Groundwater Exploration in Parts of Enugu East Local Government Area, Enugu state, Nigeria.

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Abstract
Groundwater exploration has been carried in some part of Enugu East LGA, Enugu State, Southeastern Nigeria. The electrical resistivity method was utilized, employing the Schlumberger configuration technique. The area is underlain by Enugu Shale. A total of twelve (12) Vertical Electrical Sounding (VES) was acquired within the study area, employing the Schlumberger configuration. Interpreted VES data show clay/shale lithologies, with thin sandy laminar up to depth of 120meters. Predominance of KQH curve type indicates possible fracture – shale subsurface. Contour maps of layer aquifer resistivity, depth and thickness show variations of the interpreted model parameters. The various contour maps will serve as a useful guide for groundwater exploration in the study area.
Keywords: Aquifer Resistivity, Lithology, Curve type, Contour maps, VES, Groundwater.

Introduction

Most towns in Enugu East local government area are the fastest growing rural cities around the Enugu city capital. In recent times, there has been a geometrical rise in population growth and therefore a high demand for adequate and good quality water supply. Surface water sources and water bodies; Ekulu, Iyioku rivers and Nike and Kporoko lake. Hand dug wells largely exists in the study area. Due to its contaminations and seasonal fluctuation, gave rise to the community and habitants, of the area to rely on Groundwater exploration and exploitation of groundwater, which is one of the most valuable and reliable natural resources in the area. As it is vital in sustenance of life, both in domestic use, Irrigation and Industry. In the present study, attempts have been made to investigate the underlying rocks in the study area for deeper groundwater prospects for sustainable abstraction.

Location and Physiography

The study is located in the Eastern parts of Enugu state, Nigeria. (Figure 1). The area is characterized by undulating topography with an elevation of 223 meters above sea level (Figure 2). It has its boundary in the North by Isiuzo L.G.A, South by Awgu / Aniri LGA, West by Nkanu west L.G.A, East by Ebonyi state government, as it lies within the rain forest belt of Nigeria. Two main seasons exist in Nigeria, the dry season, which runs through the month of October to March and rainy season which begins in March to October. The average monthly rainfall for 30years period ranges from less than 1mm in the dry season, to about 30mm in the rainy season. The wet periods characterized by moderate temperature to lower relative humidity, while dry periods have high temperature and lower relative humidity.

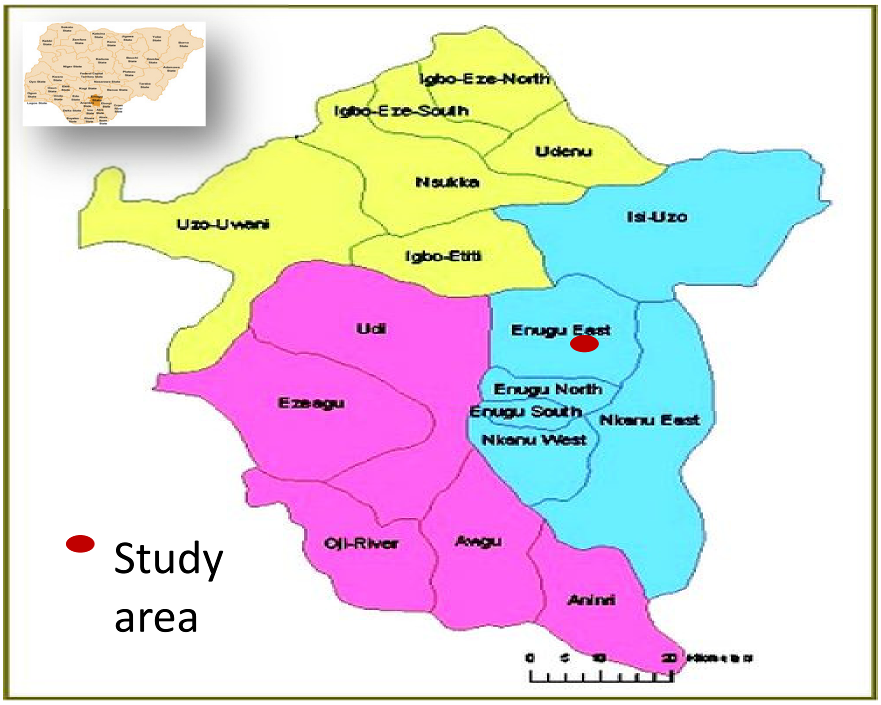


Figure 1: Map of Enugu state showing location of the study area (Insert: map of Nigeria). (World Gazette, 2011).

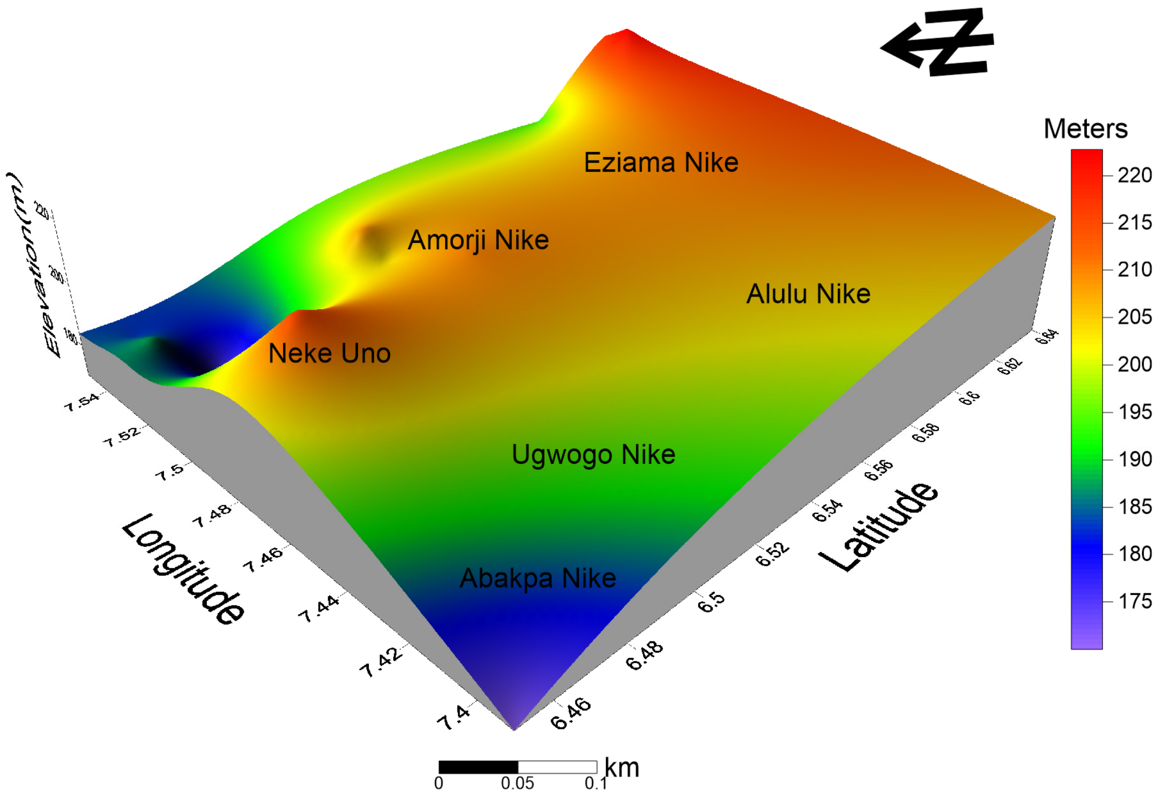


Figure 2: Surface map of the study area.

