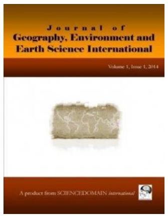

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Preliminary Study on the Viability of Developing Borehole Water Supply System in Afugiri Community and Its Environs, Abia State, South Eastern Nigeria

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Authors' contributions

This work was carried out in collaboration between both authors. Author GUC designed the study, performed the start analysis, wrote the protocol and first draft of the manuscript. Author NE and GUC managed the analysis of the study. Author NE managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Electrical resistivity method for groundwater investigation using vertical electrical sounding (VES) technique was carried out in parts of Afugiri in Umuahia-North Local Government Area of Abia State. The major aim is to delineate the aquiferous units within the study area by determining their thickness, resistivities and the potential borehole depths. The geology revealed that the study area is sedimentary environment and predominantly Bende-Ameki Formation. Prior to this study, there had been serious speculation that borehole could not thrive within the study area (mainly Afugiri). Actually, there had been no existing borehole in the area. Twelve vertical electrical soundings using the Schlumberger configuration were carried out within the study area. The data obtained were interpreted using computer software (IPI2WIN) and Surfer 8 for contouring and map production. The subsurface area investigated is made up of 5-7 geoelectric layers which are not of uniform

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thickness as revealed by the correlated geoelectric section. In Afugiri, the resistivity values and signatures in Vertical Electrical Sounding Stations (VES 1 and VES 3) show that they are likely to hold water at depths of 61.1 and 27.3 meters respectively. The likely aquiferous zone in VES 1 has a thickness of about 32.2 meters while the thickness of the aquiferous unit in VES 3 is about 9.61 meters. The electrical properties of VES 1 and VES 3 shows that they are likely to be sand or fractured shales. The resistivity values of the likely aquiferous zones in VES 1 and VES 3 range from about 2000 to 440,000 Ω-m. `It is recommended that boreholes be drilled much beyond the depth range of 17 m to 229 m which represent the range of water table in the study area to harness potable water within the aquifer region.

Keywords: Resistivity; vertical electrical sounding; aquifer; lithology; preliminary; Afugiri.

1. INTRODUCTION

Owing to the fact that groundwater is a renewable resource and an essential commodity to mankind, the need and search for groundwater have become quite intense in human history. This is due to the fact that government is unable to meet the ever-increasing water demand for the people. Therefore, people have to look for alternative sources of water supply such as surface steams, shallow wells and boreholes. Many hand-dug and machine-drilled wells that were sunk in the study area failed and were abandoned.

Groundwater is trapped by geological formations [1]. Water is one of the most precious resources of life. It is found everywhere in the earth's ecosystem [2]. However, water which exists in such abundance on the earth is unevenly distributed in both time and space and in circulation [3]. The quantity and disposition of groundwater depends on the geological characteristics of host rock formation. Water yield in basement terrain is usually found in areas where the overburden overlies fractured zone [4]. The zones are often characterized by relatively low resistivity and discontinuities [5].

In sedimentary terrain, permeable and porous rock masks such as sandstone, lose sand, etc, are good indicators of aquifer. The search for ground water is faced with a lot of uncertainties; to minimize or avoid failures altogether, it is pertinent that the right techniques are utilized in the delineation of subsurface water-bearing formations [6].

Electrical resistivity method of geophysical exploration happens to be one of the most applied methods in groundwater exploration. This is applied through the use of vertical electrical sounding (VES) technique. The VES is a geoelectrical method for measuring vertical changes of electrical resistivity. The method has been recognized to be more appropriate for hydro geological study of sedimentary basins. The reason for its wide use is because the instrument is simple to handle, also, the field logistics are easy and straight forward while the analysis of data is less tedious and economical. These are the reasons why many researchers have used this method for determination of aquifer boundaries. Ground water is explained as water situated below the ground surface in soil pore spaces and in the fractures of lithologic formations. A unit of rock or an unconsolidated deposit is called an aquifer when it is capable of producing reasonable quantity of water.

2. MATERIALS AND METHODS

2.1 Location and Physiogrphy of the Study Area

The area investigated, Afugiri is located at Ohuhu, in Umuahia North Local Government Area of Abia State. It lies between latitude 5.55^0N and 5.62^0N and longitude 7.46^0E and 7.50^0E. It covers a total surface area of about 29.65 square kilometers. The climate of the study area usually alternates with the dry and rainy season. The area which lies within the south – eastern part of Nigeria has a total annual rainfall of over 1400 mm spread over the month of April to October. The highest amount of rainfall is observed in the month of July. The dry season is from November to March. There is characteristic "August break" lasting about two weeks in which the rains cease. This occurs during the months of August but may extend to early September. The vegetation of the area is that of the rainforest which comprises of various species of shrubs and tall forest plants all over the area. The topography as seen from 3-D relief map (Fig.1) shows a fairly undulating topography characterized by hills which are irregularly truncated by valleys. The lowest elevations of about 72 m above mean sea levels are seen around Umuegwu- Okpuala at the south-western part of the study area while the highest points stand at elevation of about 126 m above mean sea level around Akpahia at the north eastern part of the area investigated. The area is well drained by the structurally controlled Ikwu- Stream which flows in a NE-SW direction, making the low elevation at south-western part.

2.2 Geology of the Area

Afugiri area falls within southeastern part of the Anambra basin. Anambra basin is a most prominent basin formed during the Abakaliki tectonic episode and igneous activity around there resulting to lead-zinc mineralization [7,8,2]. The Anambra basin is dominantly filled with classic sediments constituting several distinct lithostratigraphic units ranging from Upper Companion to Recent in age.

The study area belongs to Bende-Ameki Formation. The Bende-Ameki Formation is dominantly filled with classic sediments. The source of the sediments into the basin is principally from the Cameroun massif and Afikpo syncline [9]. The Bende-Ameki Formation consists of a top lateritic sand layer underlain by a near monotonous sandy horizon, with occasional intercalations of thin clay, thick shale and gravel beds.

