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AQUIFER CHARACTERIZATION USING VERTICAL ELECTRICAL SOUNDING IN AUCHI POLYTECHNIC, AUCHI, EDO STATE, NIGERIA.

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ABSTRACT
The Schlumberger array method was used to carry out a total of eight (8) Vertical Electrical Sounding (VES) with a spread of 350 m in the study area. The Pasi 16-GL Terrameter was used to acquire the data. The data obtained were analyzed with the Winresist 1.0 software to obtain the curves of best fit to the theoretical models. The modeling program converted the apparent resistivity into true resistivity values in 1-D model curves. Five (5) to seven (7) layers were delineated which correspond to the topsoil, sandy clay, clayey sand, sand, dry sandstone and saturated sandstone. The depth to aquifer ranges from 95.0 to 169.6 m with resistivity values ranging from 324.3 to 1524.7 Ωm.

Keywords*: Apparent resistivity, Aquifer, lithology and vertical electrical sounding.*

1. INTRODUCTION

Access to potable water is an inalienable human right and a fundamental requirement for socio-economic development and sustainability. The prevalence of failed boreholes coupled with the lack of adequate information on the hydrogeology of Auchi necessitated the use of vertical electrical resistivity method to investigate subsurface lithology for aquifer characterization in Auchi Polytechnic, Etsako West Local Government Area of Edo State, Nigeria. Groundwater occurs in a highly permeable and porous geological formation known as aquifers which have the properties that allow storage and movement of water [1, 2].

Geophysical methods, especially resistivity survey method is a favourable choice in exploring for water, perhaps as a result of the link between hydrological parameters and electrical properties [2, 3].

Electrical methods have been used to supply current to the ground via electrodes, taking advantage of the fact that the changes in conductivity along the earth's strata, will vary the way current flow as it traverses the earth. Consequently, the way electric potential is distributed in the earth's crust is affected.

It follows that the extent to which the surface potential is altered depends on the geometry, dimension, property and electrical resistivity. As a result, the possibility of getting information concerning the way subsurface is distributed is obtained from measuring the potential at the surface.

Olatunji [4] carried out Vertical Electrical Soundings (VES) within the premises of the Institute of Technology, Kwara State Polytechnic Campus, Ilorin, Kwara State, Nigeria. The study revealed three to four geoelectric sections with varied thicknesses and resistivity. The lateritic clay layer ranges from 53.1 Ωm to 302 Ωm, the weathered horizon resistivity ranges from 22.7 Ωm to 474.2 Ωm while the competent rock has resistivity values greater than 220.3 Ωm. The lateritic clay layer resistivity and thickness range from 53.1 Ωm to 302 Ωm and 1.9 m to 8.0 m respectively, the weathered horizon resistivity and thickness ranges from 22.7 Ωm to 474.2 Ωm and 4.4 m to 11.7 m respectively while the competent rock has resistivity

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and thickness values greater than $220.3\ \Omega m$ and $6.1\ \Omega m$ to infinity respectively. The third geoelectric layer constitutes the aquiferous zone in the 4-layer geoelectric section while the second geoelectric layer is the aquiferous zone in all the 3-layer geoelectric sections.

Aluko [5] applied two-dimensional resistivity survey to groundwater exploration in a problematic sedimentary terrain where thick clay layers impede groundwater aquifer recharge. Six profiles of $830\ m$ length each were surveyed to probe the subsurface lithologies and their groundwater potentials. Results of the study revealed the different rock layers beneath the survey lines, their spatial distribution and their resistivities. The inverted subsurface resistivity image revealed heterogeneous lithologic units whose resistivity values range from $13.7\ \Omega m$ to $19790\ \Omega m$. The four geo-electric units delineated correspond to top-soil unit, consolidated dry sand unit, sandy clay unit, and saturated (wet) sand unit.

Layade [6] carried out geophysical investigation for groundwater at Gbongudu area, Akobo Ojurin, Ibadan, Southwestern, Nigeria. The Vertical Electrical Sounding using the Schlumberger configuration was employed. The VES results revealed a maximum of five geo-electric layers, viz: topsoil/lateritic sand, shale/clay, weathered layer, fractured basement and fresh basement respectively. Geoelectric sounding results were critically analyzed and interpreted. The yields of wells dug in most of these locations may be insufficient, even for domestic use because of its relatively small thicknesses. However, at a depth of $9.1\ m$, a fracture zone occurs in the area with resistivity value of $17.8\ \Omega m$, suggesting the presence of groundwater.

