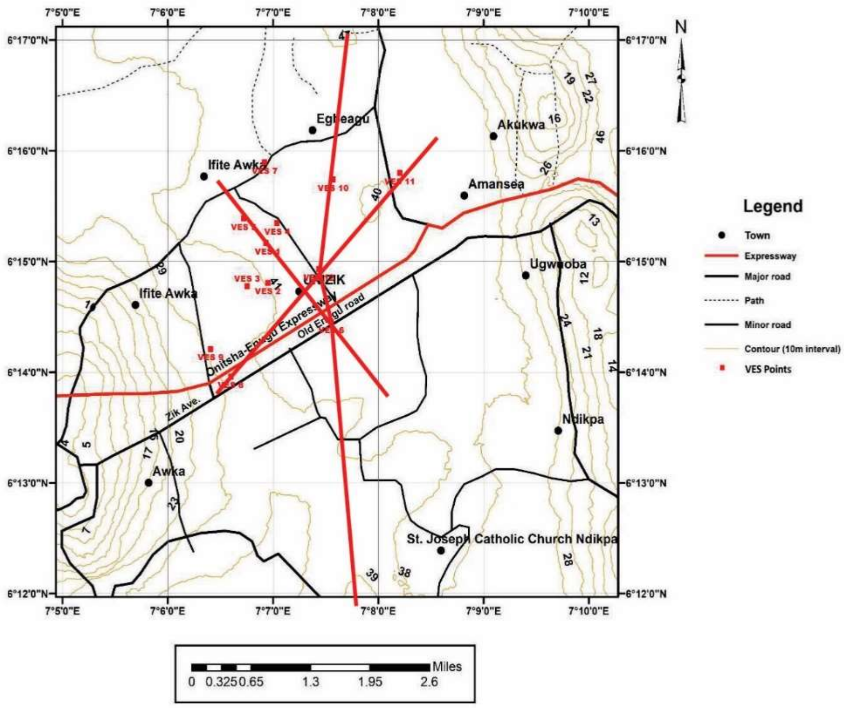


Figure 3: Vertical Electrical Sounding (VES) map

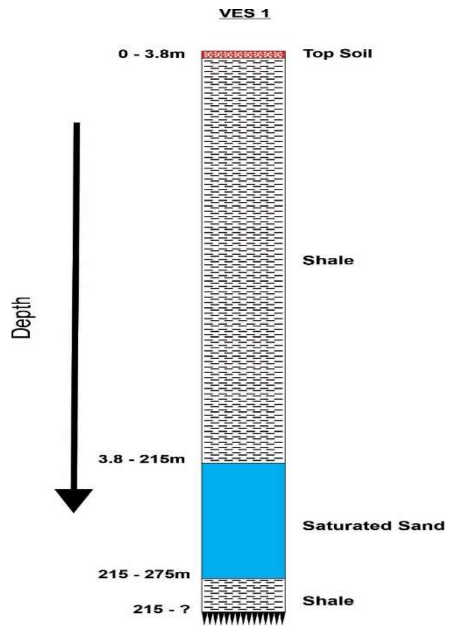
Interpretation of results from Station 1.

Latitude : N06º15’9”
Longitude : E007º06’56”
Elevation: 48m

The data shows that this station has 4 geo-electric layers (Table 1 and Fig 4). The first layer was interpreted as Topsoil having an apparent resistivity of 60Ωm at a depth of 3.8m. The second geo-electric layer was interpreted as Shale, as it is often known due to the fall in resistivity, 18Ωm having a depth of 215m. A shale is a geologic unit that can retain water but cannot readily give out it; therefore, it is porous but impermeable. This makes it a non-aquiferous unit. The third geo-electric layer was interpreted as Saturated Sand. This is called so because of the sudden increase in resistivity as Sand has high resistivity. It has an apparent resistivity of 653Ωm at a depth of 275m. Saturated implies that the geologic unit is filled with water. Sandstone is porous and permeable. That is to say, it can retain water simultaneously and readily give out water, so this is the aquiferous unit. The fourth layer was interpreted as Shale having an apparent resistivity of 30Ωm with depth unknown as the base was not reached.

