British Journal of Applied Science & Technology
4(13): 1978-1988, 2014

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Vertical Electrical Sounding Survey for Groundwater Exploration in Parts of Anyigba and its Environs, in the Anambra Basin of Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author MO designed the study interpretation of the analysis results, author AD performed data analysis using IP2WIN software and writing of final manuscript, author AE wrote the first draft of the manuscript and managed literature searches. Author MSK managed literature searches and redesigned the manuscript. All authors read and approved the final manuscript.

Short Research Article

Received 2nd September 2013
Accepted 13th November 2013
Published 13th March 2014

ABSTRACT

Aim: The aim of the study is to delineate the subsurface geologic layers and evaluate the aquifer potential in Anyigba and its environs.
Study Design: The resistivity sounding surveys were carried out randomly within the study area with half of the total surveys carried out within Anyigba town. Lithologic logging of boreholes close to the survey lo\ations were also carried out.
Place and Duration of Study: The study area is Anyigba and its environs in Kogi state, central Nigeria. Field geophysical resistivity survey and borehole lithologic logging of the study area were carried out between March 2010 and December 2012.
Methodology: The field resistivity sounding surveys were carried out with an ABEM SAS (1000) Terrameter using the Schlumberger electrode array.
Drill cuttings from boreholes sampled at 3 meters interval were used for the identification of the subsurface lithology.
Results: The results of the study reveal the presence of four to six geologic layers within the study area. The geologic layers and the mean thicknesses of the layers are: i. Lateritic top soil (1.022m), ii. Lateritic sandy layer (5.285m), iii unsaturated loosely compacted sandstone layer (9.843m), iv. unsaturated compact sandstone layer (45.8m),

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v. partly saturated sandstone layer (26.9) and vi. A fully saturated sandstone layer.
Conclusion: Four to six geologic layers have been delineated within the study area. The fifth (partly saturated sandstone) layer and the sixth (fully saturated sandstone) layer constitute the main aquifer units in the study area.

Keywords: Aquifer; sandstone; geoelectric; layer; resistivity.

1. INTRODUCTION

Anyigba and its environs in Kogi state, central Nigeria, lie within the Anambra sedimentary basin. The area has witnessed a large influx of people following the creation of Kogi state and this has led to an increase in demand for water supply. The principal stores of groundwater in Africa are concentrated in the earth to a depth of 400metres [1]. Groundwater is widely known to be more hygienic than surface water, thus the possibility of utilizing it as a source of water supply for public use is always attractive [2]. The Vertical Electrical Sounding survey method of geophysical exploration is very useful in groundwater exploration [3]. Olorunfemi and Fasuyi [4] identified aquifer types/hydrogeologic characteristics of part of the central basement terrain of Nigeria using the vertical electrical sounding method. Olayinka [5] used the resistivity sounding method in groundwater investigation in the basement complex terrain of Egbeda- Kabba in Kogi state, Nigeria. This study is aimed at delineating the geological sequence and identifying the aquifer units in Anyigba and environs using the vertical electrical sounding method of geophysical surveying.

1.1 Geologic and Hydrogeologic Setting

The study area is part of the Anambra sedimentary basin and lies within latitude 6º 52′ 30″ N to 7º52′30″ N and longitudes 6º45′ to 7º52′ E The Anambra basin is a nearly triangular shaped embayment covering an area of about 300, 0000 sq. km. It stretches from the area just south of the confluence of the rivers Niger and Benue to as far as Awka, east of the river Niger (Fig.1). The lithostratigraphic units underlying the study area are:

(i) The basal Nkporo Group which is of Campanian age and consists of dark shales and mudstones with occasional thin beds of sandy shale and sandstone.

(ii) The Mamu Formation, which overlies the Nkporo Formation is Lower Maestritichtian in age and consists of distinct assemblages of mudstones, sandstone, siltstone, sandy - silty shale, grey shales, carbonaceous shales and coal seams [6]. The Mamu Formation serves as a confining Formation for the overlying Ajali Formation.

(iii) The Ajali Formation (Upper maestrichtian) is the main aquiferrous Formation within the Anambra basin. The Formation has an average thickness of about 300 meters. The Ajali Formation consists essentially of stratified sandstone units with planar cross bedding and coarse to fine grained texture. The Formation is capped by a considerable thickness of red earth at the top resulting probably from weathering and ferrugenisation. The Formation is readily recharged in its outcrop belt around the Idah-Nsukka-Enugu escarpement.