Geology

The study area lies on the Campano-Maestrichtian sediment of South-Eastern Nigeria (Figure 3), called the Enugu Shale (Reyment, 1965). This rock unit is made up of dark grey, fissile shale with occasional thin beds of Siderite and Mudstone. Nkporo Shale is the lateral equivalent of Enugu Shale. The estimated maximum thickness of Nkporo Shale is over 500meters. Early workers described it as soft grayish blue shales with frequent bands of clay ironstone. These shales weather rapidly to a red or pinkish clay soil or laterite with concretions. The shale is well exposed in River Asata and Ogbete. They pass up gradually into the Lower Coal measures and the passage zone between the formations corresponds with the foot of the Escarpment or Udi Hill which forms the scenic hill flanking in the west.

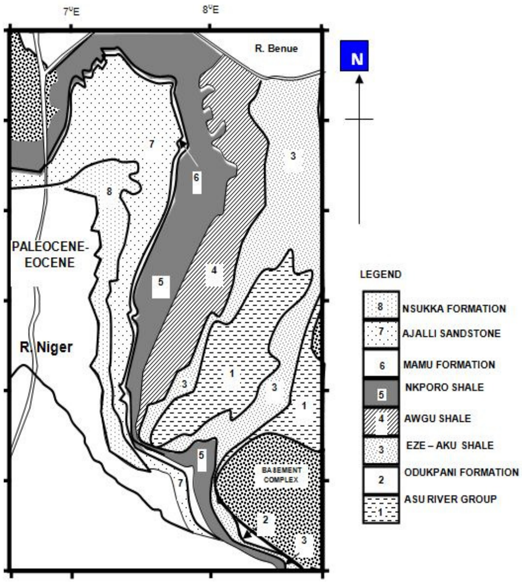


Figure 3: Regional geologic map of South Eastern Nigeria. (Nwajide, 1990).

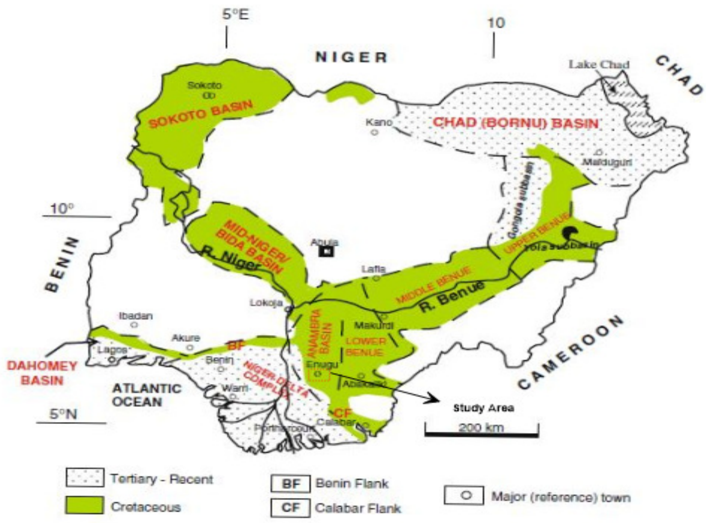


Figure 4: Map of Sedimentary Basin of Nigeria showing the Study area (Obaje, 2009).

Hydrogeology

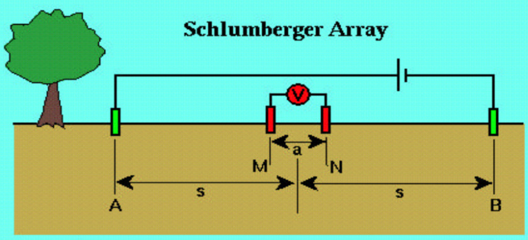
The study area falls within the Anambra Basin (Figure 4). The Anambra Basin appears to represent an inverted triangular depression with its base along the Benue river axis, and its apex pointing towards Onitsha on the main trunk of the River Niger (Offordile, 2012). The basin consists of Campanian to Tertiary geological formations, with Enugu Shale being the oldest from the base. The Enugu Shales consist essentially of clay, shale and siderites, and as a result is an aquiclude or aquitard. Of the various geological material that occur in the area, the fracture zone in Enugu Shale, contributes to have the potential of being significant Aquifer in the area, with other unit which constitute of more shale and mudstone. The area is being overlain by Mamu Formation (Reyment 1965), which also contributed to its prominent ground water flow.

Theory and Method

The electrical resistivity method is utilized in diverse ways for groundwater exploration (Zohdy, 1976; Choudhury, et al, 2001; Frohlich and Urish, 2002). Electrical surveys are usually designed to measure the electrical resistivity of subsurface materials by making measurements at the earth surface. Current is introduced into the ground by a pair of electrodes, while measuring the subsurface expression of the resulting potential field with an additional pair of electrodes at appropriate spacings.

Data Acquisition and Processing

A total of Twelve (12) vertical electrical sounding (VES) was acquired within and outside the study area. Some were stationed very close to existing boreholes, for correlation purposes. The Schlumberger



$$\rho_a = \frac{\pi(s^2 - a^2/4)}{a}\frac{\Delta V}{i}$$

Figure 5: Schlumberger Array and apparent resistivity formula (Burger, 1992).