Table 1: Geo-electric parameters of VES Station 1

GEO-ELECTRIC LAYERS	DEPTH (M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-3.8	3.8	60	Topsoil
2	3.8-215	211	18	Shale
3	215-275	60	653	Saturated Sand
4	275-???	_	30	Shale



Figuer 4: Geo-electric Section of VES Station 1.

Interpretation of results from Station 2

Latitude : N06º14'48"
Longitude : E007º06'55"
Elevation: 46m

The geo-electric section (Fig 5) was interpreted to have 4 layers (Table 2). The first layer, having an apparent resistivity of 72Ωm with a thickness of 3.1m, was interpreted as Topsoil. This layer could contain loamy soil/humus soil/laterite because it is mostly an overburden that agents of erosion or man transported, so it is loose and poorly compacted. The second layer was interpreted as Shale having a low resistivity of 19Ωm with a thickness of 190.9m, indicating its predominance within the study area. The third geo-electric layer was interpreted as Saturated sand having an apparent resistivity of 512Ωm with a thickness of 43m. Given its resistivity and thickness, this layer can be called an aquifer; a borehole can be sited. The fourth layer was interpreted as Shale, which has an apparent resistivity of 38Ωm, with thickness still unknown as the base was not reached.

Table 2: Geo-electric parameters of VES Station 2

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-3.1	3.1	72	Topsoil
2	3.1-194	190.9	19	Shale
3	194-237	43	512	Saturated sand
4	237-???	_	38	Shale

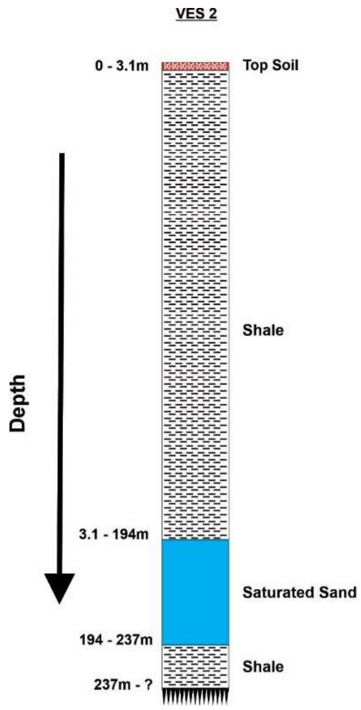


Figure 5: Geo-electric Section of VES Station 2

Interpretation of results from Station 3.

Latitude : N06º14'45"
Longitude : E007º06'45"
Elevation: 58m

This station was interpreted to have five layers (Table 3). The first geo-electric layer (Fig 5) was interpreted as Topsoil having an apparent resistivity of 1360Ωm at a depth of 4.7m. Having a very high resistivity in this station, which is different from the previous stations, only confirms the nature of Topsoil and its variations in resistivity. The second geo-electric layer was interpreted as Sandy shale having an apparent resistivity of 413Ωm at a depth of 11m, implying that sand is more abundant than shale in this geo-electric layer. The third layer was interpreted as Shale having an apparent resistivity of 11.4Ωm at a depth of 189m. The fourth geo-electric layer was interpreted to be saturated sand with a depth of 251m and an apparent resistivity of 87.7Ωm. Here, an aquifer can be said to be seen as there is a drastic rise in resistivity. The fifth layer was interpreted as Shale having an apparent resistivity of 8Ωm, with depth unknown because the base was not reached.