(iv) The marine shales of the Imo and Nsukka Formation which were deposited in the Paleocene overlie the Ajali Formation.

(v) The continental Nanka and Ameki sandstones of Eocene age overlie the Imo and Nsukka Formation (Fig. 2)

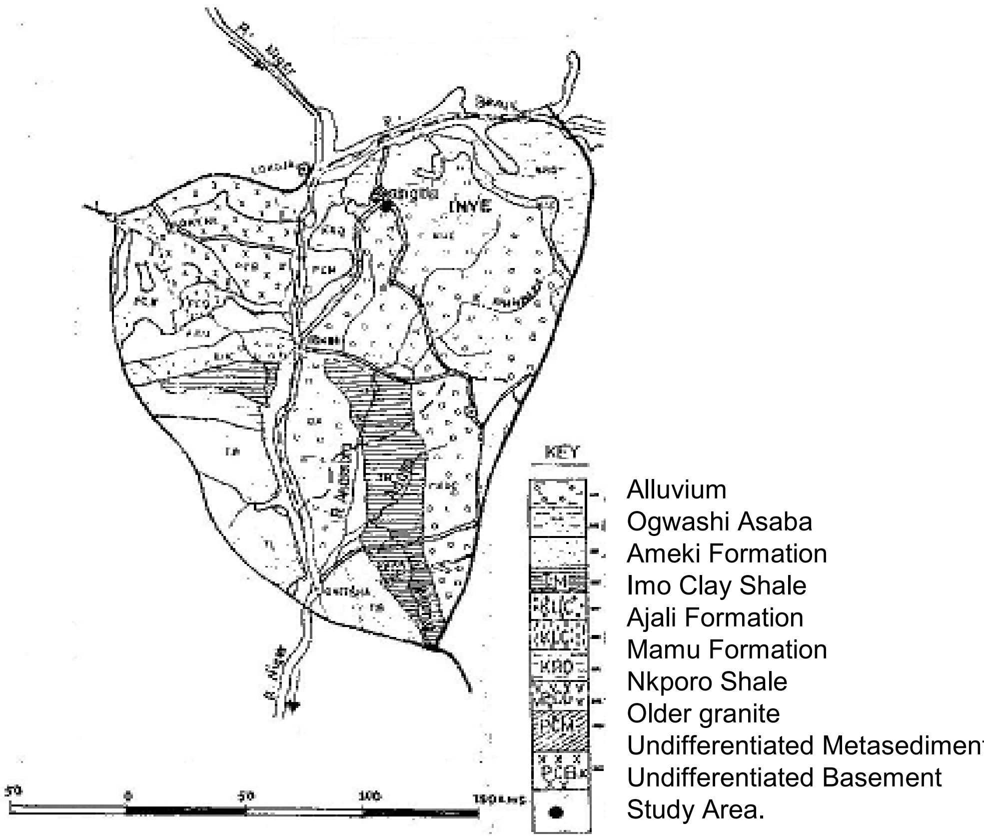


Fig. 1. Geologic Map of the Anambra basin showing the study area

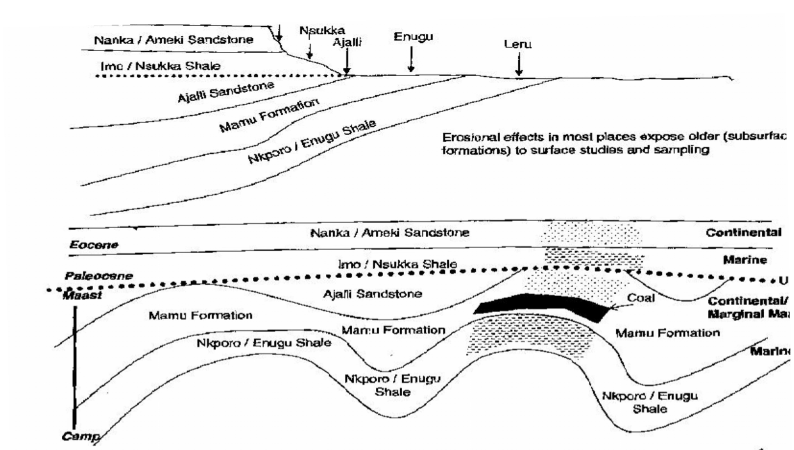


Fig. 2. Stratigraphic successions in the Anambra basin (After Obaje, 2009)

2. METHODOLOGY

A total of 10 VES sounding surveys were carried out in the study area as shown in Fig. 3.