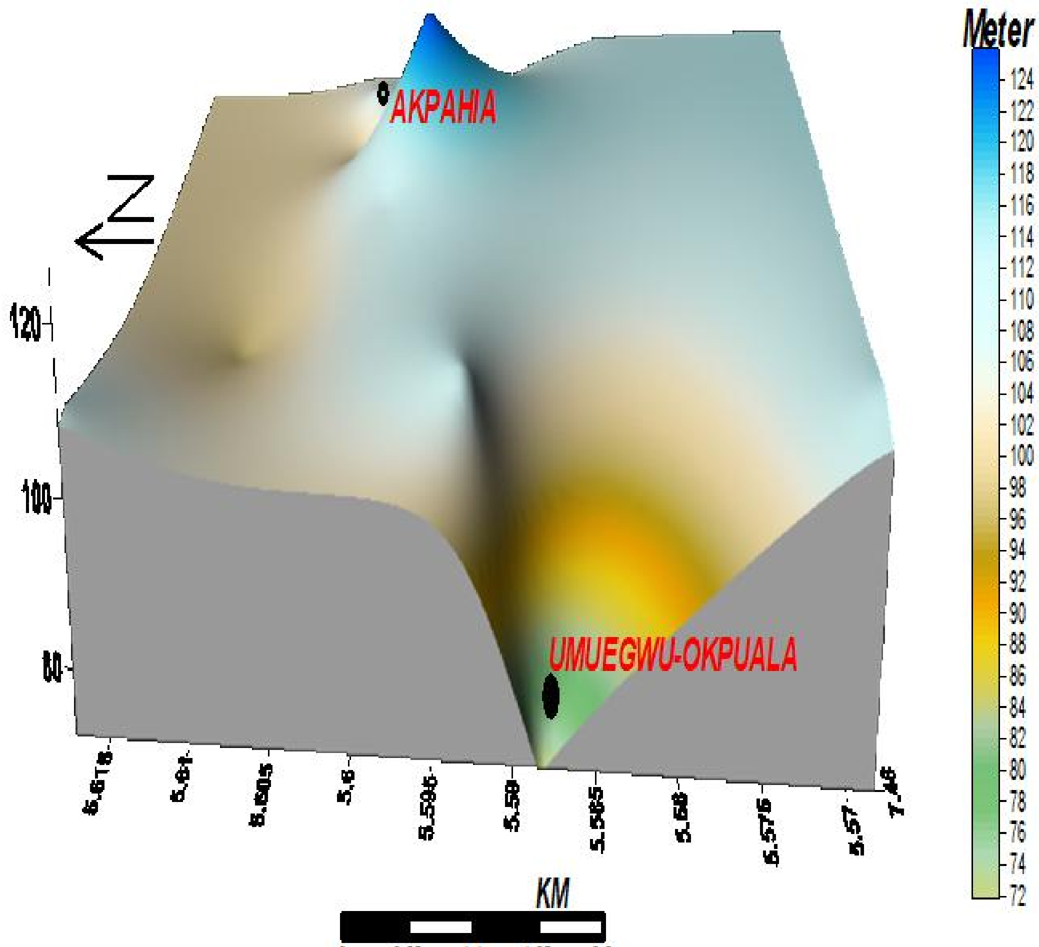


Fig. 1. 3-D relief map of Afugiri SE Nigeria showing the highest and the lowest elevations of the study area

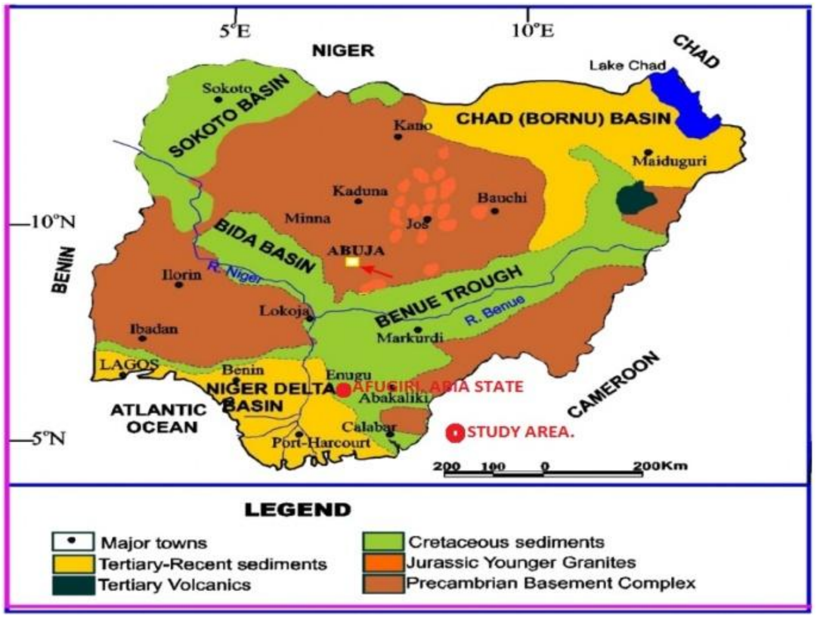


Fig. 2. Geological map of Nigeria showing the main basin and southern part of Benue trough (lower Benue trough). Adopted from Obaje et al., 2011 [10]