Table 3: Geo-electric parameters of VES Station 3

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-4.7	4.7	1360	Topsoil
2	4.7-11	6.3	413	Sandy shale
3	11-189	178	11.4	Shale
4	189-251	62	87.7	Saturated sand
5	251-???	_	8	Shale

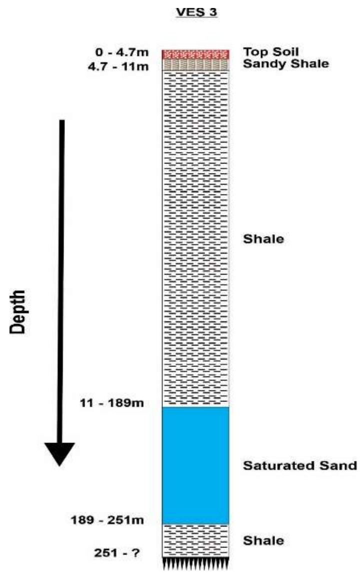


Figure 6: Geo-electric Section of VES Station 3

Interpretation of results from Station 4.

Latitude : N06º15'20"
Longitude : E007º07'01"
Elevation: 52m

A sum of 6 geo-electric layers (Table 4 and Fig 7) was interpreted with the Topsoil as the first layer having an apparent resistivity of 80Ωm with a thickness of 3.8m. The second geo-electric layer was interpreted as Shale having an apparent resistivity of 65Ωm with a thickness of 21.2m. Further below is Sandy shale, the third geo-electric layer of apparent resistivity of 190Ωm and a thickness of 53m, indicating that sand is dominant in the layer. The fourth layer was interpreted as Shale with a thickness of 154m and an apparent resistivity of 10.5Ωm. The fifth geo-electric layer was interpreted as Saturated sand having an apparent resistivity of 598Ωm with a thickness of 21m. Here, a fully saturated aquifer can be found. The sixth geo-electric layer was interpreted as Shale having a resistivity of 19Ωm with thickness unknown as the base was not reached.

Table 4: Geo-electric parameters of VES Station 4

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-3.8	3.8	80	Topsoil
2	3.8-25	21.2	65	Shale
3	25-78	53	190	Sandy shale
4	78-232	154	10.5	Shale
5	232-253	21	598	Saturated sand
6	253-???	_	19	Shale

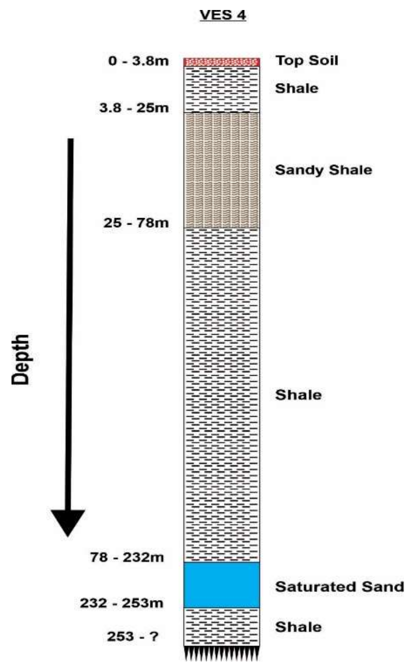


Figure 7: Geo-electric Section of VES Station 4

Interpretation of results from Station 5.

Latitude : N06º15'23",
Longitude : E007º06'41",
Elevation: 43m

The geo-electric layers were interpreted as 4 layers, as shown in Fig 8 and Table 5. The first layer was interpreted as Topsoil at a depth of 3m having an apparent resistivity of 20Ωm. The second geo-electric layer was interpreted as Shale, having an apparent resistivity of 15.4Ωm at a depth of 236m. The third geo-electric layer was interpreted as Saturated sand having an apparent resistivity of 590Ωm at a depth of 252m. This is considered to be the aquiferous unit. The fourth layer was interpreted as a Shale with unknown depth since the base was not reached, having a resistivity of 12Ωm.

Table 5: Geo-electric parameter of VES Station 5

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-3	3	20	Topsoil
2	3-236	233	15.4	Shale
3	236-252	16	590	Saturated sand
4	252-???	_	12	Shale

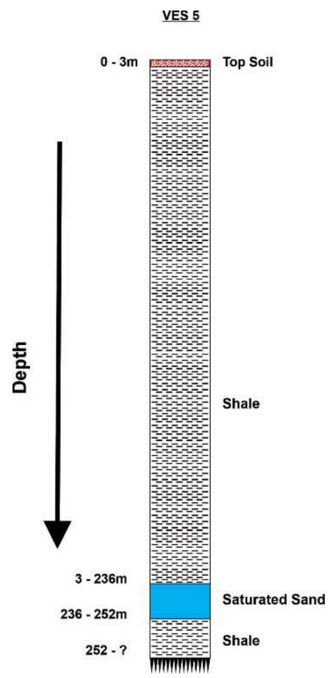


Figure 8: Geo-electric Section of VES Station 5

Interpretation of results from Station 6.