The VES survey was carried out using the Schlumberger array. Current Electrode spacing (AB/2) was varied from 1 to 600m with a maximum spread length of 1200m. The VES data were acquired using an ABEM (SAS 1000) terrameter.

The Apparent resistance value, (Ra), as displayed by the terrameter was multiplied by the "geometric factor" for the Schlumberger array to obtain the apparent resisitivity (ρ_a) of the spread concerned. The apparent resistivity values for the corresponding current and potential electrode separation was plotted against half of the current electrode separation (AB/2) on a log-log graph paper using the IP2WIN software. The software iteratively adjusts the field curve until it matches the theoretical curve within a tolerance of 5.0% Root Mean Square (RMS).

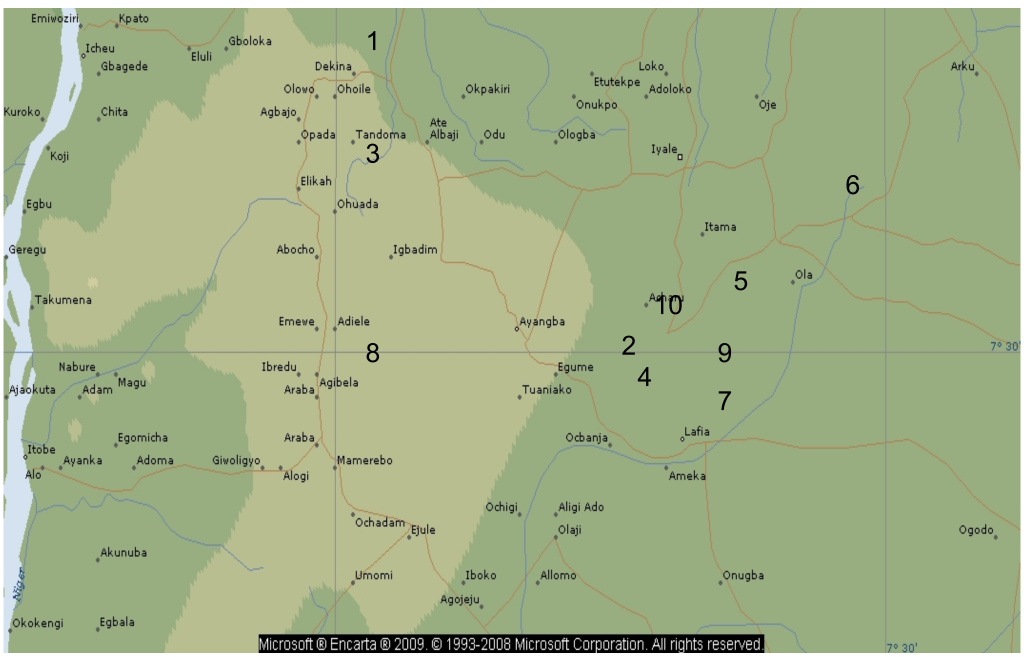


Fig. 3. Map of Anyigba And its Environs showing the VES points

3. RESULTS AND DISCUSSIONS

The Apparent Resistivity values for the different electrode spacing for the VES locations are presented below (Table 1). Plots of Apparent Resistivity Versus Current Electrode Separation (AB/2) were generated. The VES curves showing the field resistivity, calculated resistivity and thickness of the subsurface layers in the area are presented below (Figs. 4-13).

Table 1. Apparent resistivity values for different electrode spacing obtained in the survey area

