Journal of Applied Sciences, Information, and Computing
Vol. 1, No. 2 (December, 2020)
School of Mathematics and Computing, Kampala International University

ISSN: 1813-3509 https://jasic.kiu.ac.ug

GEO-ELECTRICAL DELINEATION FOR GROUNDWATER RESOURCES OVER GIDAN-DOYA BASEMENT AREA, CENTRAL NIGERIA.

Ohakwere-Eze M. C.[1], Ahamefule C. Y.[2] Eme U. K[3] and Jatto S. S.[4]

[1,*]Department of Physics, Faculty of Science, Federal University of Kashre, Gombe State. michael.ohakwereze@gmail.com
[2]Department of Physics, College of Natural & Applied Sciences, Gregory University Uturu, Abia State. ahamefulec@gmail.com
[3]Department of Physics, College of Physical & Applied Sciences, Michael Okpara University of Agriculture, Umudike, Abia State. felixkalu2@gmail.com
[4]Environmental Research Unit, Centre for Atmospheric Research, Anyigba, Kogi State.

Abstract
Groundwater development is very important in the survival of the human. This research was carried out in a newly developing area with population increase and agricultural development hence the need for this study. The objective is to carry out a geophysical investigation, delineate aquiferous zones, and groundwater potential for the study area. An electrical resistivity method for groundwater investigation using the Vertical electrical sounding (VES) technique was adopted. The survey involved three profiling and seven VES points using the Schlumberger configuration to delineate the subsurface lithologies and aquiferous zones within the study area. It was observed that the study area is composed of highly weathered and fractured rocks; hence there is a tendency for groundwater migration and accumulation in the weathered fractured horizons. Two geo-electric sections and a basement map were produced. The area generally showed four to five lithology units; which include topsoil, laterite, weathered basement, fractured basement, and the fresh basement. The thickness of the overburden ranges from 0 - 12.8m and the saturated layers have resistivity values ranging from 19.7Ωm - 849.8Ωm with depths to water range of 10.5m – 61.1m respectively. VES points 2, 4, and 5 showed good potential for groundwater with aquiferous unconfined zones ranging depths of about 45.0m - 60.0m. It was also deduced that areas, where thick overburden complemented with the presence of weathering and fractures within the study area, are zones for groundwater accumulation.

Keywords: Electrical resistivity, VES, aquifer, groundwater

1. Introduction

The increasing population and developmental growth of Gidan-doya area prompted this research work to delineate the hydrogeological potential. Gidan-doya is a newly developing area covering an area of about 3km², located within the Basement complex Southwest of Lokoja. The study area is in the demand for potable water for human consumption and agricultural production, therefore a need for the location of sustainable groundwater supply. The application of geophysical electrical resistivity methods (the conventional vertical electrical sounding, VES) to finding groundwater locations was adopted for this project. Figure 1 shows the topographic map of the study area while figure 2 shows the topographic map with the VES points marked.

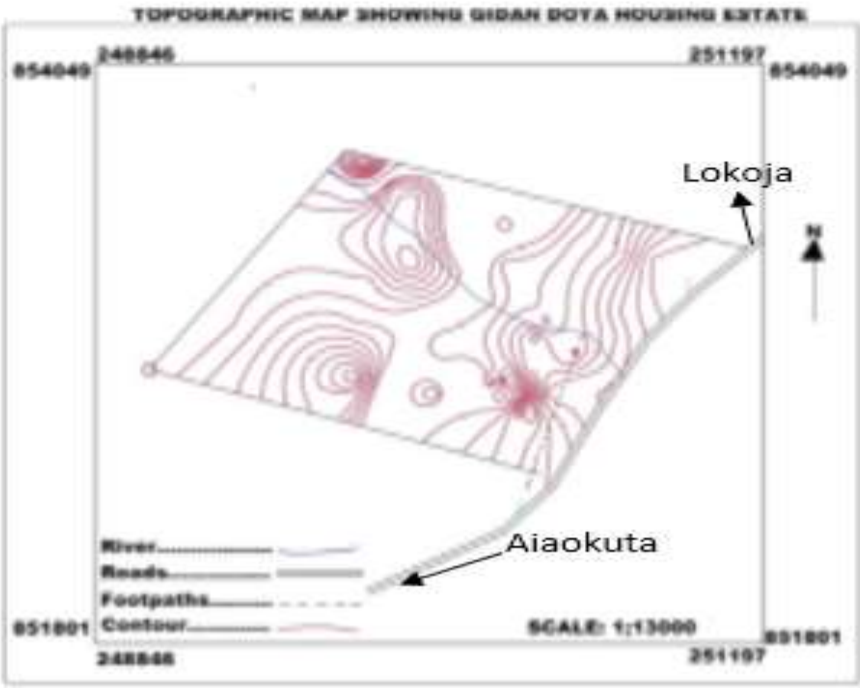


Figure 1: Topographic Map of the Study Area.