Adagunodo [7] carried out geophysical investigation involving an electrical resistivity method using a Schlumberger electrode array was conducted around Aaba residential area, a basement terrain of southwestern Nigeria. The geoelectrical imaging from this study revealed that the lithologies are divided into topsoil, lateritic soil, Sandy clay/clayey sand/clay/ weathered rock and the bedrock. Subsurface geoelectrical maps (overburden thickness, weathered layer's thickness, weathered layer's resistivity, bedrock relief, bedrock resistivity, and correlations from geoelectric sections) were used to generate information about the groundwater potential of the study area.

Aigbogun [8] carried out geophysical investigation to ascertain groundwater potential in Egbeta, using one-dimensional (1-D) Vertical Electrical Sounding (VES) technique. The result from this study reveals three VES curves: AAK, HAKQ and HAAK, with the AAK being dominant. The aquifer depth in the area is in the range of $59.8\ m$ to $159.5\ m$ and the resistivity value at this location dropped from $11201.7\ \Omega m$ to $607.2\ \Omega m$.

The aim of this study therefore, is to employ the use of geoelectrical survey to investigate the water bearing layer and delineate the subsurface lithology in Auchi Polytechnic and its environs.

2. MATERIALS AND METHODOLOGY

In this work, the Schlumberger array was adopted since it provides more information about the deeper sections of the subsurface. The field equipment comprises of twenty five (25) metal electrodes, two (2) measuring tapes, four (4) hammers, Global Positioning System (GPS), two (2) reels of red and blue colored electric cables, the Pasi (16-GL) terrameter was powered with a 12 volts 60 Ah battery and data sheet for recording the field data.

Typical of a Schlumberger arrangement, the electrodes were placed on a straight line, where the current electrodes were positioned externally and the potential electrodes kept on the inside. The depth range of the measurements was altered when the current electrodes are placed outwards.

When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the potential electrodes must also be displaced outwards otherwise the potential difference becomes too small to be measured with sufficient accuracy [9].

A total of eight (8) VES were carried out in four (4) locations with a spread of 350 m. Current was supplied to the current electrodes by the 12 volts battery and the corresponding values of the resistance obtained from the voltage and current values read off from the Pasi resistivity meter (terrameter) were recorded. Apparent resistivity values were measured at each location and plotted against half current electrode spacing (AB/2). The graph obtained for VES profile is a curve.

Further analysis was carried out on the VES data using the WinResist 1.0 software to iterate the data in order to get the curves of best fit to the theoretical models. The computer modeling software converted the apparent resistivity values into true resistivity values in 1-D model curves. Geoelectric sections for each of the VES points were drawn on the basis of the resistivity data interpretation with the use of the autocad software.

2.1 Location of the study area

The geophysical survey was carried out in Auchi Polytechnic, Auchi. The first location being Auchi Poly Staff Primary School, and has the following coordinates: Latitude 07° 03′ 42.2″and Longitude 006° 16′ 14.7″. These coordinates were obtained using Garmin 12 Global positioning system (GPS). Actual site observation and information from existing geological maps classify surface sand of the study area and its environs as members of the Ajali formation [10].

2.2 Theory of experiment

The theory of electrical resistivity of a layered earth is well known and has been very well described by Telford [12]. Therefore, electrical resistivity is expressed as:

$$J = \sigma E \quad (1)$$

Where σ is the static resistivity (measured in volt-metre per ampere, Vm/A);
E is the magnitude of the electric field (measured in volts per metre, V/m)
J is the magnitude of the current density (measured in amperes per square metre, A/m^2).
Simon Ohm it was, who established a relationship between the electric current (I) in a conducting wire, and the potential difference (V) across it. The linear relationship is expressed by equation (2).

$$V = IR \quad (2)$$

For a given material, the resistance **R** is proportional to the length **L** and inversely proportional to the cross-sectional area **A** of the conductor, as expressed in equation (3).