Electrode Spacing AB/2(m)	Ra (Ohm -m)			Electrode Spacing AB/ 2(m)	Ra (Ohm-m)				Electrode Spacing AB/2 (m)	Ra (Ohm -m)		
	Anyigba VES 1	Anyigba VES 2	Anyigba VES 3		Anyigba VES 4	Anyigba VES 5	Anyigba VES 6	Anyigba VES 7		Anyigba VES 8	Anyigba VES 9	Anyigba VES 10
1	116	100.2	380.4	1	650	520	520	940	1.1	541.56	904.64	495.49
1.5	149	126.3	528.6	1.3	763	620	500	872	1.6	511.43	1118.34	638.03
2	178.1	140.	750.1	1.8	884	700	470	735	2.3	550.1	1345.79	770.03
3	260	190.3	1079.9	2.4	980	760	442	607	3.4	533.55	1962.35	904.64
5	370	213	1511	3.2	1217	850	429	528	5	267.1	354.33	1118.34
7	398	200	1700	4.2	1000	750	365	565	7.3	611.39	2068.46	1345.79
10	370	205	2120.8	5.6	800	700	320	600.8	10.7	1289.72	2802.53	1962.35
15	420.3	207	2288	7.5	650	600	260	723.7	15.8	729.21	3779.15	354.33
20	415.5	240.6	2832.9	10	707	545	285	843	23.3	896.44	5326.35	2068.46
25	400	282.6	3197.6	13.3	800	700	360	870	34.1	1020.43	7251.64	2802.53
30	363.1	320.1	3390.2	18	1000	800	513	989	50	824.96	8107.79	3779.15
40	322.1	385	3999	24	1200	900	640	1100	73.5	848.75	7247.11	5326.35
50	300.2	417.3	4022	32	1500	1154	711	1289	108	5745.1	7697.42	7251.64
60	270.1	470	4809	42	1800	1300	795	1400	158.7	1381.1	13758.64	8107.79
70	257.1	511	5011.1	56	1505	1100	970	1592	233.3	1104.61	926.17	7247.11
80	252	524	5077.5	75	1300	950	1378	1765	343	1474.96	6664.98	7697.42
100	278	589.1	4288.1	100	1200	850	1830	2243	504.3	3772.44		13758.64
120	270	570	2755.1	133	900	800	2376	2500				
150	435	639.1	1811.6	180	920	900	2849					
200	366	740.6	838.4	240	1000	1000	3200					
300	582	673.7	453.2	320	1200	1100	3280					
400	461	560.7	411									
500	300	330.3	310									
600	205.1	300	288.2									

Table 2. Geoelectric layer Resistivities and Thicknesses obtained in the VES locations in the survey area

Community	VES	RMS	Geoelectric Layer Resistivity						Geoelectric Layer Thickness				
	Location	Errors	1	2	3	4	5	6	1	2	3	4	5
	1	3.93	69.2	521	105	2540	9.59		0.5	15.9	25.6	55.3	
Anyigba	2	5.23	75	377	821	957	3.99		0.66	2.38	4.62	190	
	3	4.54	227	2992	16076	313			0.5	10.4	4.9		
	4	4.11	409	4531	133	7666	116	5448	0.5	0.59	1.71	10.1	23.3
	5	3.27	336	2011	136	6157	241	1828	0.5	1.06	2.03	7.22	30.5
	6	3.24	508	118	1405	48088	167		2.31	3	26.7	27.8	
	7	2.33	104	1066	1236	1280	4966		0.39	0.58	1.19	33.4	
	8	5.15	659	4091	107	262269			1.43	5.49	10.8	29.4	
	9	2.98	504	1032	9043	699	904021		3.06	12.9	20.8	47.1	
	10	4.26	248	2792	2792	1120	13802		0.37	0.55	0.08	11.85	
Mean		3.904	313.92	1953.1	3185.4	33108.9	115415.82	3638	1.022	5.285	9.843	45.796667	26.9

The Root mean Square errors for the analysis were found to be very low with an average of 3.90 (Table 2). This underscores the reliability of the analysis tool for this type of work.

Figs. 4-13 also show the various number of geoelectric layers expected in the subsurface as outlined in Table 2. The table shows the geoelectric layers penetrated at each VES location.