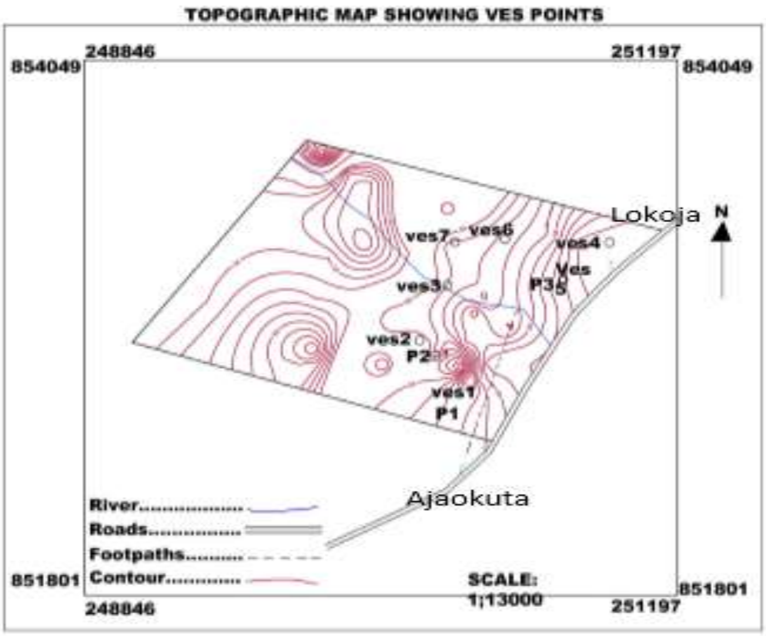


Figure 2: Topographic map of the Study Area with VES points.

The area is characterized by two distinct seasons namely, the rainy and dry seasons. The rainy season commences in April and lasts till October, while the dry season is from November to March. The annual average rainfall ranges between 1000mm and 1500mm while the mean annual humidity is about 70%. The annual average temperature is 27°C, with an annual average sunshine hour of 6.7 per day. A high temperature of 36°C - 48°C is experienced in the area (Omada *et al*., 2009). The area is drained by few stream channels, the drainage system in the area is mainly dendritic.

It is of the Guinea Savannah, with denser (gallery) forests fringing some of the rivers with a mixture of trees, shrubs, and grasses. The vegetation within the study area is influenced by the rate at which rainfall occurs, which also affects the quantity of water available, the vegetation cover, the porosity of the soils and rocks, their initial moisture content, and the position of the zone of saturation. (Musa, *et. al,* 2011).

Dada et. al., (2011) carried out electrical resistivity profiling along six traverses and it was designed to cover strategic areas of need on Salem University campus

Lokoja Kogi State. The Wenner electrode configuration was used, at 10m electrode spacing. Measurements extended over 1.2km along the six traverses. Based on the interpretation of the VES data, six to seven main geo-electric units were identified in the investigated area. The units can be broadly grouped into four main lithologic units. The overburden, lateritic layer, weathered and fractured basement. The overburden topsoil above lateritic sand and clay layers, mostly humid in some areas, overlay the first aquifer unit. This is the weathered basement. The second aquifer unit is a fissured fracture basement. The bedrock, solid crystalline basement rock, is generally encountered from 50-70 meter depths in the area.

Omada et. al., (2009) worked on the groundwater situation in Lokoja's environment. Their finding reveals that abundant groundwater is concentrated in aquiferous conglomerate and sandstone horizons of Lokoja and Patti Formations where spring water emanates in many locations. Yield from boreholes is most prolific at the contact between and the cover sediments as well as within the paleo-alluvial of the River flood-plains.

Musa, et. al., (2011) worked on the investigation of concealed lineament for groundwater exploration at the Kogi State Polytechnic, Osara. Their findings indicated that the presence of subsurface layers comprising the topsoil, weathered basement fresh bedrock, confined and unconfined fractured basement all constitute the aquifer units.

Rocks within the study area are well exposed, moderately to highly weathered, fractured, and with pegmatitic intrusions and micro folds. Some native metals and graphite conduct electricity, most rock-forming minerals are electrical insulators. Measured resistivities in earth materials are primarily controlled by the movement of charged ions in pore fluids. Although water itself is not a good conductor of electricity, groundwater generally contains dissolved compounds that greatly enhance its ability to conduct electricity. Hence, porosity and fluid saturation tend to dominate electrical resistivity measurements. In addition to pores, fractures within the crystalline rock can lead to low resistivities if they are filled with fluids, (Pellerin, 2002). The low resistivity zone within the bedrock suggests that it is associated with a fractured zone (Asry et al., 2012). Unweathered and unfractured hard rocks such as volcanic rocks, plutonic rocks, and some metamorphic rocks generally have high resistivities. The presence of fracturing and weathering lowers the resistivity of these rocks. Additionally, the occurrence of groundwater will greatly reduce the resistivity of all rocks through electrolytic conduction. Because of this effect, groundwater is a good target for electrical and electromagnetic geophysical methods that measure resistivity. VES has been employed extensively in groundwater investigations in many basement complex terrains of Africa (Adeniji et. al., 2013)

2. Materials and methodologies

Materials used for the field exercise include a compass, a global positioning system (GPS), field notebook, masking tape, marker, tetrameter, reels of wire, ropes, tape, and electrodes.

Electrical resistivity profiling surveys were carried out within the study area to obtain probable areas for electrical sounding. The tetrameter is used to produce and measure current and potential differences in the field to detect the subsurface structure.

Three profiling were done; it served as a reconnaissance survey, to select the best possible point for the electrical sounding. The field procedure involved four electrodes placed on a straight line at intervals (spacing) of 10m. After each successive survey readings, all electrodes are moved 10m away from the initial point until a distance of about 200m is obtained for the survey.

Seven VES point data were obtained from the probed sections of the subsurface through two potential electrodes in form of potentials. The techniques measured depths of different geologic materials sampled from the surface by injecting current into the ground through current electrodes and receiving information. Thus by measuring the resistance of these materials, the subsurface strata were determined.

2.1. Equations

The vertical electrical sounding helped to determine the apparent resistivity of various layers of the geological formation by increasing the current electrode distance (AB). The apparent resistivities obtained are plotted against AB/2 for Schlumberger configuration. From the sounding curve obtained with the aid of computer programming, conclusions about the true resistivities and the true thicknesses of the layers were drawn.