$$R = \rho \frac{L}{A} \quad (3)$$

The proportionality constant **ρ,** is the resistivity of the conductor measured in ohm-meter (Ωm). It is a physical property of the conductor, which expresses its ability to oppose the passage of current.
Current is sent through the electrodes A and B of Figure 2, and voltage variations are made with electrodes M and N. Where VM and VN are potentials at M and N, AM = distance between electrodes A and M, BM = distance between electrodes B and M, BN = distance between electrodes B and N.
AN = distance between electrodes A and N.
When an electrical current is passed into the ground via two electrodes known as current electrodes (as shown in Fig. 2), the two potential electrodes record the resultant potential difference between them, depending on the arrangement or configuration of these pairs of electrodes, the current and potential measurements may be used to calculate resistivity [13]. Apparent resistivity, ρ is measured from:

$$\rho = K \frac{V}{I} \quad (4)$$

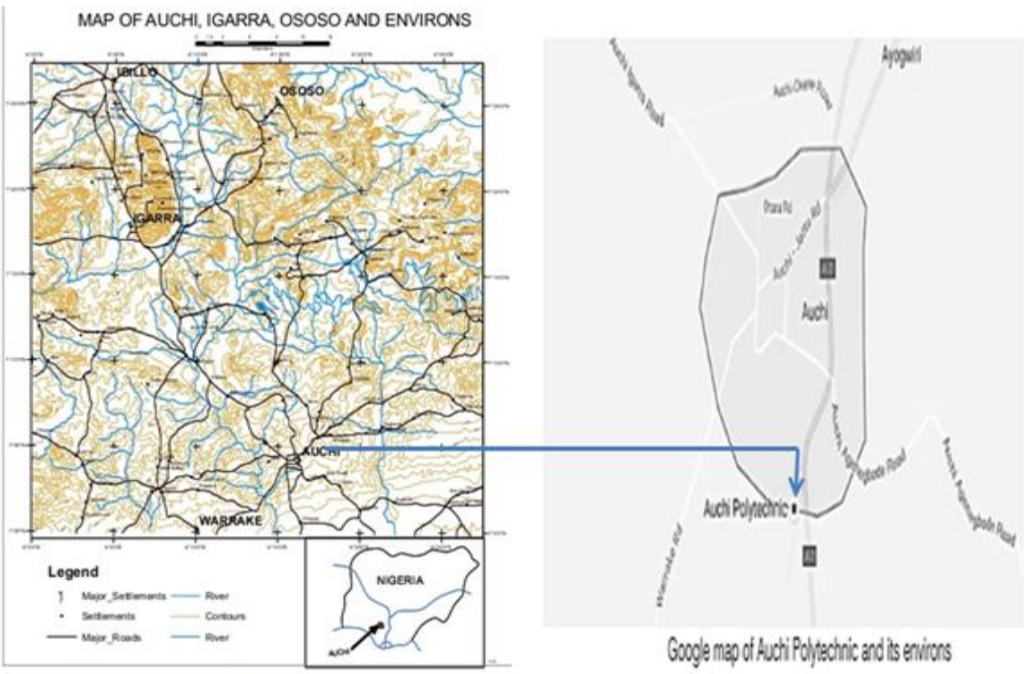

Figure 1: Geophysical map of Auchi [11]

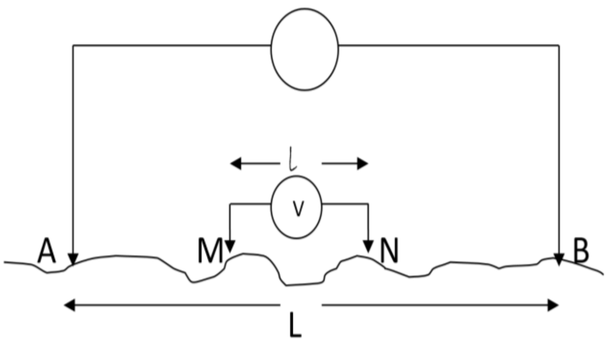

Figure 2: Diagram showing resistivity measurement.

2.3 Schlumberger array

Here, the midpoint of the electrode configuration is held constant, but the distance between the electrodes changes to have more information about how deep the subsurface is. Schlumberger arrangement is shown in Fig. 2.

3. RESULTS

Results of the VES interpretation are presented in Table 1.