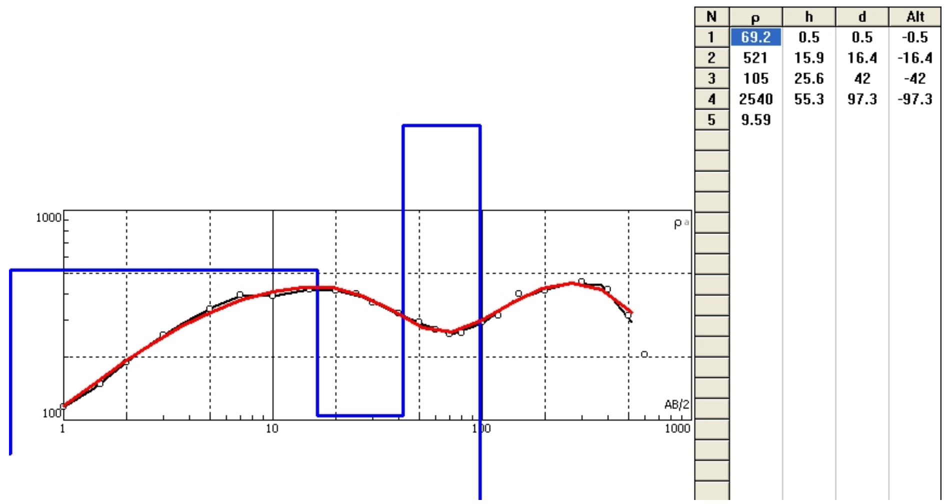


Fig. 4. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 1

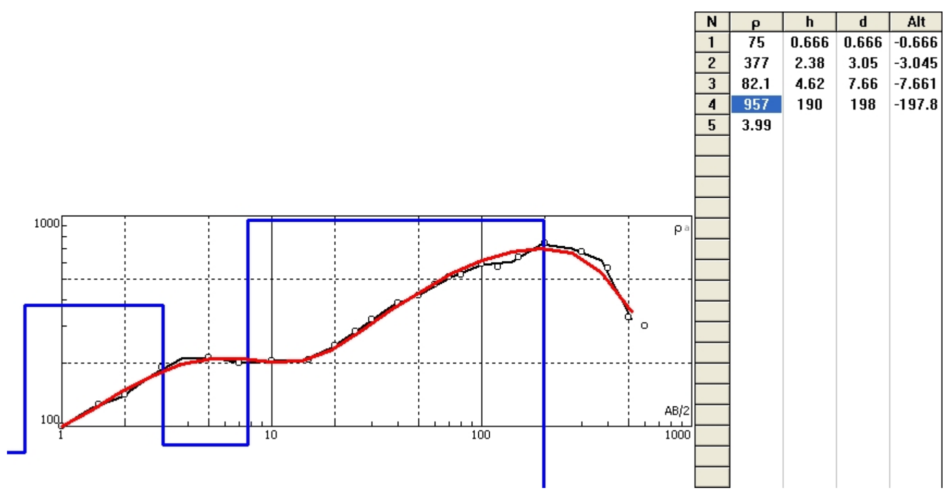
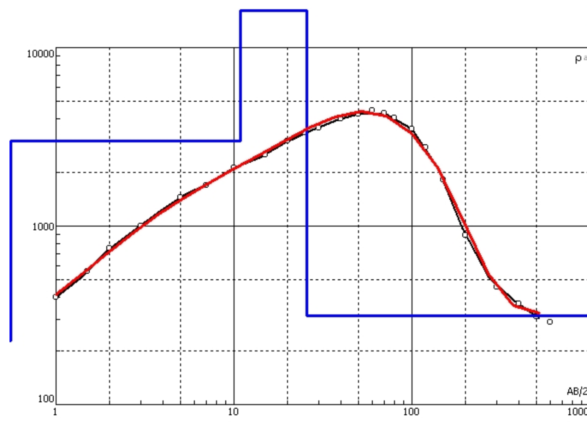
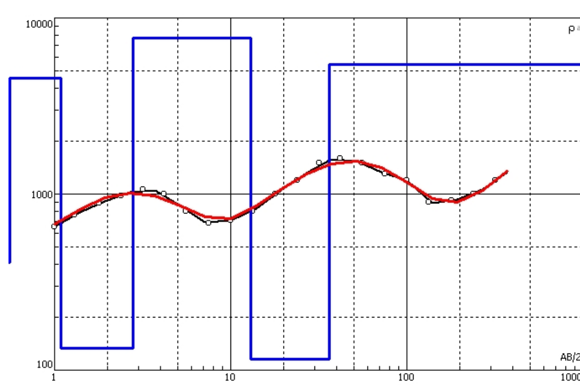