The Schlumberger method was used to delineate the vertical variations of resistivity of different rocks. For a Schlumberger survey, the spread comprises a two-pair electrode arrangement, one pair of current electrodes, and another pair of potential electrodes. The current electrodes are normally spaced wider than the potential electrodes which are placed in between the two current electrodes. The centre of the spread is customarily permanently fixed while the electrodes are laterally moved on both sides of the profile, the potential electrodes are much less frequently moved than the current electrodes. The electrodes are arranged such that the separation between the current electrodes $AB \geq 5MN$ where MN is the potential electrodes. The current electrodes are connected to the current terminals of the instrument while the potential electrodes are connected to the potential terminals.

The survey was conducted by arranging four electrodes in a straight line on the surface and acquired data from the Tetrameter. Apparent resistivity is given by Eq. (1).

$$\ell a = \frac{\Pi((\frac{AB}{2})2-(\frac{MN}{2})2)}{MN}.\mathrm{R}$$

Eq. (1)

Where

ℓ = apparent resistivity

AB = distance between the current electrodes

MN = distance between the potential electrode

3. Results

3.1. Interpretation of VES Point Data.

Based on the figures and tables shown, the VES data identifies four to five geo-electric layers in the area. The resistivity and thickness of these layers vary in each area surveyed. The VES results are discussed in tables 1 to 7 while the curves are presented in figures 3 to 9. The values in the tables are as computed from the figures.

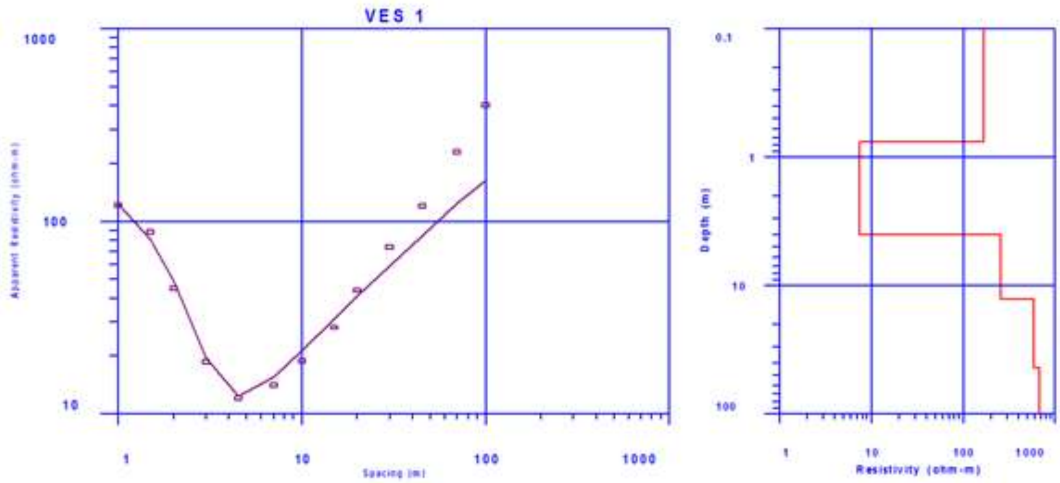


Figure 3: Resistivity curve for VES 1.

Table 1: VES 1 LAYER MODEL

LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	ELEVATION (m)	LITHOLOGY
1	167.3	0.8	0.8	-0.8	Top-soil
2	7.5	3.2	4.0	-4	Laterite
3	254.2	8.8	12.8	-12.8	Weathered Basement
4	582.4	31.2	44	-44	Weathered/Fracture Basement
5	678.1				Fresh Basement

Table 1 show four lithologies; layer 1 the topsoil with resistivity value of 167.3Ωm and thickness of 0.8m, layer 2 the lateritic overburden with resistivity value of 7.5Ωm and thickness of 3.2m, layer 3 the weathered basement with a resistivity of 254.2 Ωm and thickness of 8.8m, layer 4 weathered/ fractured basement with a resistivity of 582.4Ωm with a thickness of 31.2m.