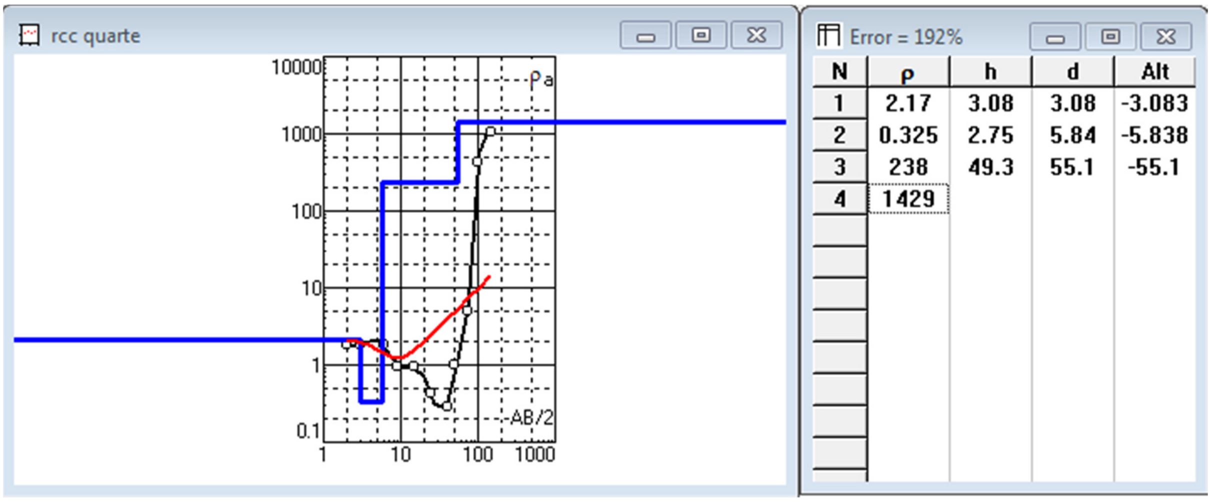
electrode configuration (Figure 5) was used with maximum current electrode separation ranging from 300m to 400m. After acquiring the data, the measured field resistance (R) in ohms was converted to apparent resistivity (ρ_a) in ohm-meter by multiplying resistance (R) by the geometric factor (K). A log-log graph plot of apparent resistivity (ρ_a) against current electrode distance (AB/2) was plotted for each VES station to generate a sounding curve. Using the conventional partial curve matching technique, in conjunction with auxillary point diagrams (Orellana and Mooney, 1966; Koefoed, 1979; Kellar and Frischknecht, 1966), layer resistivities and thickness were obtained, which served as a starting point for computer-assisted interpretation. The computer program IPI2WIN was used to interpret all the data sets obtained. Surfer *version 10* contouring toolkits were used to generate the contour maps.

Data Interpretation

The form of curves (Figures 6-17), obtained by sounding over a horizontally stratified medium is a function of the resistivity and thickness of the layers as well as the electrode configuration (Zohdy, 1976). The resistivity curve type associated with the study area from VES 1-12 include: HA, KQH, QH, QHA, QHA, KQH, KKH, KHK, HQH, HQKH, HHAA, and QHQ curve types respectively (Table 1). The first dominant curve type is Q. This is indicating a shaly terrain. The H curve type is the second dominant. In the multi-layer system, the frequency plot distributions of the curve types in the study area show that KQH dominates (Figure 18). This also indicates fractured shale horizons which are targets for groundwater exploration.

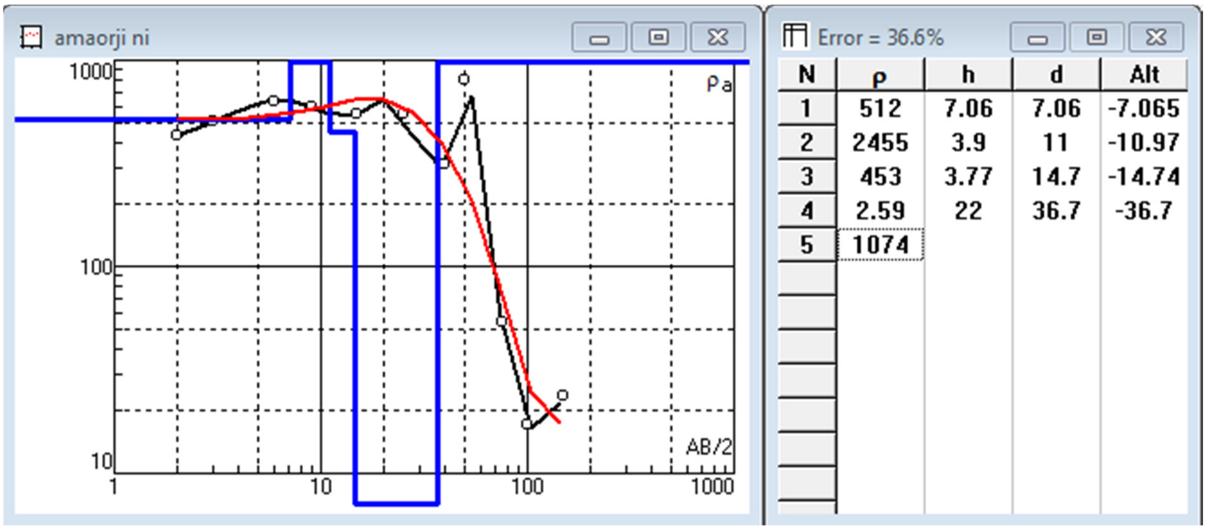
Table 1. Summary of Interpreted layer model and curve types.

S/N	LOCATION	VES NO	NL	ρ_1	ρ_2	ρ_3	ρ_4	ρ_5	ρ_6	ρ_7	ρ_8	Aquifer Thickness(m)	Aquifer Depth(m)	Curve type
1	RCC QUARTERS	1	4	2.17	0.325	238	1429	-	-	-	-	49.3	55.1	HA
2	AMORJI NIKE	2	5	512	2455	453	2.59	1074	-	-	-	22	36.7	KQH
3	AIRPORT EXTENSION, EMENE	3	4	605	225	3.92	65.3	-	-	-	-	5.07	12.3	QH
4	PHASE SIX T/EKULU	4	6	719	169	109	1.49	14.8	329	-	-	14.7	65.3	QHA
5	ALULU NIKE	5	6	1532	108	33.4	3.78	280	722	-	-	33.5	86.3	QHA
6	ABAKPA NIKE	6	6	60	537	24.4	214	0.699	73	-	-	26.8	58.3	KQH
7	NWANNEDINAMBA	7	6	135	500	3.4	265	4.47	1250	-	-	15.3	23.8	KKH
8	EZIAMA NIKE	8	7	104	759	209	600	32.9	409	23.9	-	7.56	19.00	KKHK
9	NEKE UNO	9	8	104	4.84	321	34.5	3.46	1.97	0.265	652	5.99	19.5	HQQH
10	UGWOGO NIKE	10	8	104	27.6	684	125	2.14	5.42	3.86	652	13.6	34.1	HQKH
11	DESTINY LAYOUT	11	7	891	2.8	94.5	2.35	63.3	330	2920	-	7.99	25.7	HHAA
12	THINKERS CORNER	12	7	570	728	57.6	9.72	7042	218	2920	-	119	144	QHQ