Fig. 5. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 2



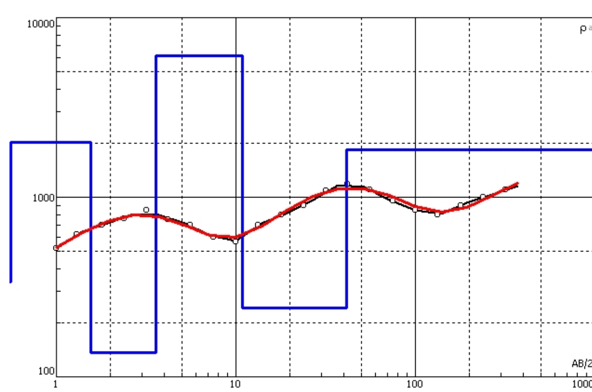
N	ρ	h	d	Alt
1	227	0.5	0.5	-0.5
2	2992	10.4	10.9	-10.9
3	16076	14.9	25.8	-25.77
4	313			

Fig. 6. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 3



N	ρ	h	d	Alt
1	409	0.5	0.5	-0.5
2	4531	0.585	1.09	-1.085
3	133	1.71	2.79	-2.792
4	7666	10.1	12.9	-12.93
5	116	23.3	36.2	-36.24
6	5448			

Fig. 7. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 4



N	ρ	h	d	Alt
1	336	0.5	0.5	-0.5
2	2011	1.06	1.56	-1.56
3	136	2.03	3.59	-3.59
4	6157	7.22	10.8	-10.81
5	241	30.5	41.3	-41.31
6	1828			