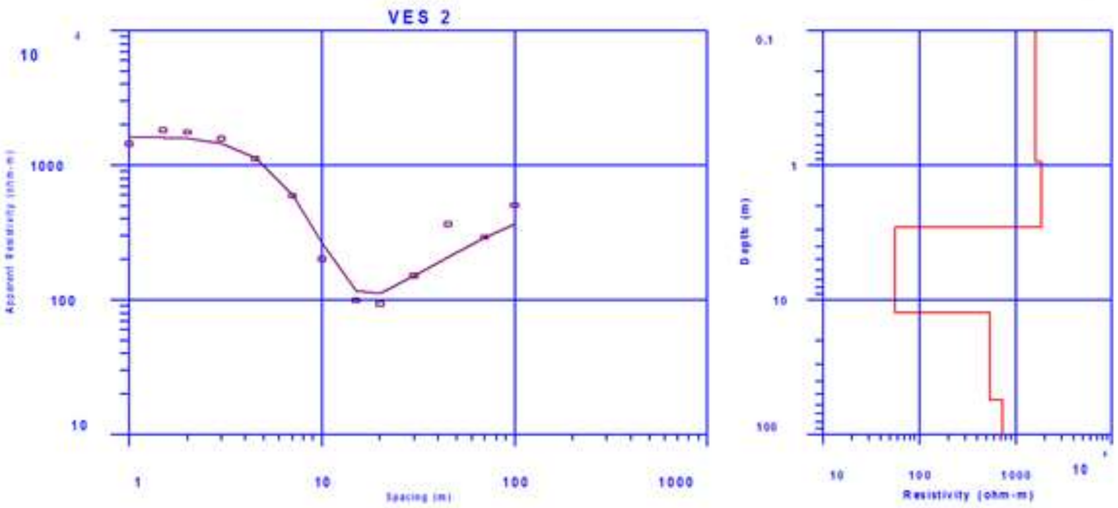


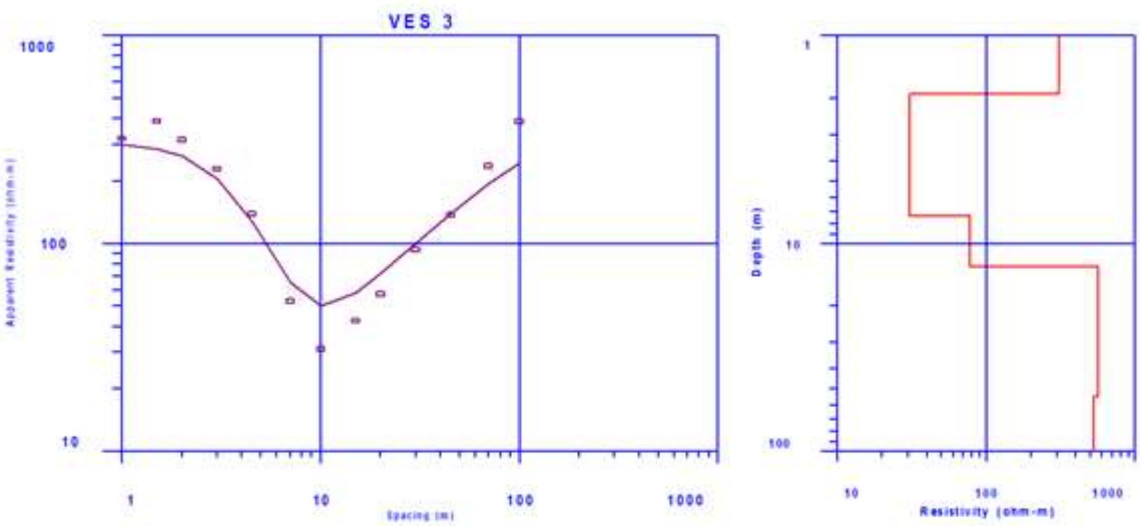
Figure 4: Resistivity curve for VES 2.

Table 2: VES 2 LAYER MODEL

LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	ELEVATION (m)	LITHOLOGY
1	1620.1	0.9	0.9	-0.9	Topsoil
2	1846.7	1.9	2.9	-2.9	Laterite
3	56.5	9.5	12.4	-12.4	Highly Weathered Basement
4	534.7	43.1	55.4	-55.4	Fractured Basement
5	733.4				Fresh Basement

Table 2 show four lithologies; layer 1 the topsoil with resistivity value of 1620.1 Ωm and thickness of 0.9m, layer 2 the lateritic overburden with resistivity value of 1846.7Ωm and thickness of 1.9m, layer 3 the weathered basement with a resistivity of 56.5Ωm and thickness of 9.5m, layer 4 weathered/ fractured basement with a resistivity of 534.7Ωm with a thickness of 43.1m.

Figure 5: Resistivity curve for VES 3.



3: VES 3 LAYER MODEL

LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	ELEVATION (m)	LITHOLOGY
1	308	1.9	1.9	-1.9	Topsoil
2	30.9	5.5	7.4	-7.4	Laterite
3	78.1	5.5	12.9	-12.9	Highly Weathered Basement
4	563.1	41.4	54.4	-54.4	Fractured Basement
5	525.5				Fresh Basement

Table 3 show four lithologies; layer 1 the topsoil with resistivity value of 308Ωm and thickness of 1.9m, layer 2 the lateritic overburden with resistivity value of 30.9Ωm and thickness of 5.5m, layer 3 the weathered basement with a resistivity of 78.1Ωm and thickness of 9.5m, layer 4 weathered/ fractured basement with a resistivity of 563.1Ωm with a thickness of 41.4m.

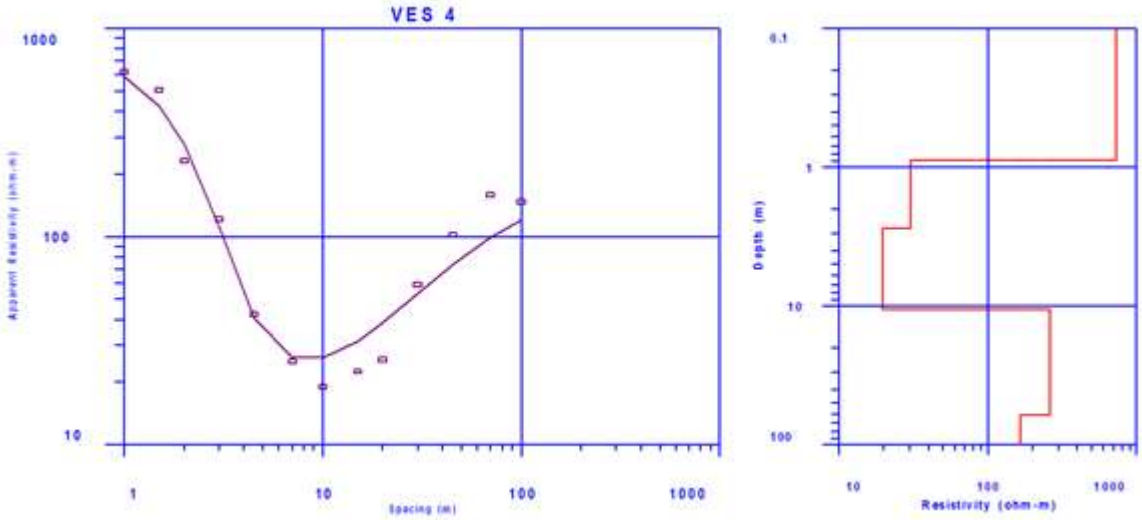


Figure 6: Resistivity curve for VES 4.