Latitude : N06º14'27",
Longitude : E007º07'33",
Elevation: 42m

The first layer (Table 6 and Fig. 9) was interpreted as Topsoil having an apparent resistivity of 91Ωm with a thickness of 3.9m. The second geo-electric layer was interpreted as Shale with a given thickness of 93.1m and apparent resistivity of 50Ωm. The third geo-electric layer was interpreted as Saturated sand due to an increase in resistivity, which is 170Ωm and a thickness of 83m. This is an aquiferous unit. The fourth layer was interpreted as Shale having a resistivity of 37.2Ωm with a depth unknown as the base was not reached.

Table 6: Geo-electric parameters of VES Station 6

GEO-ELECTRIC LAYERS	**DEPTH(M)**	**THICKNESS(M)**	**APPARENT RESISTIVITY(ΩM)**	**INFERRED LITHOLOGY**
1	0-3.9	3.9	91	Topsoil
2	3.9-97	93.1	50	Shale
3	97-180	83	170	Saturated sand
4	180-???	_	37.2	Shale

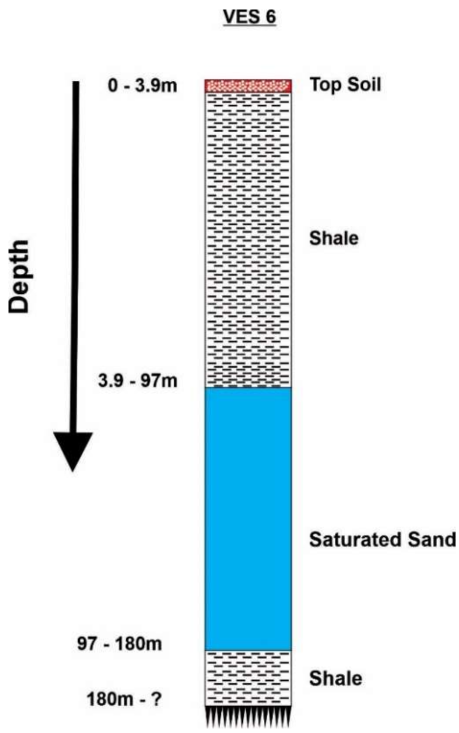


Figure 9: Geo-electric Section of VES Station 6

Interpretation of results from Station 7.

Latitude : N06º15'54"
Longitude : E007º06'54"
Elevation: 45m

The first layer (Table 7) was interpreted as Topsoil having an apparent resistivity of 44.5Ωm with a thickness of 3m, as seen in Fig 10. The second geo-electric layer was interpreted as Shale having an apparent resistivity of 80Ωm with a thickness of 11m. The third geo-electric layer was interpreted as Dry Sand, and it was called that because of its apparent resistivity of 873Ωm with a thickness of 85m. The fourth layer was also interpreted as Saturated sand. That is, it is fully filled with water and has an apparent resistivity of 612Ωm with a thickness of 91m. This can be considered as the aquiferous unit, fully saturated with water. The fifth layer is Shale, having an apparent resistivity of 180Ωm with a thickness unknown as the base was not reached.