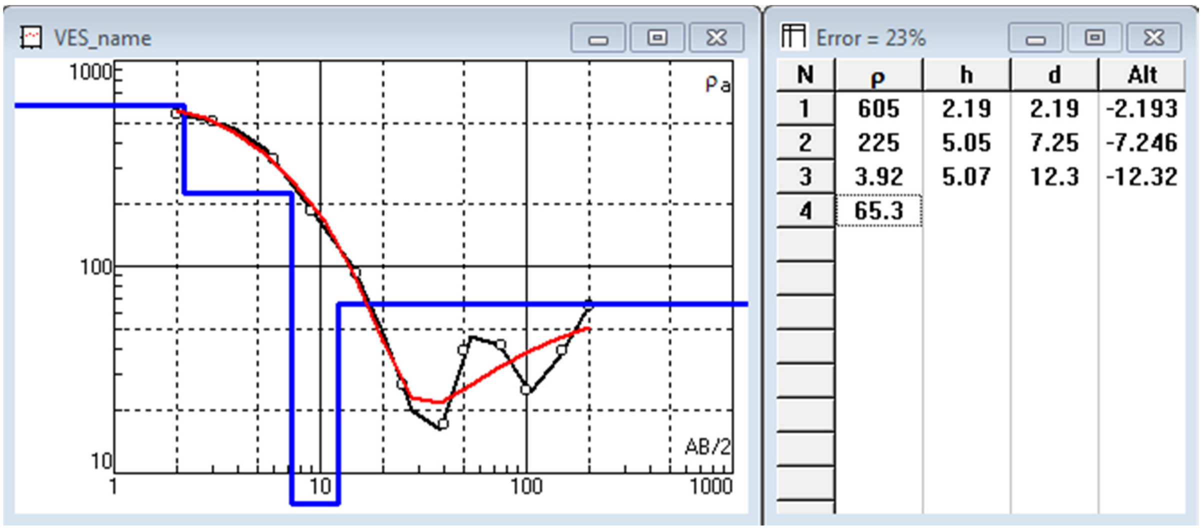
N	ρ	h	d	Alt
1	2.17	3.08	3.08	-3.083
2	0.325	2.75	5.84	-5.838
3	238	49.3	55.1	-55.1
4	1429			

Figure 6: Resistivity Curve. VES 1



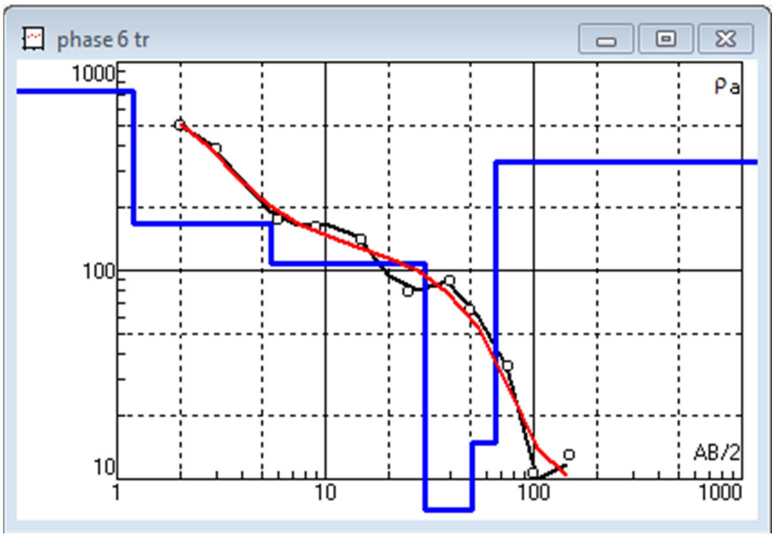
N	ρ	h	d	Alt
1	512	7.06	7.06	-7.065
2	2455	3.9	11	-10.97
3	453	3.77	14.7	-14.74
4	2.59	22	36.7	-36.7
5	1074			

Figure 7: Resistivity Curve. VES 2



N	ρ	h	d	Alt
1	605	2.19	2.19	-2.193
2	225	5.05	7.25	-7.246
3	3.92	5.07	12.3	-12.32
4	65.3			

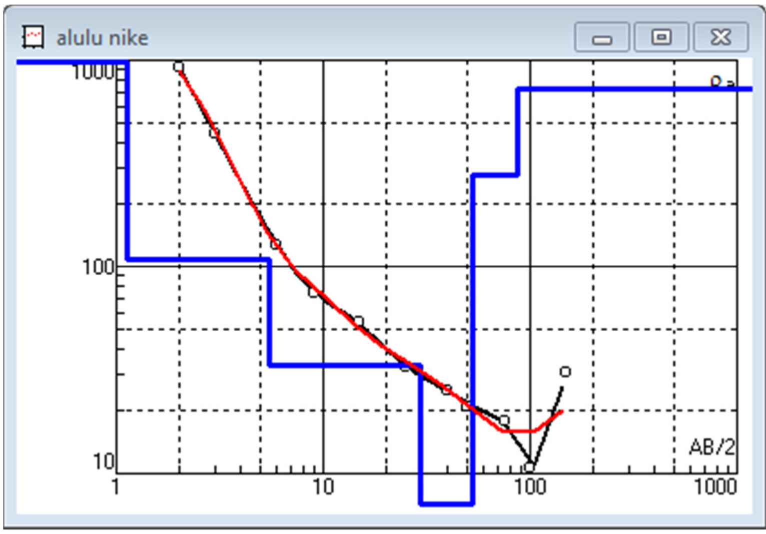
Figure 8: Resistivity Curve. VES 3.



Error = 14.8%

N	ρ	h	d	Alt
1	719	1.19	1.19	-1.195
2	169	4.29	5.49	-5.489
3	109	24.5	30	-29.95
4	1.49	20.7	50.6	-50.63
5	14.8	14.7	65.3	-65.34
6	329			

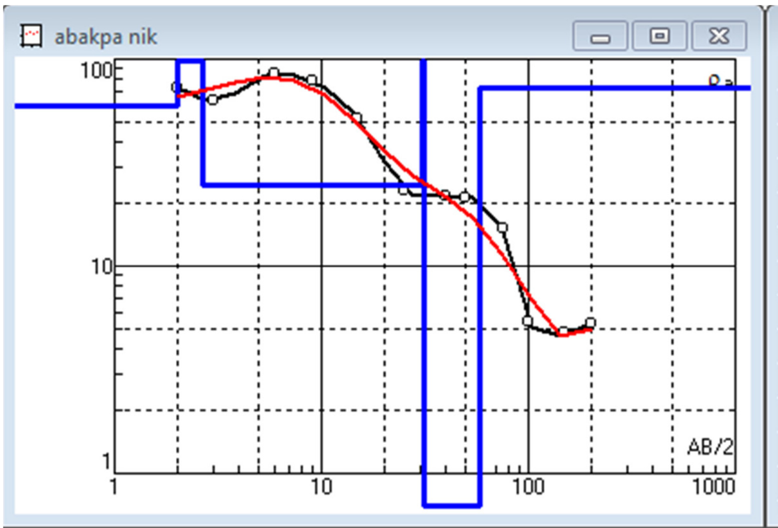
Figure 9: Resistivity Curve. VES 4.