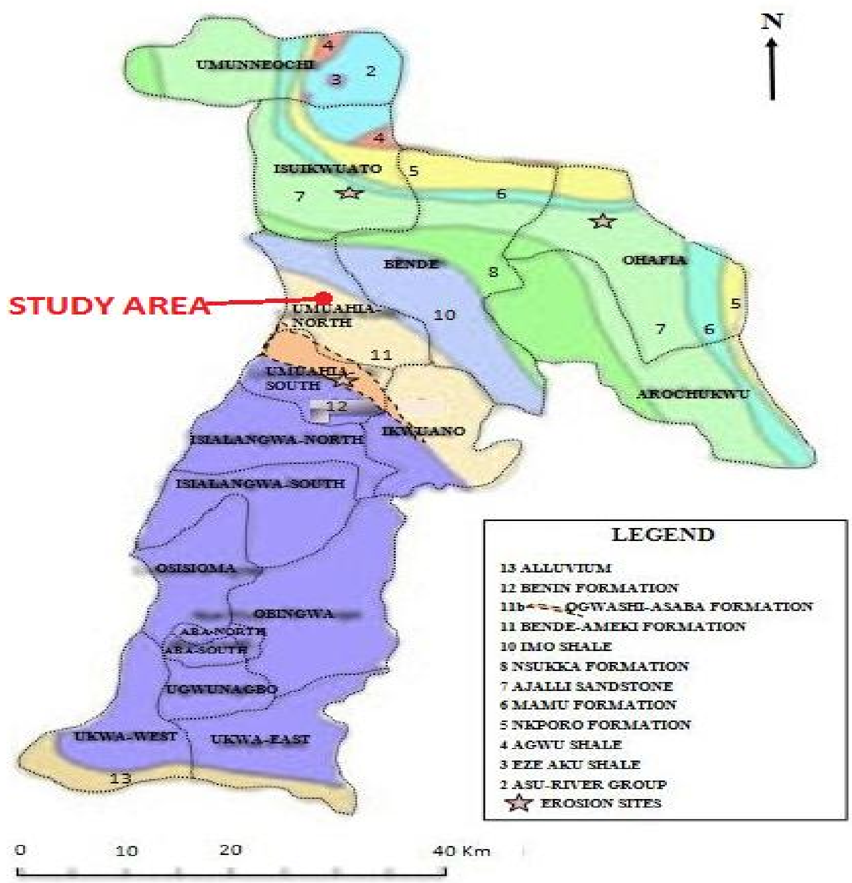


Fig. 3. Geological map of Abia State showing the study area. Adopted from John et al., 2015 [3]

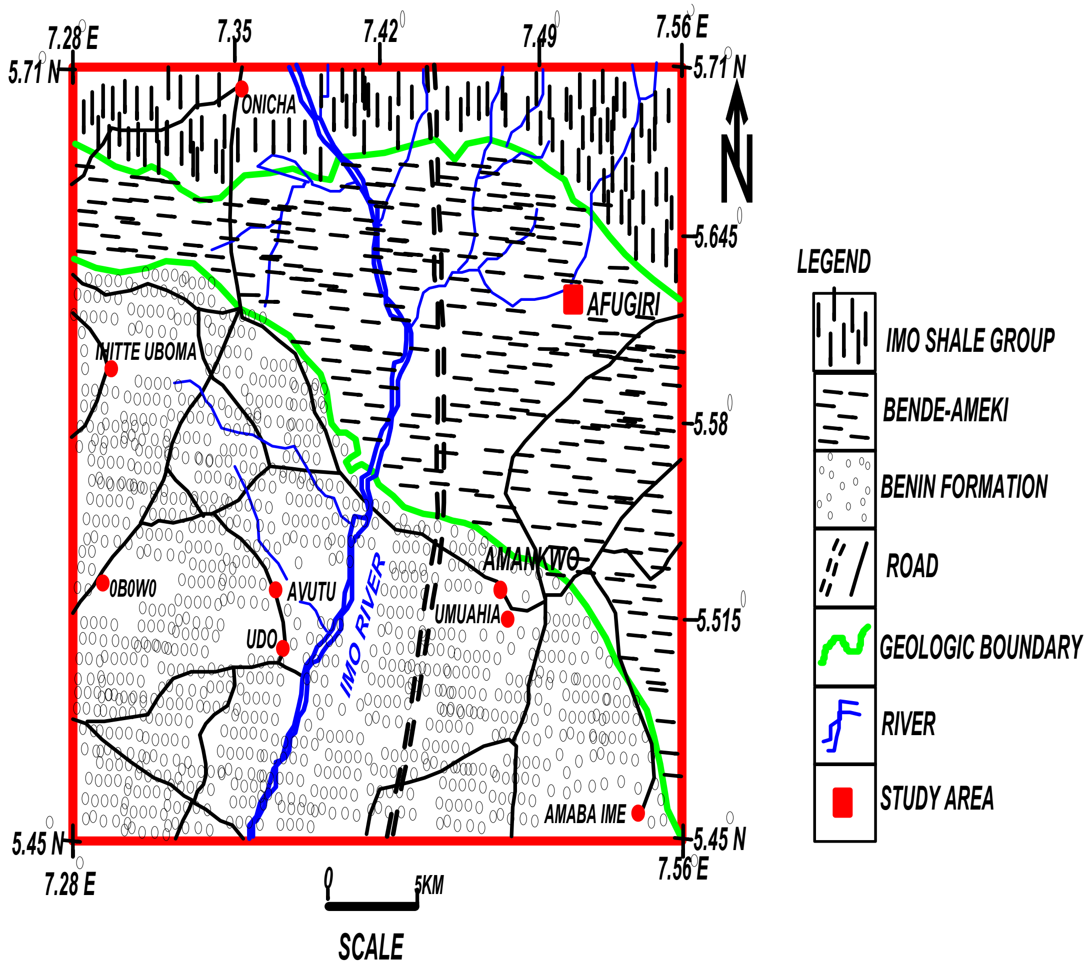


Fig. 4. Geological map of Afugiri and environs south-eastern Nigeria

2.3 Survey Techniques

There are different geophysical methods, which can be applied in groundwater exploration. The methods include the gravity, seismic, magnetic and the electrical resistivity. Electrical resistivity method has gained acceptance as the most widely used geophysical method in groundwater investigations [11].

A high resolution and sensitive instrument called Terrameter Omega 1000 was used in the measurement. This instrument gives the apparent resistivity of the ground.

The Schlumberger array adopted in this study was used to delineate the vertical variations of resistivity at different depths. The sketch in Fig. 3 shows Schlumberger electrode configuration.

In this layout, four electrodes were employed and earthed along a straight line profile in the order AMNB, two that conduct current in and out of the ground (A and B) and the other two that measure potential difference generated by the current (M and N).