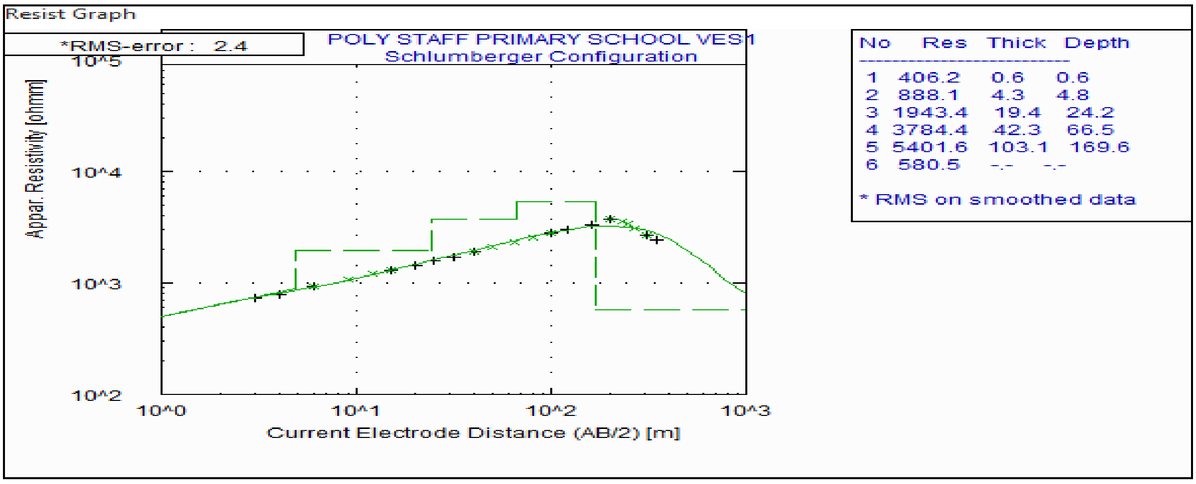

Figure 3: Resistivity curve for VES 1

Table 1: Model parameters of VES 1.

VES NO	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	INFERRED LITHOLOGY
LOCATION 1: AUCHI POLY STAFF PRIMARY SCHOOL					
1	1	406.2	0.6	0.6	Topsoil
	2	888.1	4.3	4.8	Clayey sand
	3	1943.4	19.4	24.2	Sand
	4	3784.4	42.3	66.5	Sandy clay
	5	5401.6	103.1	169.6	Sandstone(dry)
	6	580.5	Infinity	infinity	Sandstone (saturated)

Table 2: Model parameters of VES 2.

VES NO	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	INFERRED LITHOLOGY
LOCATION 1: AUCHI POLY STAFF PRIMARY SCHOOL					
2	1	275.5	0.6	0.6	Topsoil
	2	1009.9	3.7	4.3	Clayey sand
	3	3231.8	6.2	10.6	Clayey sand
	4	4387.0	10.5	21.1	Sand
	5	1181.1	39.9	61.0	Sandy clay
	6	7143.3	90.1	151.1	Sandstone(dry)
	7	445.3	Infinity	infinity	Sandstone (saturated)