Error = 13.1%

N	ρ	h	d	Alt
1	1532	1.13	1.13	-1.133
2	108	4.4	5.54	-5.537
3	33.4	24	29.5	-29.51
4	3.78	23.3	52.9	-52.85
5	280	33.5	86.3	-86.34
6	722			

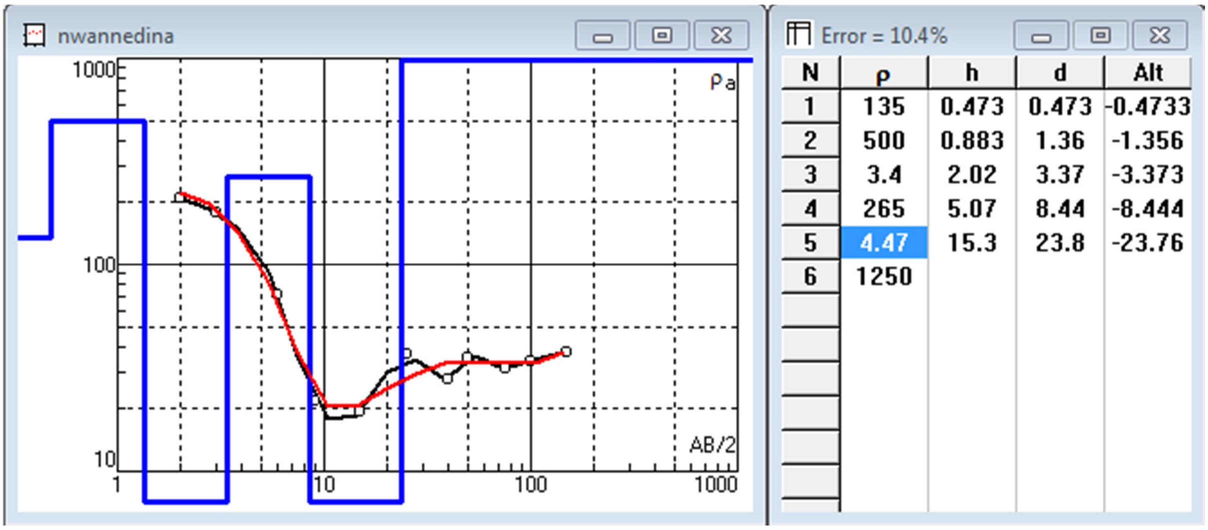
Figure 10: Resistivity Curve. VES 5.



Error = 15.4%

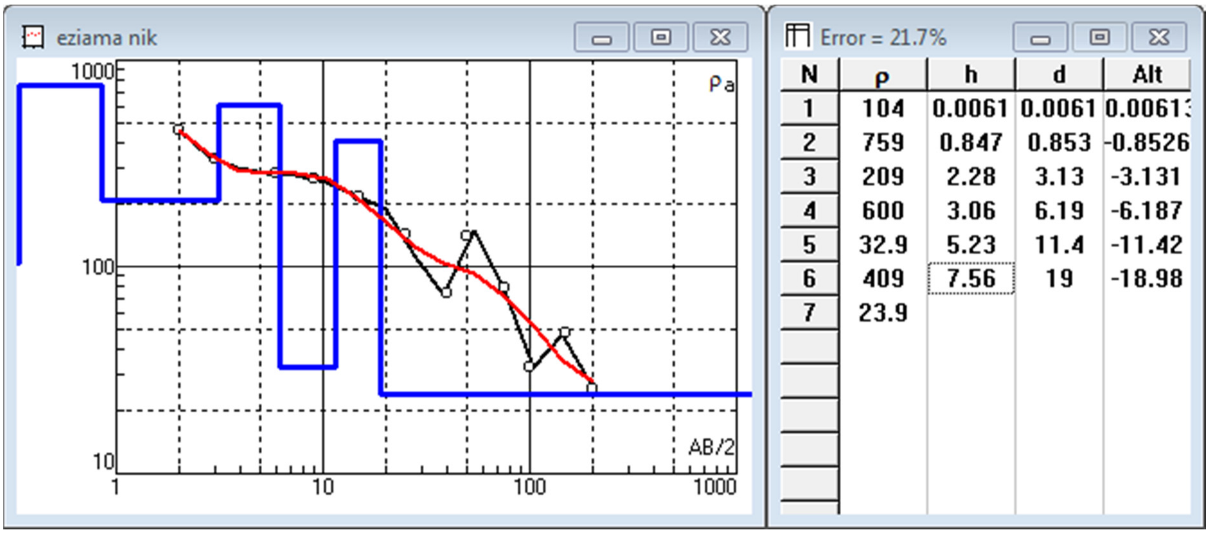
N	ρ	h	d	Alt
1	60	2.02	2.02	-2.018
2	537	0.646	2.66	-2.665
3	24.4	28.1	30.8	-30.81
4	214	0.754	31.6	-31.57
5	0.699	26.8	58.3	-58.33
6	73			

Figure 11: Resistivity Curve. VES 6.



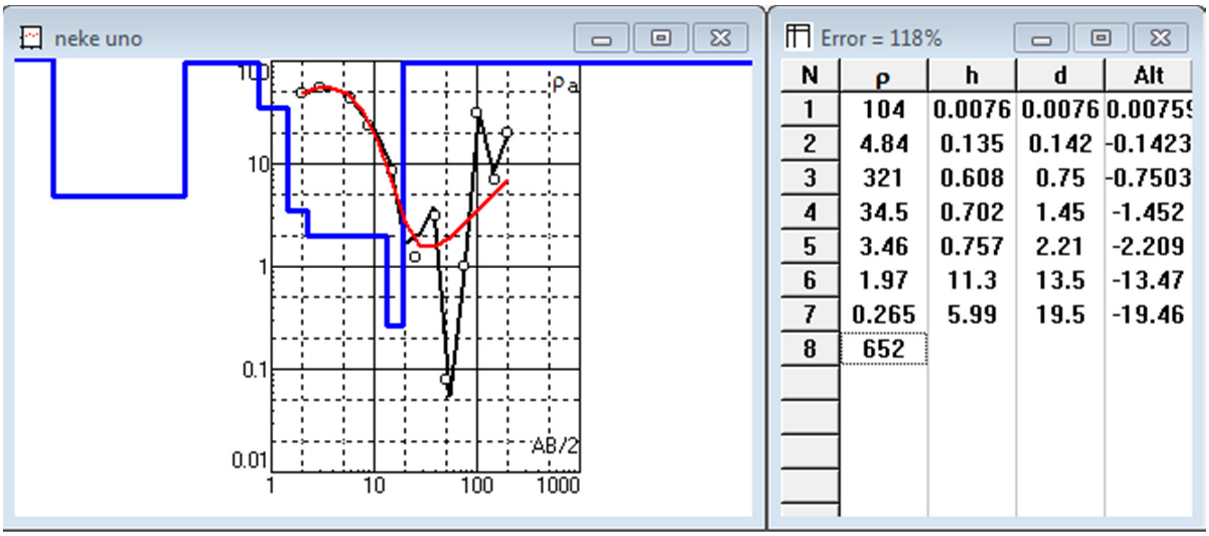
N	ρ	h	d	Alt
1	135	0.473	0.473	-0.4733
2	500	0.883	1.36	-1.356
3	3.4	2.02	3.37	-3.373
4	265	5.07	8.44	-8.444
5	4.47	15.3	23.8	-23.76
6	1250			