Table 4: VES 4 LAYER MODEL

LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	ELEVATION (m)	LITHOLOGY
1	728.4	0.9	0.9	-0.9	Topsoil
2	30.3	1.9	2.8	-2.8	Laterite
3	19.7	7.8	10.5	-10.5	Highly Weathered Basement
4	263.6	50.6	61.1	-61.1	Fractured Basement
5	164.8				Fresh Basement

Table 4 show four lithologies; layer 1 the topsoil with resistivity value of 728.4Ωm and thickness of 0.9m, layer 2 the lateritic overburden with resistivity value of 30.3Ωm and thickness of 1.9m, layer 3 the weathered basement with a resistivity of 19.7Ωm and thickness of 7.8m, layer 4 weathered/ fractured basement with a resistivity of 263.6Ωm with a thickness of 50.6m.

Figure 7: Resistivity curve for VES 5.

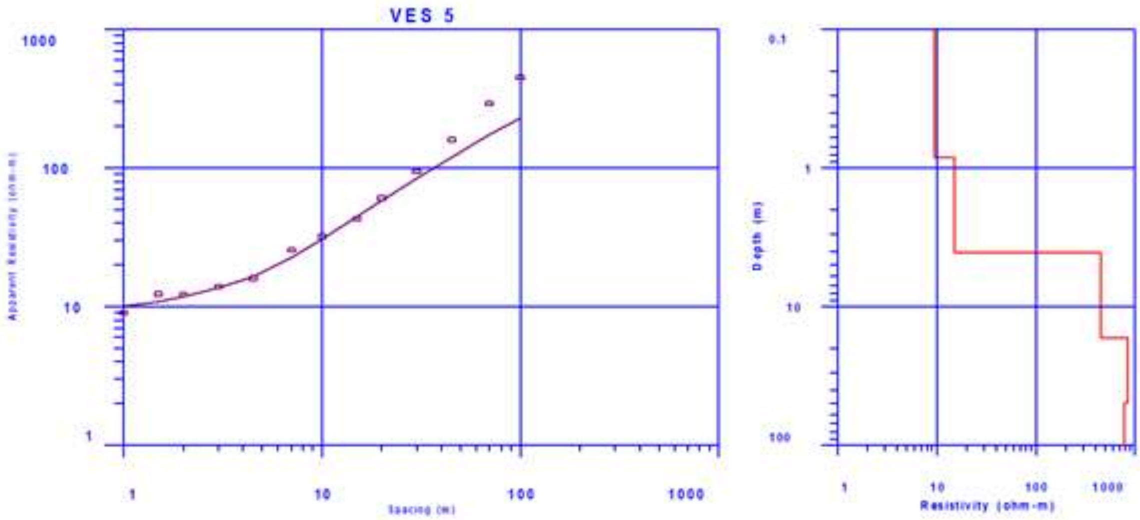


Table 5: VES 5 LAYER MODEL

LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	ELEVATION (m)	LITHOLOGY
1	9.5	0.8	0.8	-0.8	Topsoil
2	15	3.2	4.1	-4.1	Laterite
3	450.3	12.8	16.9	-16.9	Weathered Basement
4	849.8	32.2	49.1	-49.1	Fractured Basement
5	777.5				Fresh Basement

Table 5 shows four lithology units; layer 1 the topsoil with resistivity value of 9.5Ωm and thickness of 0.8m, layer 2 the lateritic overburden with resistivity value of 15Ωm and thickness of 3.2m, layer 3 the weathered basement with a resistivity of 450.3Ωm and thickness of 12.8m, layer 4 weathered/ fractured basement with a resistivity of 849.8Ωm with a thickness of 32.2m.

Figure 8: Resistivity curve for VES 6.

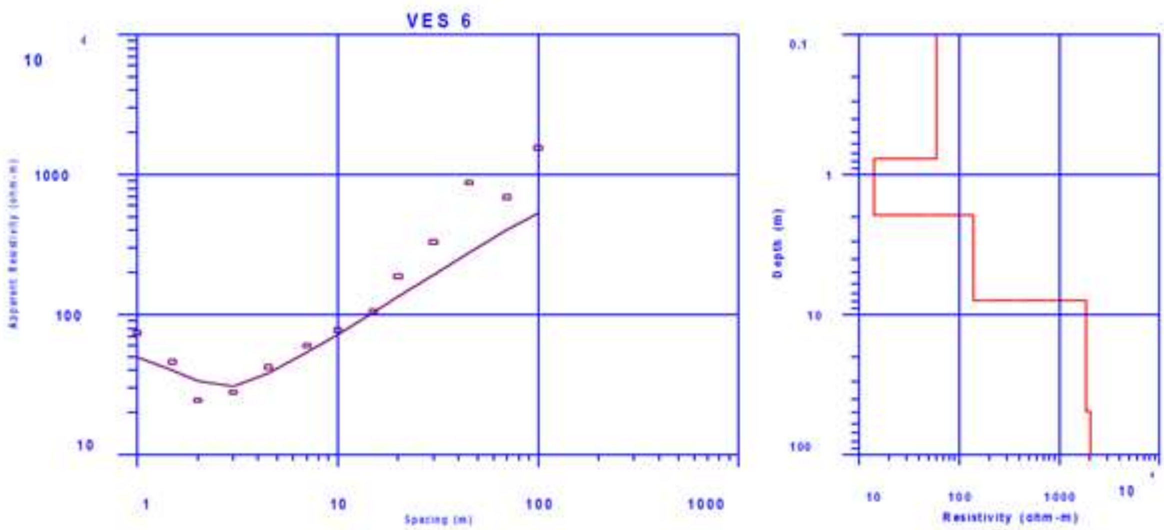


Table 6: VES 6 LAYER MODEL

LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	ELEVATION (m)	LITHOLOGY
1	59.9	0.8	0.8	-0.8	Topsoil
2	14.1	1.2	1.9	-1.9	Laterite
3	139.9	6	8	-8	Weathered Basement
4	1839.9	40.9	48.9	-48.9	Fractured Basement
5	2061.2				Fresh Basement