The field procedure consists of expanding the current electrodes AB while keeping the potential electrodes MN relatively fixed. For each reading, the current was sent into the ground through current electrodes A and B which set up the measured potential difference between the potential electrodes M and N. The magnitude of the potential difference developed is a measure of the electrical resistance of the ground between the probes. The resistance is in turn a function of the geometrical configuration of the electrodes and the electrical parameters of the ground [12].

As AB gets larger, the potential set-up between electrodes tends to affect the measuring capabilities of the instrument. This is due to the fact that the field at the centre of the configuration varies inversely as the square of the length of the configuration AB, when the situation occurs, a new value, typically about 3 times larger than the proceeding value is taken for MN as suggested by Mooney [13]. The procedure for measurement of the potential developed was then continued by duplicating the last two values with the new MN value.

The field work required a five-man crew. Two men taped the distances, laid the cable, and moved and stood by the two current electrodes A and B. The third man, the observer, remained at the centre point; and is responsible for taking the measurements and for moving the electrodes M and N. Contact between the three men was established by cell phone or walkie-talkie.

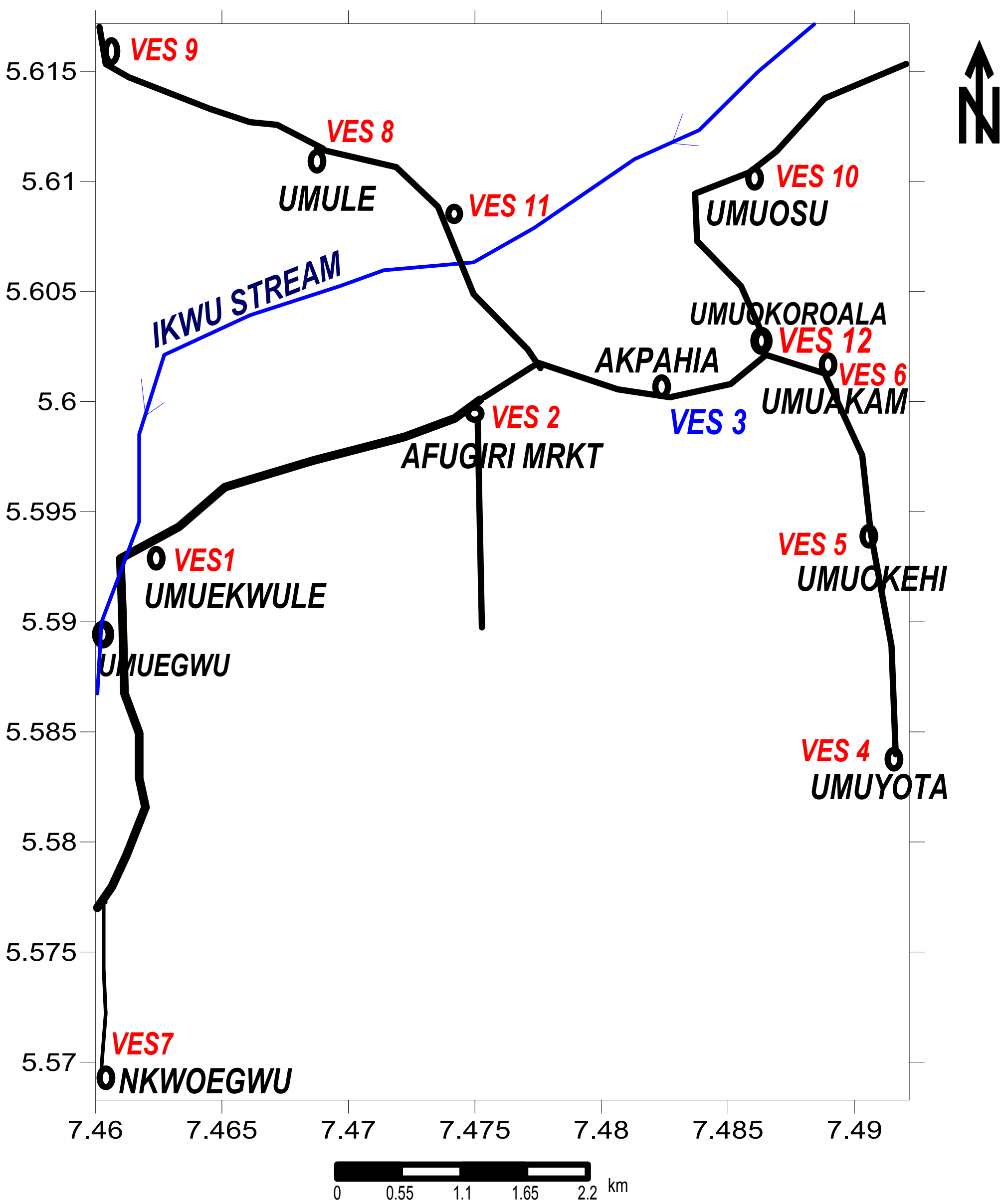


Fig. 5. Map of Afugiri showing VES location

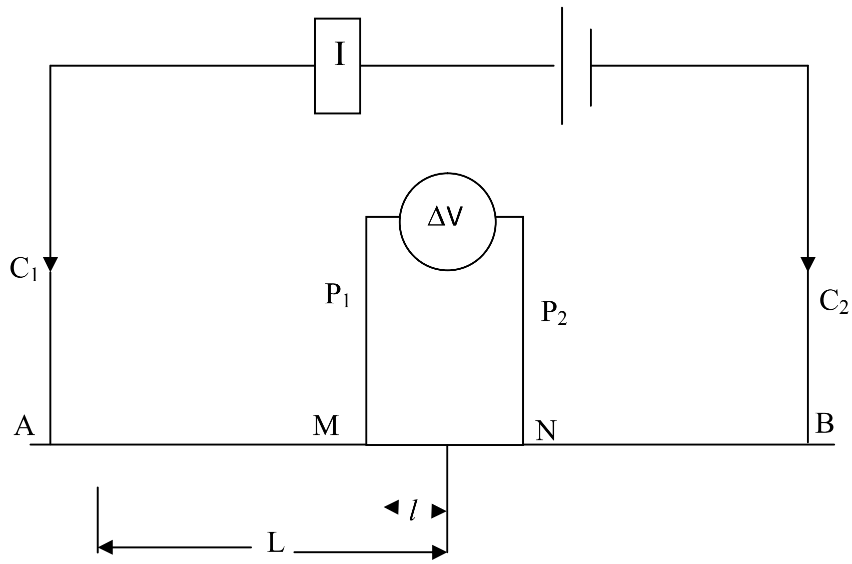


Fig. 6. Schlumberger electrode configuration
where C_1 and C_2 are current electrodes
P_1 and P_2 are Potential electrodes