Figure 12: Resistivity Curve. VES 7.



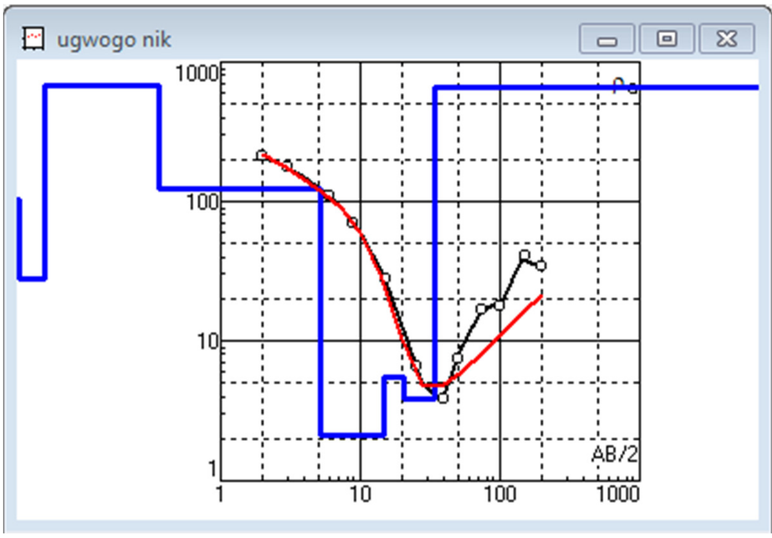
N	ρ	h	d	Alt
1	104	0.0061	0.0061	0.00613
2	759	0.847	0.853	-0.8526
3	209	2.28	3.13	-3.131
4	600	3.06	6.19	-6.187
5	32.9	5.23	11.4	-11.42
6	409	7.56	19	-18.98
7	23.9			

Figure 13: Resistivity Curve. VES 8.



N	ρ	h	d	Alt
1	104	0.0076	0.0076	0.00759
2	4.84	0.135	0.142	-0.1423
3	321	0.608	0.75	-0.7503
4	34.5	0.702	1.45	-1.452
5	3.46	0.757	2.21	-2.209
6	1.97	11.3	13.5	-13.47
7	0.265	5.99	19.5	-19.46
8	652			

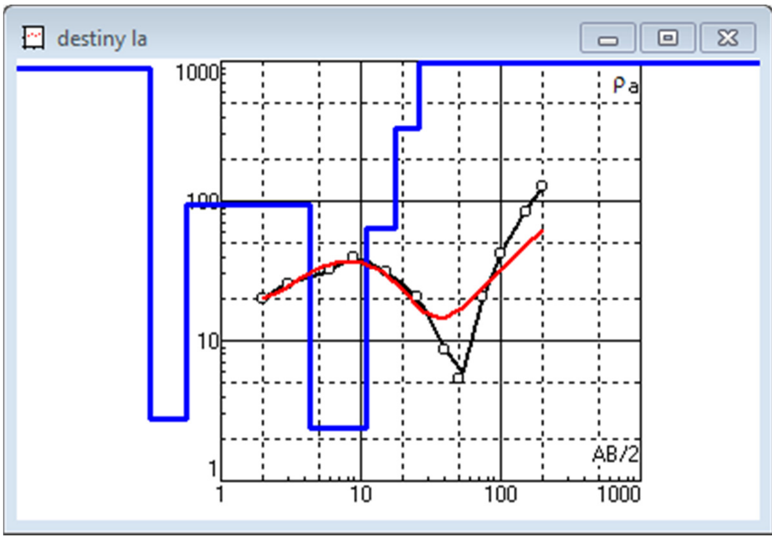
Figure 14: Resistivity Curve. VES 9.



Error = 37.4%

N	ρ	h	d	Alt
1	104	0.0076	0.0076	0.00759
2	27.6	0.0474	0.055	-0.055
3	684	0.304	0.359	-0.3591
4	125	4.77	5.13	-5.13
5	2.14	9.59	14.7	-14.72
6	5.42	5.78	20.5	-20.5
7	3.86	13.6	34.1	-34.08
8	652			

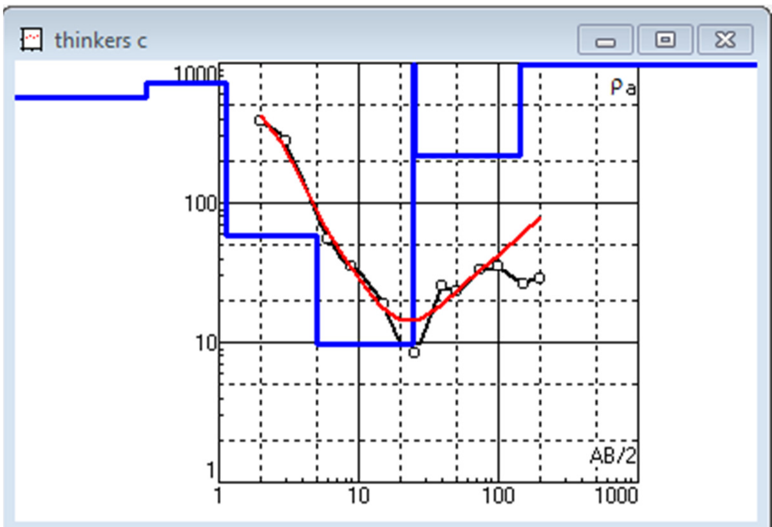
Figure 15: Resistivity Curve. VES 10.