Table 7: Geo-electric parameters of VES Station 7

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-3	3	44.5	Topsoil
2	3-14	11	80	Shale
3	14-99	85	873	Dry sand
4	99-190	91	612	Saturated sand
5	190-???	_	180	Shale

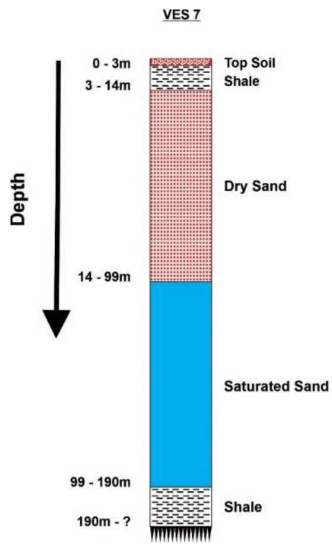


Figure 10: Geo-electric Section of VES Station 7

Interpretation of results from Station 8.

Latitude : N06º13'56"
Longitude : E007º06'36"
Elevation: 62m

Five (5) geo-electric layers (Fig 11) were interpreted from the data (Table 8). Topsoil was interpreted as the first geo-electric layer, having an apparent resistivity of 312Ωm at a depth of 1.4m. The second geo-electric layer was interpreted as Sandy shale having an apparent resistivity of 130Ωm at a depth of 31m, implying a higher sand content than shale in the geologic unit. The third geo-electric layer is Shale, having an apparent resistivity of 12Ωm at a depth of 190m. The fourth geo-electric layer was interpreted as Saturated sand having an apparent resistivity of 353Ωm at a depth of 260m. This layer can be considered as an aquifer. The fifth layer was interpreted as Shale having an apparent resistivity, 17Ωm, with depth unknown as the base was not reached.

Table 8: Geo-electric parameters of VES Station 8

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-1.4	1.4	312	Topsoil
2	1.4-31	29.6	130	Sandy shale
3	31-190	159	12	Shale
4	190-260	70	353	Saturated sand
5	260-???	_	17	Shale

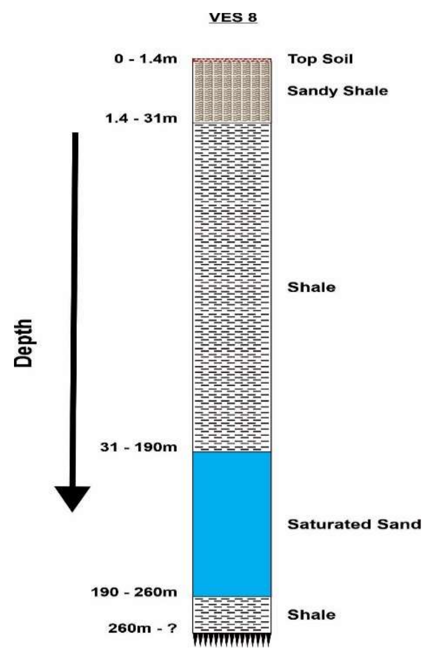


Figure 11: Geo-electric Section of VES Station 8

Interpretation of results from Station 9.

Latitude : N06º14'12"
Longitude : E007º06'24"
Elevation: 57m

The geo-electric section (Fig 12) was interpreted to have 4 geo-electric layers (Table 9). The first layer was interpreted as Topsoil having an apparent resistivity of 270Ωm at a depth of 1.5m. The second geo-electric layer was interpreted as Sandy shale having an apparent resistivity of 160Ωm at a depth of 8m. The third geo-electric layer was interpreted as Shale, having an apparent resistivity of 18Ωm at a depth of 160m. The fourth geo-electric layer is Saturated sand, having an apparent resistivity of 52.0Ωm with a depth unknown as the base was not reached.

Table 9: Geo-electric parameters of VES Station 9

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-1.5	1.5	270	Topsoil
2	1.5-8	6.5	160	Sandy shale
3	8-160	152	18	Shale
4	160-???	_	52	Saturated sand