Since the currents and voltage sent into the ground through A and B could be fatal, it was necessary to keep a man, near each electrode lest someone should accidentally step over the electrode. There was no danger of accidentally severing the current cable, because the current sender is equipped with a safety device that will turn off the circuit whenever the resistance increases above a safe value.

The readings of the resistance values (R) obtained in the field were automatically converted to apparent resistivity (ρ_a) by using equation (1).

$$\rho_a = \pi \left\{ \frac{\left[\frac{AB}{2}\right]^2 - \left[\frac{MN}{2}\right]^2}{MN} \right\} \frac{V}{I} \tag{1}$$

For interpretation, the apparent resistivities were plotted against half electrode separation (L) for each of geo-electric sounding and curves were generated from the data. The curves obtained were interpreted using IPI2WIN software. The parameters obtained from the interpretation are a set of estimates of depths to geo-electric layers and their resistivities, thus the depths to water table and aquifer thickness are inferred indirectly. It is important to note that the productivity of any well is normally correlated with the thickness of the aquifers. The advantages of Schlumberger over Wenner configuration are:

i. The Schlumberger spread is more convenient than the Wenner spread because only two electrodes need move at a time.
ii. Schlumberger sounding curves portray a slightly greater probing depth and resolving power than the other method.
iii. The manpower and time required for making Schlumberger sounding are less than required for making Wenner sounding.

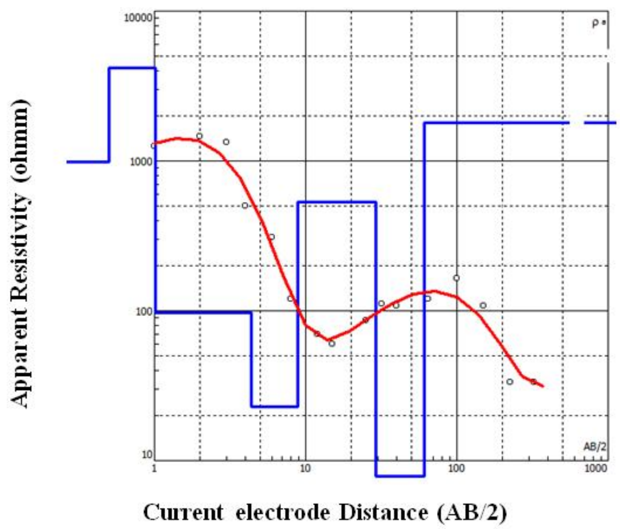
There are some precautions taken in the field during the investigation, these include;

1. The instrument was properly checked and tested to ensure that it is in good condition for efficiency and effectiveness.
2. Care was taken to make sure that the profiles were taken in a straight line and that the cables do not touch or cross each other during measurement.
3. The electrodes were fixed deep into the ground to ensure good electrical contact.

3. RESULTS AND DISCUSSION

During the course of the survey, a total of twelve geo-electrical sounding stations were covered. The stations were evaluated using (IPI2WIN) computer software. The results of the interpretation are shown in Table 1 and sounding curve were shown in Fig. 8. From the range of true resistivity values, the subsurface lithology were delineated for probably rock types and water-table information on the number of layers encountered and their respective thicknesses were obtained as shown on Table 1.

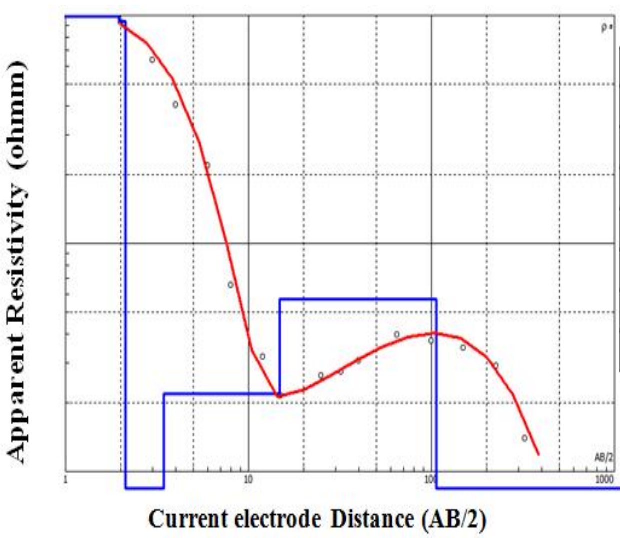
The shape of the curve depends on the number of layers encountered. The thickness and resistivity of individual layers likewise strongly affect the shape of the curve. The shape of the curve is the foundation of the analytic interpretation by which the true resistivity (ρ), the thickness, h and the depth, d of the layers can be approached. The interpreted sounding curves within this study area have about seven groups of curve types within the study. The first curve type is KHK comprises of VES 1 and VES 4. The second curve type is QHA which comprises of VES 2 and VES 10. The third curve type HAK comprises of VES 3, 6, and 12. Also, at VES 5 there is HKH type of curve present while at VES 7, there is KHH type of curve. More so, there is QQ type of curve present at VES 8 and 7. Finally, the sounding curve at VES 11 is of HK type of curve.