Error = 39.4%

N	ρ	h	d	Alt
1	891	0.313	0.313	-0.3134
2	2.8	0.252	0.565	-0.5651
3	94.5	3.71	4.27	-4.272
4	2.35	6.71	11	-10.98
5	63.3	6.72	17.7	-17.7
6	330	7.99	25.7	-25.69
7	2920			

Figure 16: Resistivity Curve. VES 11.



Error = 37.8%

N	ρ	h	d	Alt
1	570	0.303	0.303	-0.3026
2	728	0.839	1.14	-1.142
3	57.6	3.85	4.99	-4.989
4	9.72	19.5	24.5	-24.53
5	7042	0.632	25.2	-25.16
6	218	119	144	-144.1
7	2920			

Figure 17: Resistivity Curve. VES 12.

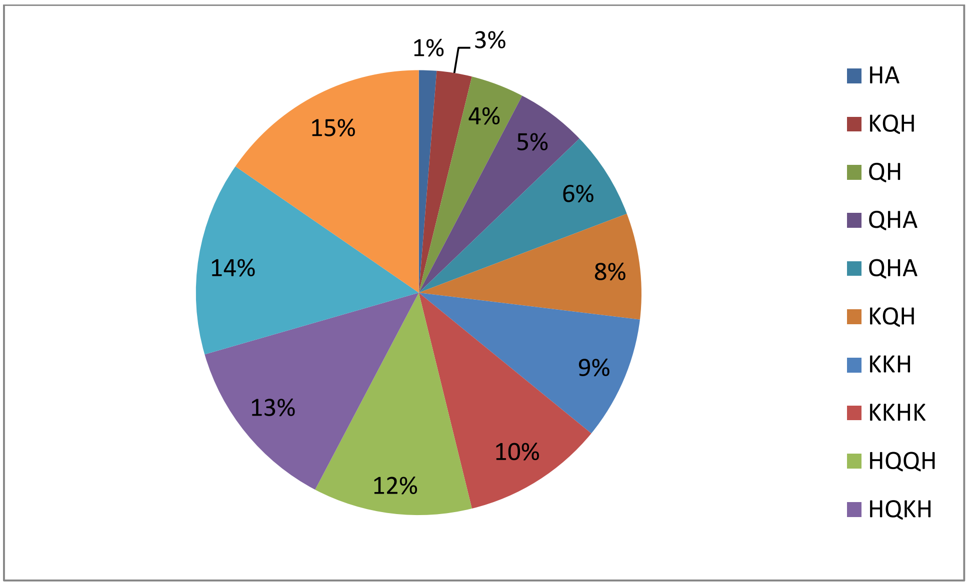


Figure 18. Curve type frequency distribution in the study area.

Results and Discussion

The Resistivity method is well known for its suitability in groundwater exploration. Key features of its suitability are quality signal resolution and great depth of probe. In the study area, contour maps of apparent resistivity, the Isopach and the depth of the aquiferous horizon have been constructed, using the results of the resistivity sounding interpretation.

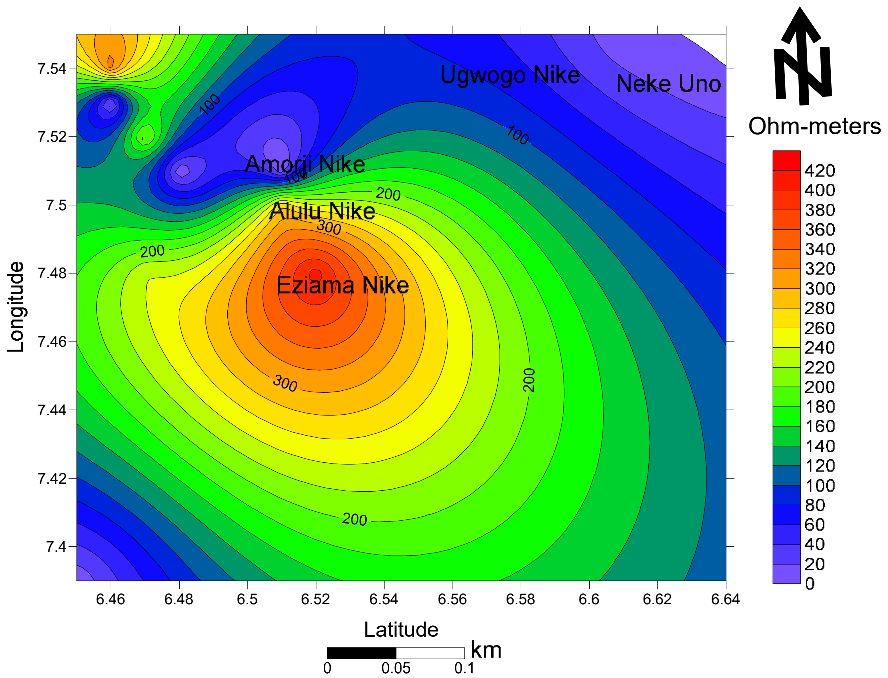


Figure 19: Aquifer resistivity map of the study area.

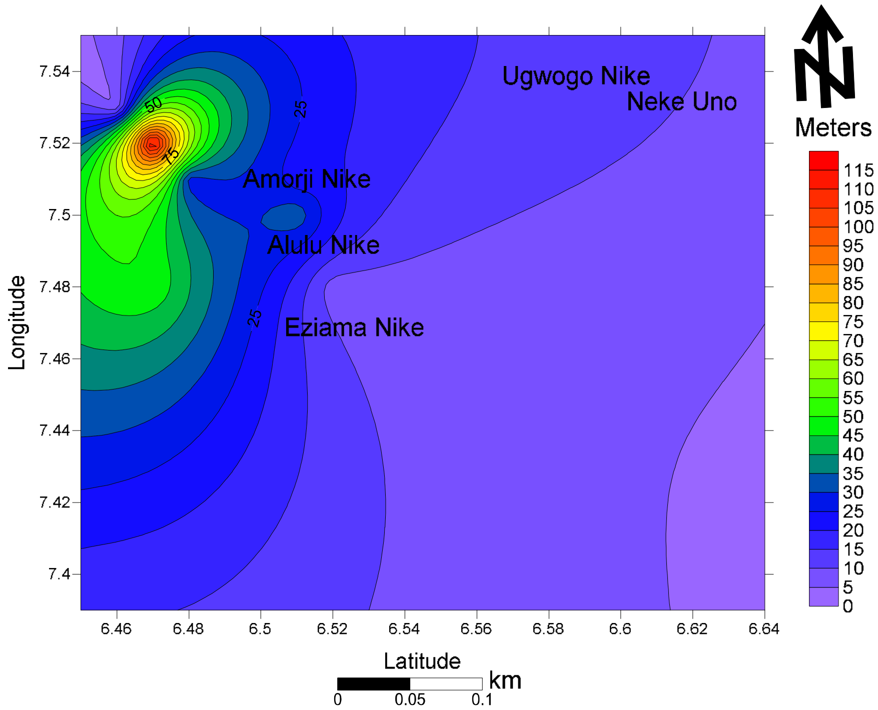


Figure 20: Aquifer Isopach map of the study area.