Table 6 show four lithologies; layer 1 the topsoil with resistivity value of 59.9Ωm and thickness of 0.8m, layer 2 the lateritic overburden with resistivity value of 14.1Ωm and thickness of 1.2m, layer 3 the weathered basement with a resistivity of 139.9Ωm and thickness of 6.0m, layer 4 weathered/ fractured basement with a resistivity of 1839.9Ωm with a thickness of 40.9m.

Figure 9: Resistivity curve for VES 7.

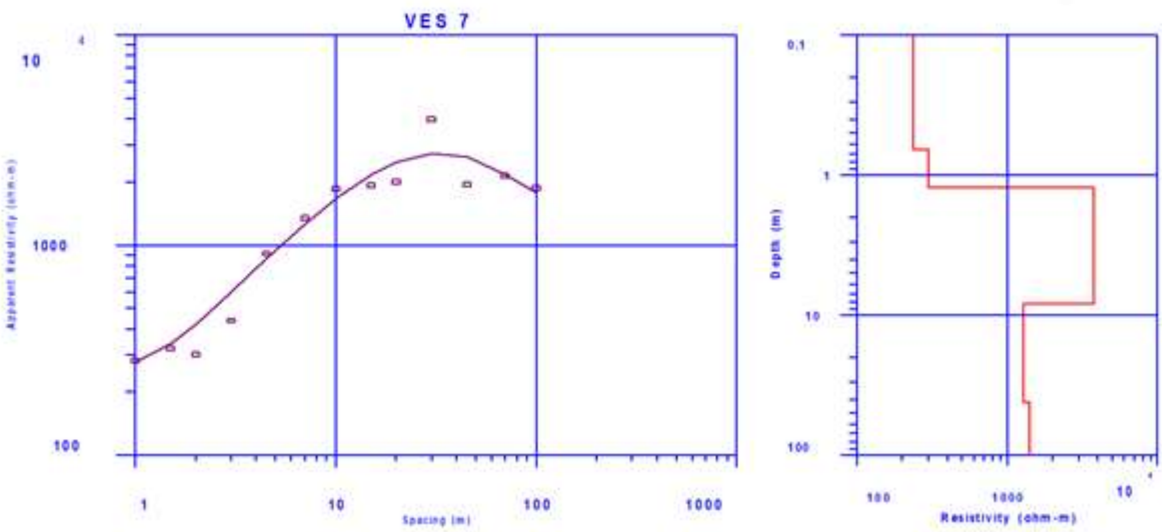


Table 7: VES 7 LAYER MODEL

LAYER	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	ELEVATION (m)	LITHOLOGY
1	237.5	0.7	0.7	-0.7	Topsoil
2	297.5	0.6	1.2	-1.2	Laterite
3	3758.7	7	8.2	-8.2	Poorly Weathered Basement
4	1289	33.6	41.8	-41.8	Fractured Basement
5	1404.2				Fresh Basement

Table 7 show four lithologies; layer 1 the topsoil with resistivity value of 237.5Ωm and thickness of 0.7m, layer 2 the lateritic overburden with resistivity value of 297.5Ωm and thickness of 0.6m, layer 3 the weathered basement with a resistivity of 3758.7Ωm and thickness of 7m, layer 4 weathered/ fractured basement with a resistivity of 1289.0Ωm with a thickness of 33.6m.

3.2. Geo-electric Section

From the result of the geophysical investigation, preliminary interpretation of the data was used to produce a geo-electric section and a basement map for the area. Two-line section (figures 10 and 11) below shows VES 1, 4, 5 and VES 2, 3, 6 were established for the construction of a geo-electric section, which shows respective layer resistivity values and thicknesses.