N	ρ	h	d	Alt
1	983	0.5	0.5	-0.5
2	4191	0.513	1.01	-1.013
3	97.1	3.33	4.35	-4.347
4	22.9	4.47	8.82	-8.816
5	528	20.1	28.9	-28.9
6	2.51	32.2	61.1	-61.08
7	1791			

VES 1

Fig. 7. Results of computer modeled curve for VES 1 (Umuegwu Okpuala)



N	ρ	h	d	Alt
1	1058	1.96	1.96	-1.957
2	944	0.165	2.12	-2.121
3	5.31	1.31	3.43	-3.428
4	21.8	11.4	14.9	-14.87
5	57.1	91.4	106	-106.2
6	2.93			

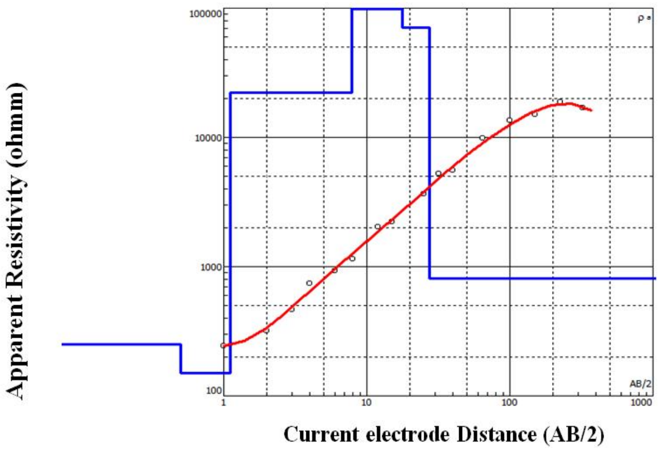
VES 2

Fig. 8. Results of computer modeled curve for VES 2 (Afugiri Market)

Table 1. Vertical electrical sounding data for VES stations 1 to 12

VES No	Location	Elevation (m)	Latitude ^{0}N	Longitude ^{0}E	No of layers	Res./ Thickness	*ρ*1h1	*ρ*2h2	*ρ*3h3	*ρ*4h4	*ρ*5h5	*ρ*6h6	*ρ*7h7
01	Umuegwu Okpuala	111	5.59	7.46	7	ρ(Ωm)	983	4191	97.1	22.9	528	2.51	1791
						h(m)	0.5	0.513	3.33	4.47	20.1	32.2	……
02	Afugiri Market	109	5.59	7.47	6	ρ (Ωm)	1058	944	5.31	21.8	57.1	2.93	……
						h(m)	1.96	0.165	1.31	11.4	91.4	……	……
03	Akpahia	127	5.59	7.48	6	ρ (Ωm)	252	150	22188	446322	70917	805	……
						h(m)	0.5	0.619	6.76	9.84	9.61	……	……
04	Umuyota	112	5.58	7.49	6	ρ (Ωm)	1577	4788	2.38	50.5	2.55	960	……
						h(m)	0.5	0.177	2.08	3.69	8.1	……	…..
05	Umuokehi	103	5.59	7.49	6	ρ (Ωm)	441	33.5	94.7	1.77	11.8	608	…..
						h(m)	0.5	0.275	1.39	0.467	91.8	……	……
06	Umuakam	109	5.59	7.48	6	ρ (Ωm)	1061	220	3.18	80.9	1.4	420	……
						h(m)	2.21	4.22	6.45	12.2	15.8	……	……
07	Nkwoegwu	114	5.56	7.46	7	ρ (Ωm)	449	3036	445	7672	17.7	2279	2822
						h(m)	0.5	0.423	1.58	8.72	15.8	75	……
08	Umulenso	97	5.60	7.47	5	ρ (Ωm)	786	233	26	1.84	669	…….	…….
						h(m)	0.847	1.64	5.96	8.69	…….	……	…….
09	Umukabia	109	5.61	7.46	5	ρ (Ωm)	650	298	153	5.66	20.5	……	……
						h(m)	1.3	4.83	1.84	6.56	…..	……	……
10	Umuosu	100	5.60	7.48	6	ρ (Ωm)	82.1	42.7	8.06	32.5	426	536	…….
						h(m)	1.47	1.69	3.61	46.3	14.7	……	…….
11	Umuoshi	107	5.60	7.48	5	ρ (Ωm)	1464	1.22	76.6	6.64	512	…….	…….
						h(m)	0.538	0.807	0.703	8.07	……	……	…….
12	Umuokoroala	98	5.65	7.47	6	ρ (Ωm)	745	2.32	21.1	2991	418	3.54	……
						h(m)	0.5	0.358	3.52	5.16	169	……	…….

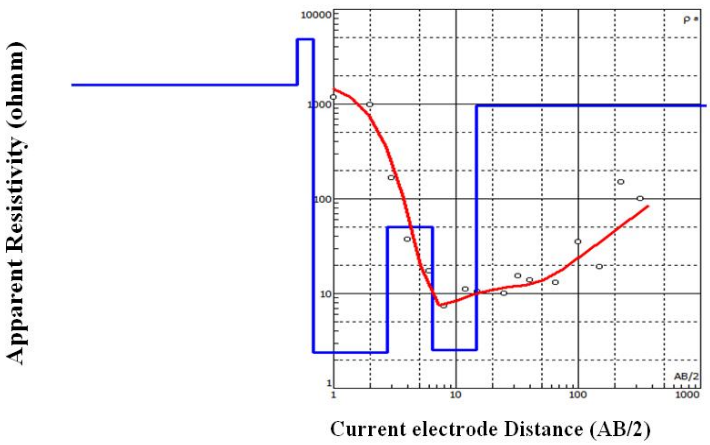
**ρ and h represents the apparent resistivity and the thickness of each of the layers*



N	ρ	h	d	Alt
1	252	0.5	0.5	-0.5
2	150	0.619	1.12	-1.119
3	22188	6.76	7.88	-7.883
4	446322	9.84	17.7	-17.73
5	70917	9.61	27.3	-27.34
6	805			