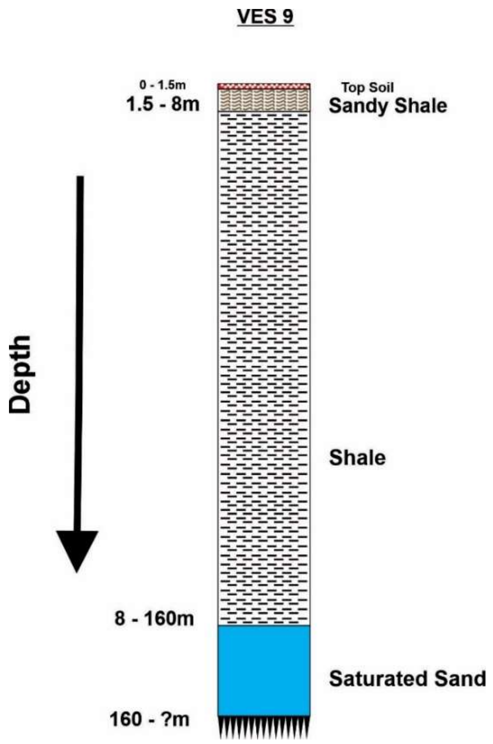


Figure 12: Geo-electric Section of VES Station 9

Interpretation of results from Station 10.

Latitude : N06º15' 44"
Longitude : E007º07'37"
Elevation: 52m

Topsoil was interpreted as the first layer (Fig 13), having an apparent resistivity of 110Ωm with a thickness of 2.2m (Table 10). The second geo-electric layer was interpreted as Shale having an apparent resistivity of 20Ωm, with a thickness of 142.8m. The third geo-electric layer is Saturated sand, having an apparent resistivity of 7599Ωm, with thickness unknown as the base was not reached. This is the aquiferous unit.

Table 10: Geo-electric parameters of VES Station 10.

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-2.2	2.2	110	Topsoil
2	2.2-145	142.8	20	Shale
3	145-???	-	7599	Saturated sand

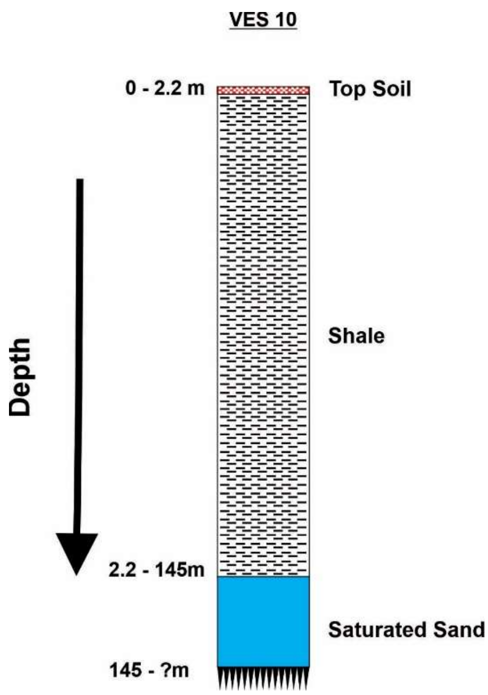


Figure 13: Geo-electric Section of VES Station 10

Interpretation of results from Station 11.

Latitude : N06º15'48"
Longitude : E007º8'12"
Elevation: 66m

The first geo-electric layer (Fig 14) was interpreted as Topsoil having an apparent resistivity of 64Ωm at a depth of 3.2m (Table 11). The second layer was interpreted as Shale having an apparent resistivity of 23Ωm at a depth of 170.8m. The third geo-electric layer was interpreted as Saturated sand having an apparent resistivity of 658Ωm at a depth of 189m. The fourth geo-electric layer was interpreted as Shale having an apparent resistivity, 35Ωm depth unknown as the base was not reached.

Table 11: Geo-electric parameters of VES Station 11

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-3.2	3.2	64	Topsoil
2	3.2-174	170.8	23	Shale
3	174-189	15	658	Saturated sand
4	189-???	_	35	Shale