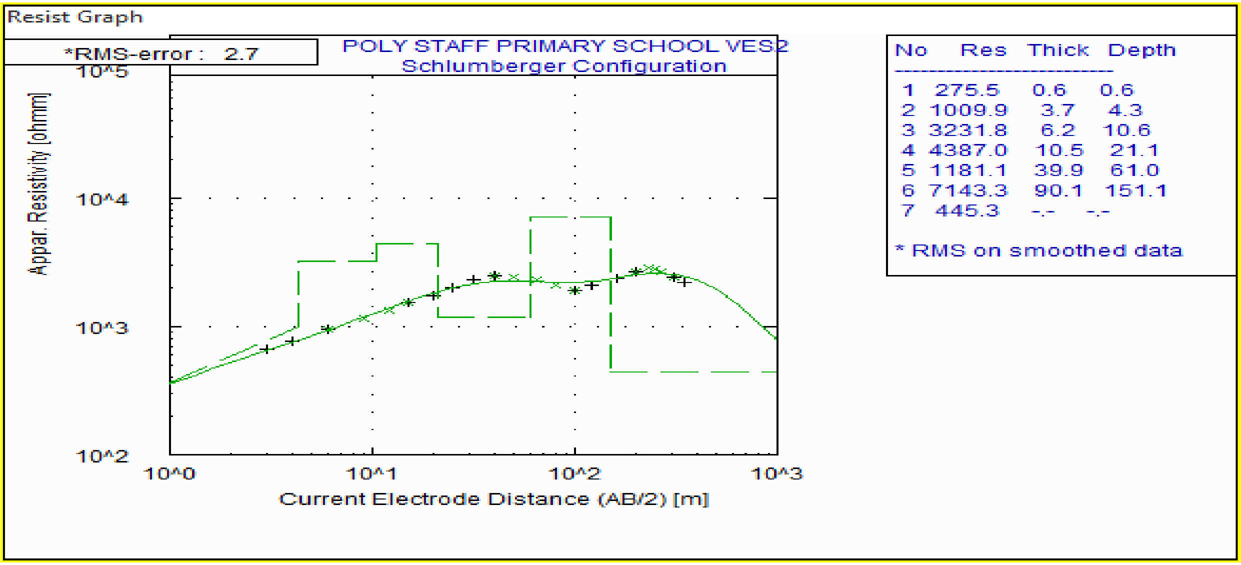

Figure 4: Resistivity curve for VES 2.