VES 3

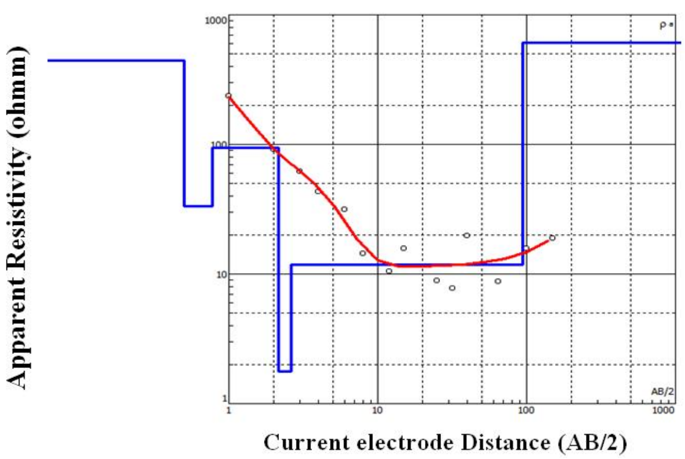
Fig. 9. Results of computer modeled curve for VES 3 (Akpahia)



N	ρ	h	d	Alt
1	1577	0.5	0.5	-0.5
2	4788	0.177	0.677	-0.6769
3	2.38	2.08	2.76	-2.756
4	50.5	3.69	6.45	-6.447
5	2.55	8.1	14.5	-14.55
6	960			

VES 4

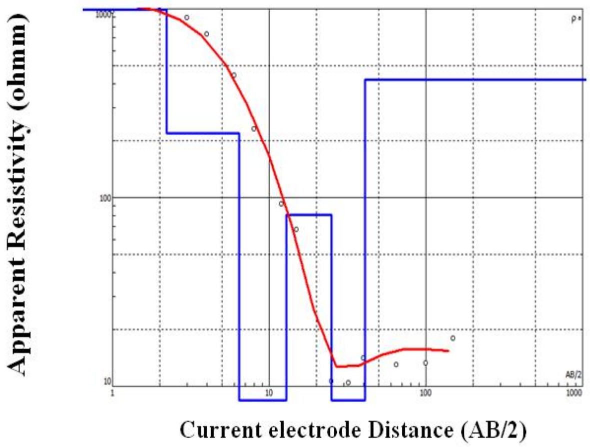
Fig. 10. Results of computer modeled curve for VES 4 (Umuyota)



N	ρ	h	d	Alt
1	441	0.5	0.5	-0.5
2	33.5	0.275	0.775	-0.7749
3	94.7	1.39	2.17	-2.167
4	1.77	0.467	2.63	-2.634
5	11.8	91.8	94.4	-94.43
6	608			

VES 5

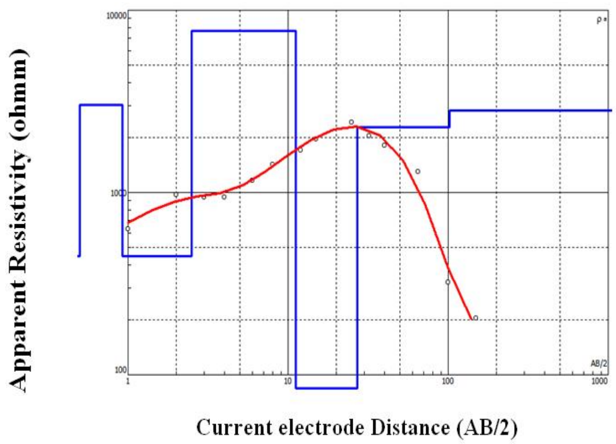
Fig. 11. Results of computer modeled curve for VES 5 (Umuokehi)



N	ρ	h	d	Alt
1	1061	2.21	2.21	-2.215
2	220	4.22	6.43	-6.43
3	3.18	6.45	12.9	-12.88
4	80.9	12.2	25	-25.05
5	1.4	15.8	40.8	-40.85
6	420			

VES 6

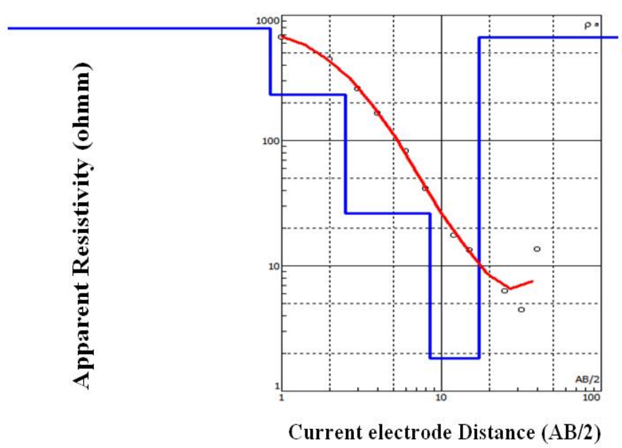
Fig. 12. Results of computer modeled curve for VES 6 (Umuakam)



N	ρ	h	d	Alt
1	449	0.5	0.5	-0.5
2	3036	0.423	0.923	-0.9231
3	445	1.58	2.5	-2.5
4	7672	8.72	11.2	-11.22
5	17.7	15.8	27	-27.02
6	2279	75	102	-102
7	2822			

VES 7

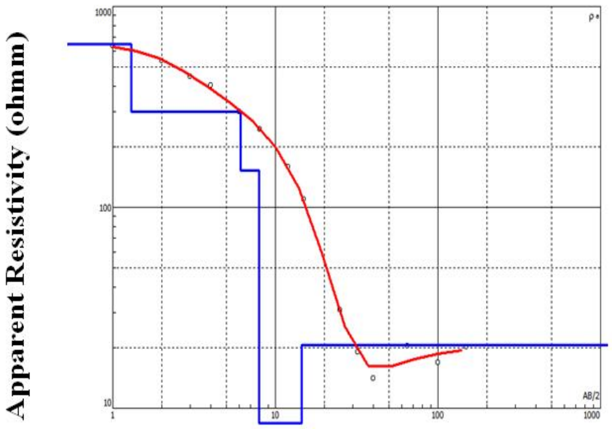
Fig. 13. Results of computer modeled curve for VES 7 (Nkwoegwu)