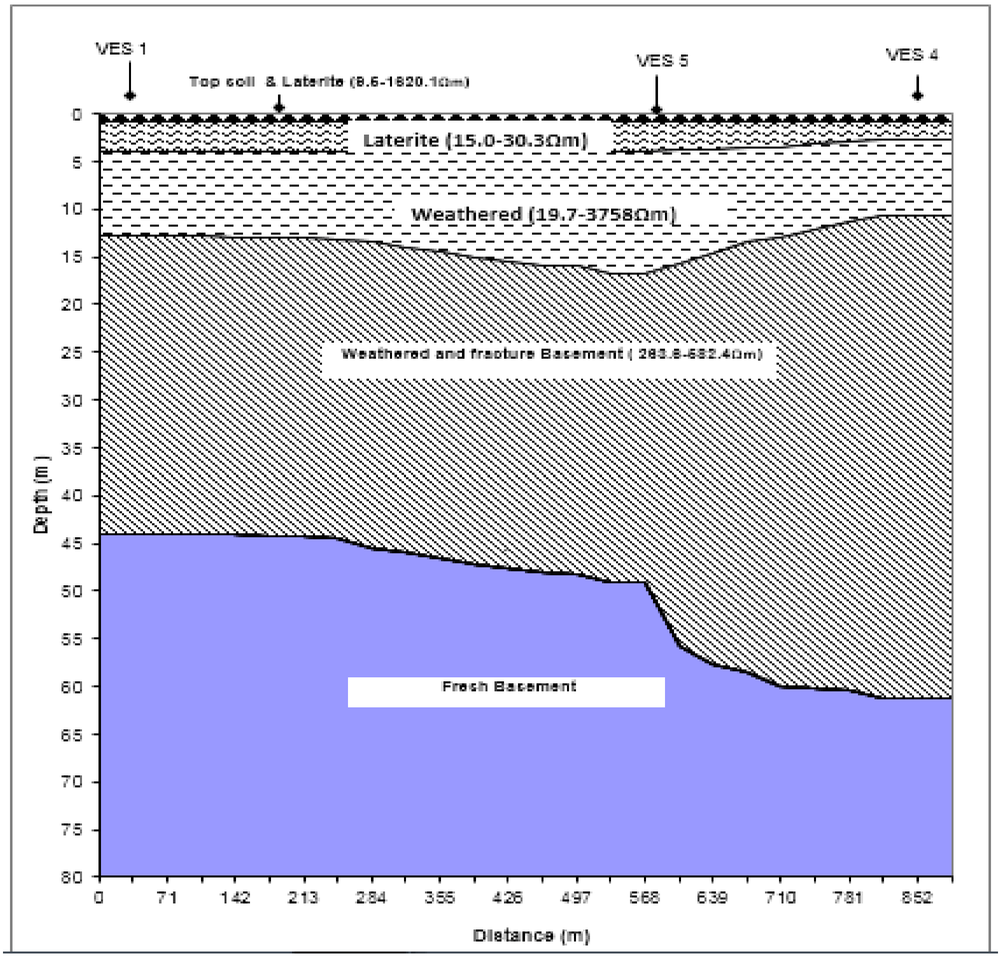


Fig 10: Geoelectric section of VES (1, 4, 5)

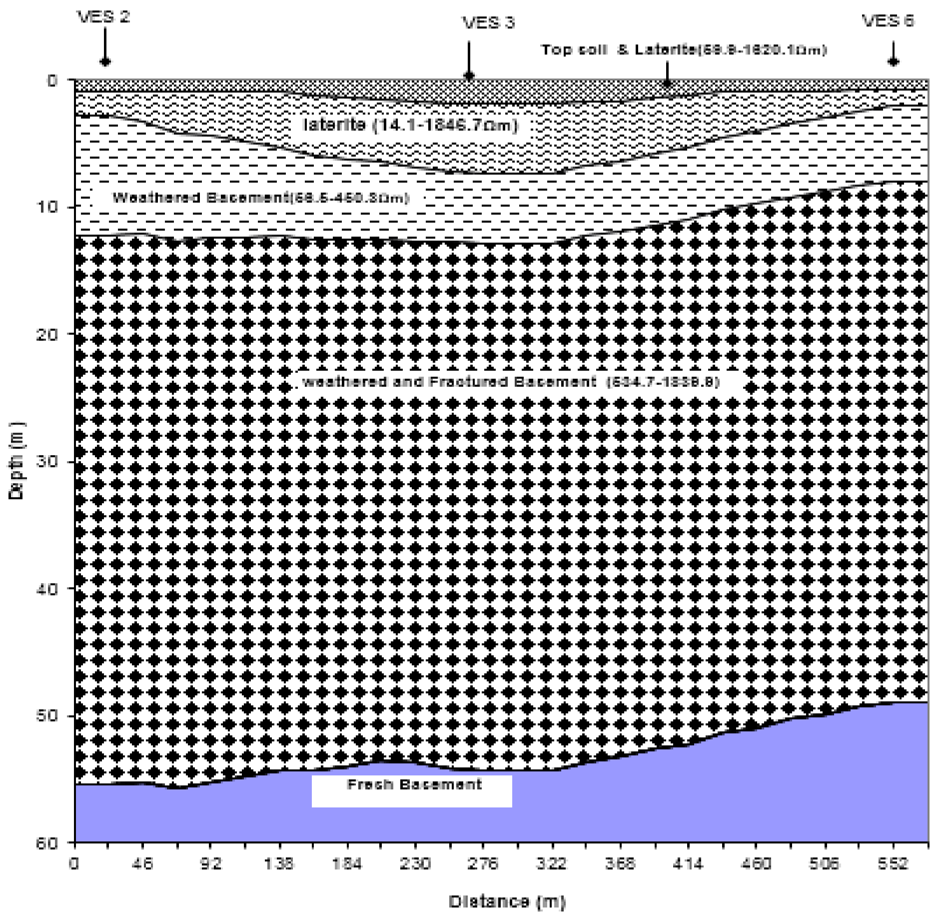


Fig 11: Geoelectric section of VES (2, 3, 6)

3.3. Basement map

The depth to fresh basement rock from the (VES) survey was contoured and shown on a Basement map (figure 12). The overburden includes; the topsoil, laterite, weathered and fractured basement. The thickness of the fractured basement varies from 31.2m - 50.6m with depths varying from 41.8m - 61.1m, the thickness of the weathered basement varies from 5.5m to 12.8m with depths varying from 8.0m - 16.9m and the lateritic overburden varies in thickness from 0.6m - 5.5m with depths varying 1.2m - 7.4m, while the topsoil has thickness and depths varying from 0.7m - 1.9m.