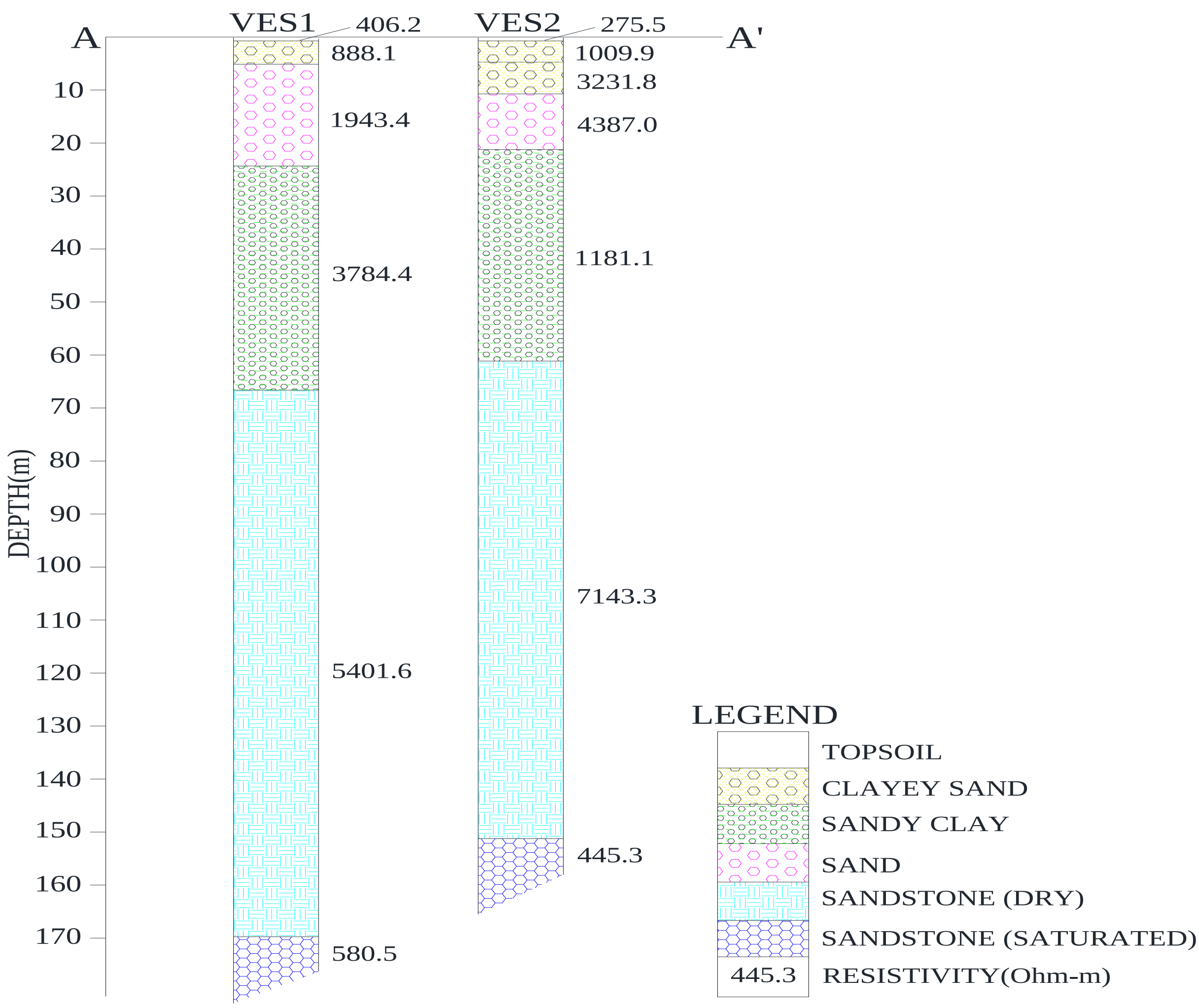

Figure 5: Geoelectric Section for VES 1 and 2 in location 1.

4. DISCUSSION

Figure 3 and 4 consists of VES 1 and 2. The section reveals six (6) to seven (7) subsurface layers namely: topsoil, clayey sand, sandy clay, sand, dry sandstone and saturated sandstone. The topsoil is characterized by resistivity values ranging from 275.5 to 406.2 Ωm and layer thickness of 0.6 m. A 2-Dimensional electric resistivity imaging (ERI) conducted by [14] in the same location, provided a complementary information about the subsurface. The results of the ERI shows topsoil with resistivity values ranging from 207 – 456 Ωm and thickness varying from 0 to 5 m. The second identified layer denotes clayey sand with resistivity and layer thickness values that ranges between 888.1 to 1009.9 Ωm and 3.7 to 4.3 m respectively. The ERI result reveals clayey sand with resistivity values ranging from 999 – 2183 Ωm, with thickness varying from 5 to 15 m. The third layer in VES 1 connotes sand with resistivity and layer thickness value of 1943.4 Ωm and 19.4 m respectively. The ERI result shows basal sand with thickness varying from 30 – 35 m and resistivity values varying from 3394 – 4817 Ωm. The sand in this zone is dry sand in which groundwater could not be found. While the sand is replaced with clayey sand in VES 2 with resistivity and layer thickness value of 3231 Ωm and 6.2 m respectively. The fourth horizon beneath VES1 signifies sandy clay with resistivity value of 3784.4 Ωm and layer thickness of 42.3 m. The sandy clay is replaced with sand in VES 2 with resistivity and layer thickness value of 4387 Ωm and 10.5 m respectively. The sand in this region is dry sand in which groundwater could not be found. The fifth substratum layer in VES 1 represents dry sandstone with resistivity value of 5401.6 Ωm and layer thickness of 103.1 m. The dry sandstone is replaced with sandy clay in VES 2 with resistivity value of 1181.1 Ωm and layer thickness of 39.9 m. The sixth geoelectric layer in VES 1 indicates saturated sandstone with resistivity value of 850.5 Ωm but the layer thickness could not be determined because current terminated there. The saturated sandstone represents an aquifer where groundwater could be found. The saturated sandstone is replaced with dry sandstone in VES 2 with resistivity value of 445.3 Ωm but the layer thickness could not be determined because current terminated within this region.

5. CONCLUSION

The interpreted results of the VES data have been presented as geoelectric sections. Five to seven geoelectric layers have been delineated, which correspond to the topsoil, sandy clay, clayey sand, sand, dry sandstone and saturated sandstone. The topsoil has a layer thickness of 0.5 to 0.7 m and resistivity values within the range of 198.3 to 451.9 Ωm. The sandy clay has a layer thickness of 4.0 to 42.3 m resistivity values ranging from 154.3 to 38991.7 Ωm. The clayey sand has layer thickness of 2.8 to 29.6 m and resistivity values ranging from 147.3 to 4412.5 Ωm. The dry sandstone has layer thickness of 52.4 to 103.1 m and resistivity values ranging from 3708.2 to 13580.9 Ωm. The study further reveals that the saturated sandstone in VES 1 to 8 has resistivity values ranging from 324.3 to 1524.7 Ωm but their thickness could not be ascertained as a result of current terminating within these zones. The ERI results gave a good complement of the VES results. The depths to aquifer lie between 95.0 to 169.6 m.

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