N	ρ	h	d	Alt
1	786	0.847	0.847	-0.8473
2	233	1.64	2.49	-2.489
3	26	5.96	8.45	-8.449
4	1.84	8.69	17.1	-17.14
5	669			

VES 8

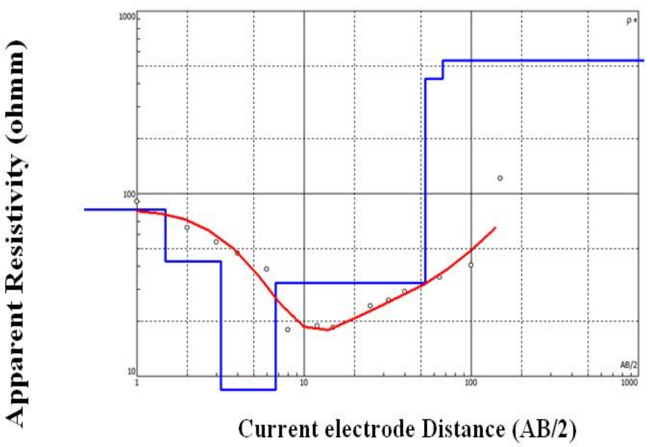
Fig. 14. Results of computer modeled curve for VES 8 (Umulenso)



N	ρ	h	d	Alt
1	650	1.3	1.3	-1.295
2	298	4.83	6.12	-6.125
3	153	1.84	7.96	-7.963
4	5.66	6.56	14.5	-14.52
5	20.5			

VES 9

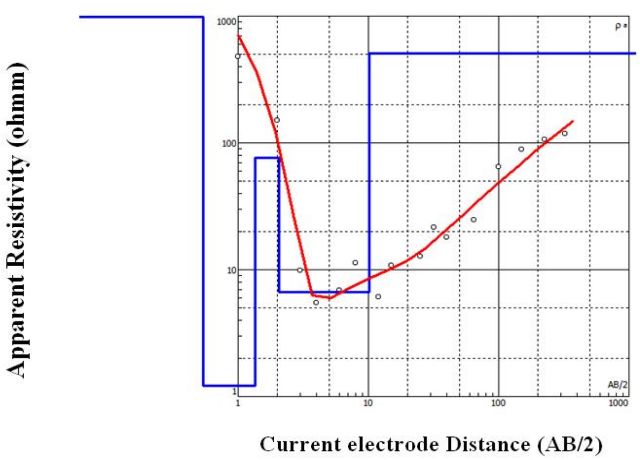
Fig. 15. Results of computer modeled curve for VES 9 (Umukabia)



N	ρ	h	d	Alt
1	82.1	1.47	1.47	-1.474
2	42.7	1.69	3.16	-3.164
3	8.06	3.61	6.77	-6.77
4	32.5	46.3	53.1	-53.12
5	426	14.7	67.9	-67.85
6	536			

VES 10

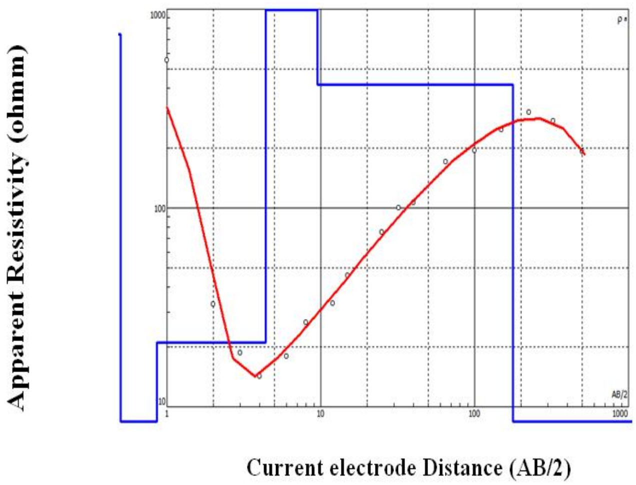
Fig. 16. Results of computer modeled curve for VES 10 (Umuosu)



N	ρ	h	d	Alt
1	1464	0.538	0.538	-0.5382
2	1.22	0.807	1.34	-1.345
3	76.6	0.703	2.05	-2.048
4	6.64	8.07	10.1	-10.11
5	512			

VES 11

Fig. 17. Results of computer modeled curve for VES 11 (Umuoshi)



N	ρ	h	d	Alt
1	745	0.5	0.5	-0.5
2	2.32	0.358	0.858	-0.8585
3	21.1	3.52	4.38	-4.378
4	2991	5.16	9.54	-9.536
5	418	169	178	-178
6	3.54			

VES 12

Fig. 18. Results of computer modeled curve for VES 12 (Umuokoroala)

4. CONCLUSION AND RECOMMENDATION

Vertical electrical sounding (VES) techniques carried out at (12) twelve stations in Afugiri Ohuhu in Umuahia North Local Government Area of Abia State, confirmed that: there are five – seven layers which comprises of top soil (dry red sand), Laterite, clay, clay-sand, shale and sand. It is also observed that the probable stations more suitable for making boreholes were stations VES 1 and 3. Looking at the resistivity values, location 7 (Nkwoegwu) has water at depth of about 102 meters. It is a sound unit of about 75 meters thick. This is further confirmed from borehole log of the area. There are productive boreholes in Nkwoegwu, a neighboring village to Afugiri. Afugiri has a complex geology, therefore water borehole drilling is very difficult. But the resistivity values and signature in VES 1 and VES 3 show that they are likely to hold water at depth of 61.1 and 27.3 meters respectively. The likely aquiferous zone in VES 1 has thickness of about 32.2 meters while the thickness of the unit in VES 3 is about 9.61 meters. The electrical properties of VES 1 and VES 3 show that they are likely to be sound unit or fracture shale. The resistivity values of the likely aquiferous zones in VES 1 and VES 3 range about 2000 to 440, 000 ohmmeters.

It is therefore recommended that further more detailed research could be done in the study area to fully ascertain viability of the identified aquifer zones.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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