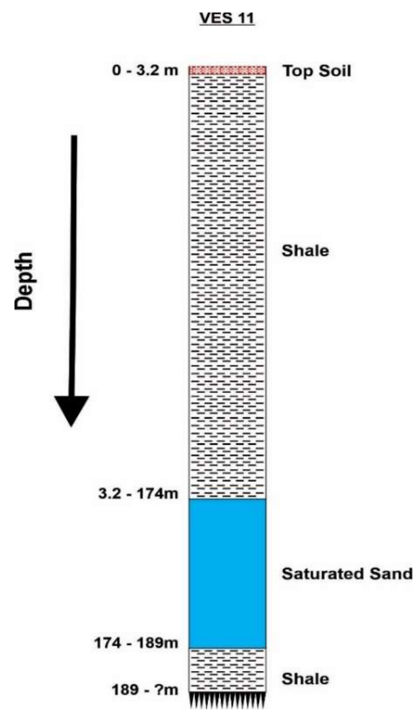


Figure 14: Geo-electric Section of VES Station 11

Interpretation of results from Station 12.

Latitude : N06º14'56"
Longitude : E007º07'26"
Elevation: 42m

The Geo-electric section, Fig 15, shows four layers. The first layer was interpreted as Top Soil having an apparent resistivity of 17Ωm with a thickness of 4.5m. The second geo-electric layer was interpreted as Shale due to its low resistivity of 11Ωm with a thickness of 152.5m. The third geo-electric layer was interpreted as Saturated sand having an apparent resistivity of 386Ωm with a thickness of 53m. This is where the aquiferous unit is situated. Meanwhile, the fourth layer was interpreted as Shale having an apparent resistivity of 31.9Ωm with thickness unknown as the bottom of the layer was not reached.

Table 12: Geo-electric parameters of VES Station 12

GEO-ELECTRIC LAYERS	DEPTH(M)	THICKNESS(M)	APPARENT RESISTIVITY(ΩM)	INFERRED LITHOLOGY
1	0-4.5	4.5	17	Topsoil
2	4.5-157	152.5	11	Shale
3	157-210	53	386	Saturated sand
4	210-???	_	31.9	Shale

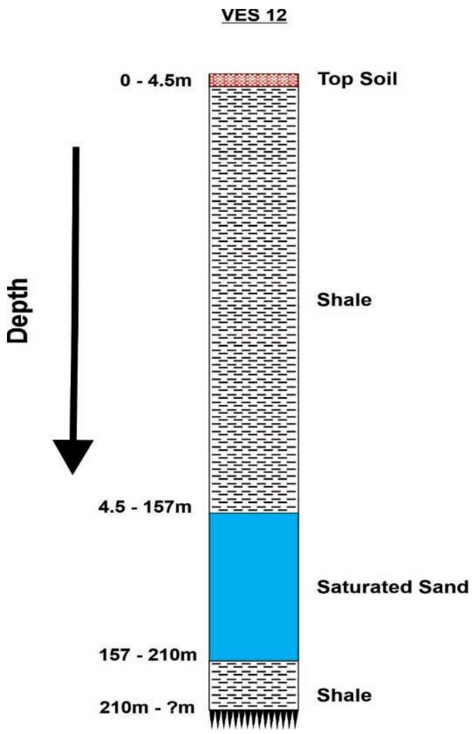


Figure 15: Geo-electric Section of VES Station 12

CONCLUSION

Geo-electric sections (Fig 3 to Fig 15) have been evaluated using VES data from twelve (12) locations in the studied areas. Geo-electric interpretation delineated a characteristic of 3-5 geo-electric layers with three dominant lithologies: a thin loamy/humus to lateritic topsoil, sandstone, and shale beds with varying depths and thicknesses across the areas. The Vertical Electrical Sounding (VES) method was employed to investigate the study area, enabling the identification of aquiferous regions. This method facilitated a comprehensive analysis of the aquifer depth, resistivity, thickness, and potential assessment in the study area. The base of the study area was primarily interpreted as impermeable Shale, resulting from the drop-in resistivity, while a little of the data had its base as Sand. The Overburden layers comprised some porous and permeable layers (Sandstone), which have low longitudinal conductance and low-to-negligible aquifer potential, making the aquifer unreadily able to give out an appreciable quantity of water. The study area primarily consists of impermeable layers, specifically shale, overlying and underlying the aquiferous unit, making it a good, confined aquifer.

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