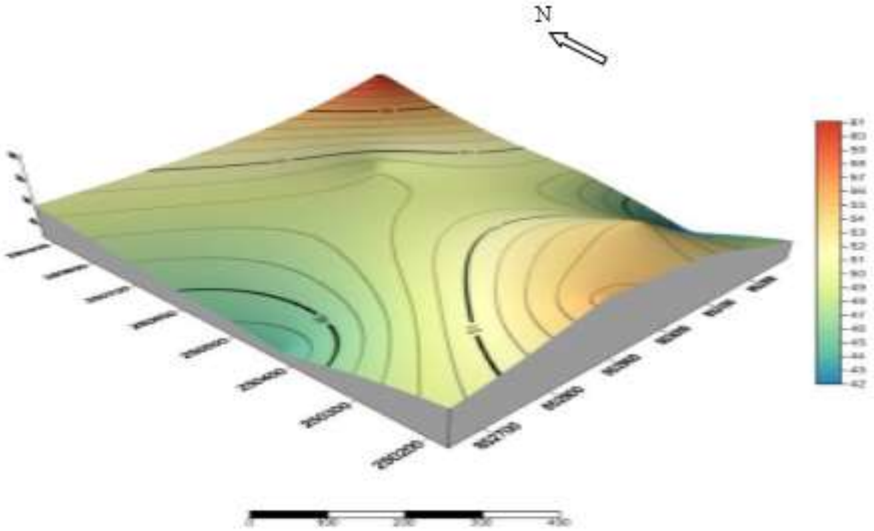


Fig 12: Basement Map of Study Area

4.0. Discussion of Result

The Geo-electric section along this profile connects VES 1, 4, and 5 (Figure 10). Four subsurface layers which are the topsoil, weathered lateritic layer, highly weathered/fractured rocks, and the fresh bedrock were identified in this section. The topsoil has layer resistivity values ranging from 9.5 Ωm - 1620.1Ωm with thickness about 0.8, laterite has layer resistivity values ranging from 15.0 Ωm - 30.3Ωm with thickness about 1.9m-3.2m**,** the weathered layer has resistivity values ranging 19.7 Ωm -3758Ωm with thickness about 7.8m-12.8m, and the weathered and fractured basement layers with resistivity values ranging 263.6Ωm -582.4Ωm, and thickness ranging about 31.2m-50.6m The highly weathered layer is observed beneath VES 4 and 5 with a thickness range of 32.2m-50.6m.

In Figure 11, the Geo-electric section along this profile connects VES 2, 3, and 6. Four lithologies were observed, which were the topsoil, weathered lateritic layer, highly weathered rocks, and the fresh bedrock. The topsoil has layer resistivity values ranging from 59.9 Ωm -1620.1Ωm with a thickness of about 0.8m-1.9m, Laterite has layer resistivity values ranging from 14.1-1846.7Ωm with a thickness of about 1.2m- 5.5m, weathered basement layer has resistivity values ranging 56.5-450.3Ωm with thickness ranging 5.5m-9.5m, and the Weathered and fracture Basement layers with resistivity values ranging 534.7-1839.9 Ωm**,** and thickness ranging 40.9m-43.1m. The highly weathered layer is observed beneath VES 2 with a thickness of 9.5m

Therefore the VES reveals areas with relatively thick, moderate, and low overburden which represents areas with high, moderate, and low groundwater potential respectively. A groundwater accumulation is dependent on the thickness of the aquifer, porosity, permeability, the degree of weathering and fracturing of the (rock) aquifer.

From the basement map and the geo-electric section, it is deduced that areas with relatively moderate to thick overburden complemented with the presence of weathering and fracturing within the study area are zones for groundwater accumulation such as VES points 2, 4, and 5 aquiferous zones with an average depth of 60.0m.

5.0. Conclusion

The Vertical Electrical Sounding (VES) technique using the Schlumberger array was successfully carried out within the study area. It was observed that the study area is composed of highly weathered and fractured rocks; hence there is a tendency for groundwater migration and accumulation in the weathered fractured horizons. The result of the investigation shows that the area is underlain by four geo-electric layers and the saturated zones have resistivity values ranging from 19.7Ωm - 849.8Ωm at maximum depth to a water table of 61.1m in the study area and serves as a guide to the development of water resources. VES 2, 4, 5 are good aquiferous unconfined zones characterized by moderate to thick overburden, small resistivity values, and a high degree of weathering and fracturing.

References

Adeniji, A. E., Obiora, D. N., Omonona, O. V., & Ayuba, R. (2013). Geoelectrical evaluation of groundwater potentials of Bwari basement area, Central Nigeria. *International Journal of Physical Sciences*, 8(25), 1350-1361.

Asry, Z., Samsudin, A. R.., Yaacob, W. Z., & Yaakub, J. (2012). Geoelectrical Resistivity Imaging and Reflection Seismic Investigations at Sg.Udang, Melaka. *American Journal of Engineering and Applied Sciences*, 5(1), 93-97.

Dada, S. S., Onugba, A., Idowu, O. S., & Adojoh C. O. (2011). *Geophysical Investigation of Salem University.* Department of Earth Sciences, Salem University, Lokoja. 34 p. (Unpublished).

Musa, M. K., Obaje, N. G., Odoma, A. N., & Hamza, H. (2011). The Bida Basin in North- Central Nigeria: Sedimentology and Petroleum Geology. *Journal of Petroleum and Gas Exploration Research*. 1(1), 1-13.

Omada, J. I., Omali, A., & Akulu, T. (2009). Groundwater Resources of Lokoja Metropolis, Central Nigeria. *Journal of Mining and Geology*. 45(1), 41-51.

Pellerin, L. (2002). Applications of Electrical and Electromagnetic Methods for Environmental and Geotechnical Investigations. *Surveys in Physics*, 23(2), 101-132.