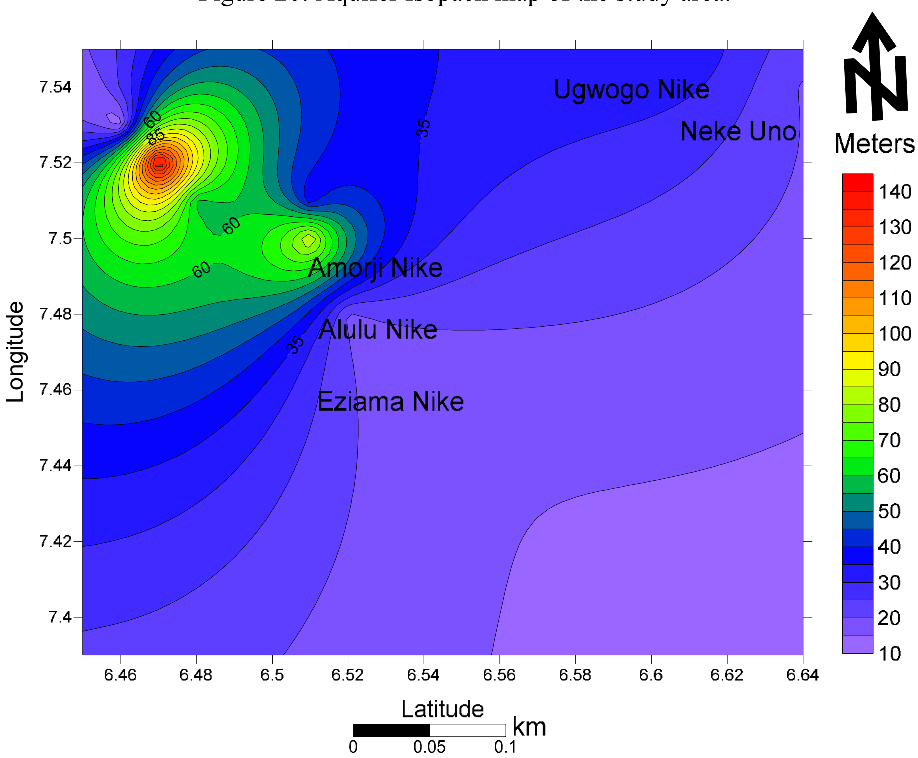


Figure 21: Aquifer depth map variation of the study area.

Aquifer resistivity map (Figure 19) show layer aquifer resistivity variations across the study area at a maximum depth of 120meters (Figure 20). The aquifer resistivity varies significantly in the study area. A general anomaly trend exists NW-SE direction (Figure 19). At Eziama Nike, and Alulu Nike, resistivity anomaly occur (Figure 19) at depths of 30 and 40meters respectively (Figure 20). Aquifer depth variation is a function of topography (Okonkwo and Ezeh, 2013). Based on the geology (Reyment, 1965) and conventional rock resistivities (Figure 22), the study area is underlain predominantly by clay/shale, with sandy laminar. Low resistivity areas mostly trend roughly NE-SW, with resistivity range of 20-100Ωm. Towns within this area are Ugwogo-Nike, Neke Uno and Amorji Nike. Aquifer thickness map (Figure 21) show variation of aquifer layer resistivity and thickness across the study area.

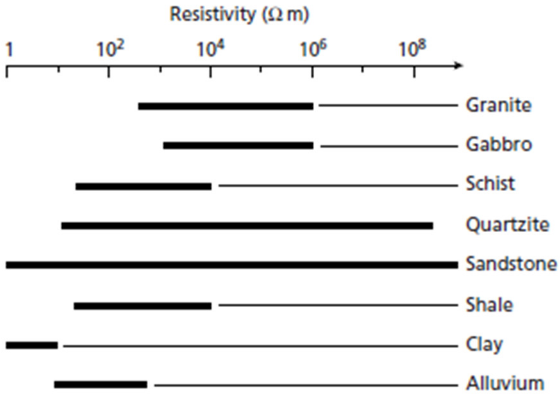


Figure 22: The approximate range of resistivity values of common rock types (Kearey, *et al*, 2002).

Conclusion

The interpreted resistivity layer models indicate that the study area is underlain by relatively low resistivity rocks, which have been deduced to be clay/shale, with subordinate sandy laminar. Based on the multi-layer curve type frequency distribution, KQH curve type predominates. Contour maps of Aquifer layer resistivity, thickness and depth were constructed to show variation of resistivity informations across the study area. The contour map can be comparable for a sustainable groundwater development in the study area. The study has therefore provided a clearer understanding of the nature of the subsurface rocks and groundwater system at the study area.

References

Burger HR (1992). Exploration Geophysics of the shallow subsurface. Prentice-Hall, Englewood Cliffs. 489p.

Choudhury K, Saha DK, Chakraborky P (2001). Geophysical study for saline water intrusion in a Coastal alluvial terrain. Jour. Of Applied Geophysics. Vol 46. p189-200.

Frohlich RK, Urish D (2002). The use of geoelectrics and test wells for the assessment of Groundwater quality of a coastal industrial site. J. Applied geophysics. Vol 46. p261-278.

Kearey P, Brooks M, Hill I (2002). An introduction to geophysical exploration. Blackwell science. 3rd Edition. 262p.

Keller GV, Frischknecht FC (1966). Electrical methods in geophysical prospecting. Pergamon Press.

Koefoed O (1979). Geosounding principles, 1 Elsevier, Amsterdam.

Nwajide CS (1990). Sedimentation and Paleography of the Central Benue Trough, Nigeria, in C.O. Ofoegbu, Ed. The Benue Trough structure and Evolution viewg. Braunchweig. P19-38.

Obaje NG (2009). Geology and Mineral Resources of Nigeria. Springer Dordrecht Heidelberg London New York.

Offodile ME (2002). Groundwater study and development in Nigeria. 2nd Edition. Mecon geology And Engineering services Ltd. Jos, Nigeria. 453p.

Orellana E, Mooney HM (1966). Master tables and curves for vertical electrical sounding over Layered structures. Interscience, Madrid.

Reyment RA (1965). Aspects of the geology of Nigeria. Ibadan University press.

World Gazette (2011). Colourful map of Nigeria with 36 states. www.world-gazette.com.

Zohdy AAR (1976). Application of surface geophysical (electrical methods to groundwater Investigations) techniques of water resources investigations of the united states geological Survey. p5-55.