Fig. 8. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 5

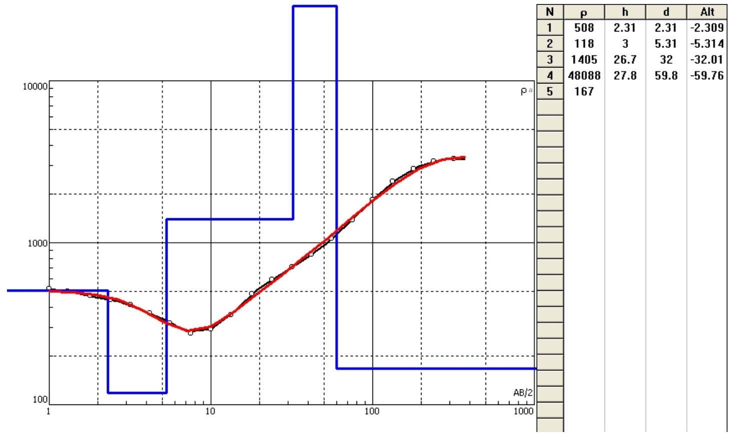


Fig. 9. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 6

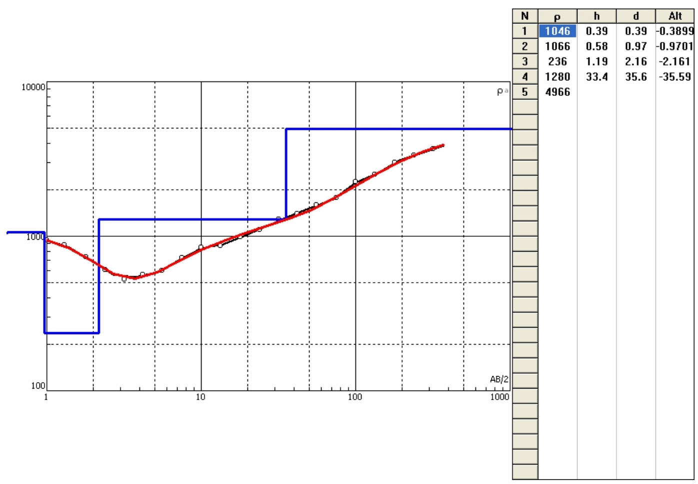


Fig. 10. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 7

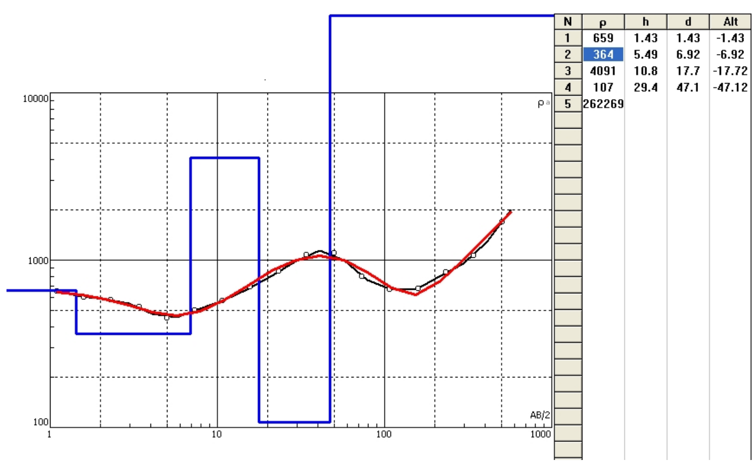


Fig. 11. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 8

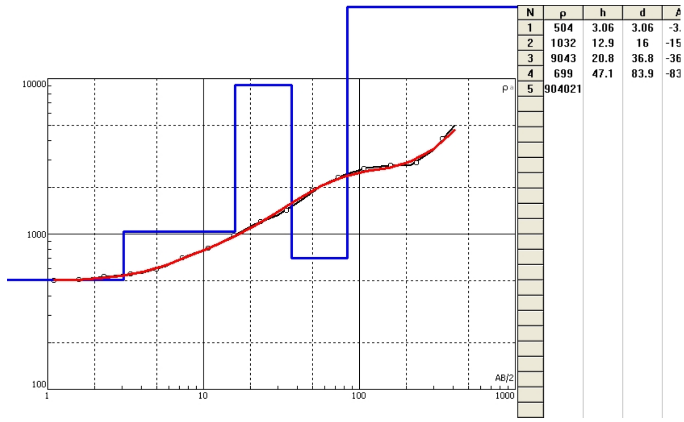


Fig. 12. Typical depth sounding curve showing synthetic curve (Red) at Anyigba Post office VES 9

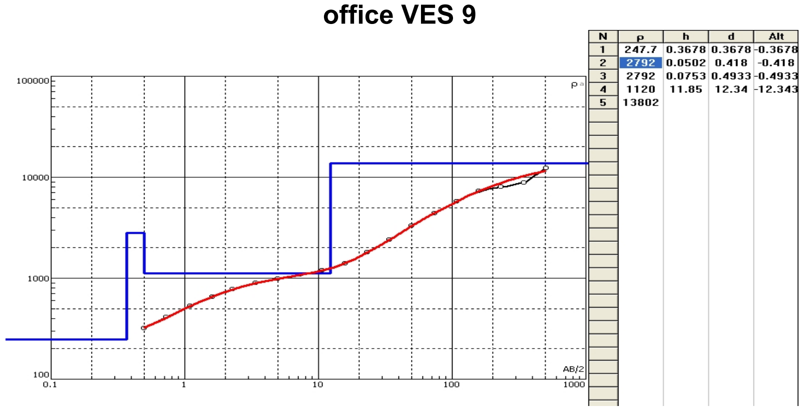


Fig. 13. Typical depth sounding curve showing synthetic curve (Red) Anyigba VES 10

The mean thickness and resistivity of the geoelectric layers for all the sounding locations have been calculated and are presented in Table 3.

The study reveals the presence of six geoelectric layers within the study area. These geoelectric layers have been identified with lithologic type using lithology logs obtained from boreholes drilled in the study area and standard rock resistivity charts.

Table 3. Geoelectric layer Parameters and the interpreted lithologic types

Number of Geoelectric Layers	Mean thickness of Geoelectric Layers (m)	Mean depth of Geoelectric Layers (m)	Mean resistivity of Geoelectric Layers (Ωm)	Lithologic type
1	1.022	1.022	313.92	Lateritic top soil
2	5.285	6.307	1953.1	Lateritic sand
3	9.843	16.250	3185.4	Unsaturated sandstone
4	45.8	62.05	33108.9	Unsaturated sandstone
5	26.9	88.95	115415.82	Partly saturated sandstone
6			3638	Saturated sandstone unit

The fifth and sixth geoelectric layers constitute the main aquifer units within the study area.

4. CONCLUSION

The aquifer units in Anyigba and environs of the Anambra basin have been delineated using the Vertical Electrical Sounding survey technique.

The aquifer units in the study area consist of the partly saturated sandstone and fully saturated sandstone units corresponding to the fifth and sixth geoelectric layers of the VES curves respectively. These layers occur at mean depths of 88.95m and beyond. It is therefore recommended that the minimum depth for successful borehole yields in the study area should be about 100m.

COMPETING INTERESTS

Authors declare that there are no competing interests.

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Peer-review history:
The peer review history for this paper can be accessed here:
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