Asian Journal of Applied Sciences (ISSN: 2321 – 0893)
Volume 03 – Issue 01, February 2015

Delineation of Aquifer Potential and Lithology from Geo-Electric Sounding in Idheze, Isoko North LGA of Delta State

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ABSTRACT--- ***A geophysical survey was carried out using Vertical Electrical Sounding (VES) adopting Schlumberger configuration in Idheze community Isoko North LGA, of Delta State. Seven Vertical Electrical Sounding were carried out with a view to study the lithology and aquifer characterization of the area. The model parameters for the whole locations show four or five distinct geoelectric layers with VES 1, 3, and 5 having four geoelectric layers while VES 2, 4 ,6 and 7 have five geo-electric layers. The four geoelectric layers have the aquiferous positions in the third layer while the five layers earth have the aquiferous positions in the fourth layer. The lithology is made of lateritic top soil, clay, sandy clay, fine sand, smooth medium sand and coarse sand. The study further shows that the seven locations have good aquifer transmissivity and Boreholes could be constructed in any of the VES locations. Location 3 has be mapped as having the best aquifer transmissivity of 251m^2/day while VES 6 has the least with aquifer transmissivity of 161.0m^2/day.***

Keywords--- Transmissivity**,** Resistivity, Idheze, Geo-electric Sounding, lithology, aquifer parameters

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1. INTRODUCTION

A geophysical survey method using the Vertical Electrical Sounding (VES) has been conducted adopting the Schlumberger configuration in Idheze Community, Isoko North Local Government Area of Delta State, Nigeria.

Idheze lies between latitude 05^0 30.75^{1}N and 05^0 29.38^{1}N and longitude 06^0 16^{1}E and 60 18^{1}E. It is very assessable with good roads linking it with Ozoro, Oyede, Irri and other communities.

The topography of Idheze is relatively flat having gentle slope close to the bank of the river. The area is of lowland without mountains and hills. The climate of the area is made up of wet and dry season with the rainy season starting from April and October while the dry season commences from November and end in March. The vegetation is of the rain forest.

Groundwater could be understood to mean water which occupies all the voids within a geologic stratum. There exists saturated and unsaturated zones. The saturated zone is zone where voids are filled with water and air (Todd, 1980). Water in this zone is important in engineering works, water supply development and geologic studies. Water in the unsaturated zones is found above the saturated zone which are further extended upward to the surface on the ground. In form soil moisture within the root zone making, making it very important for agriculture, botany, and soil science.

The proportion of groundwater use to total water use has been on the increase within Idheze community. This is because the area is fast growing in population as a result of the area being an oil producing community. These have attracted industrialization, more schools such as polytechnic at Ozoro and other commercial activities (Egbai, 2011).

The objective of this work is to carry out detailed geophysical and hydrogeological survey of Idheze to determine area where borehole could be sited to avoid abortive and unproductive boreholes. The study will help in the determination of the depth and thickness of the aquifer and the lithological set up of Idheze community.

Aquifer is a geological formation that contains sufficient saturated permeable materials capable of yielding significant quantities of water to springs and wells (Etuk-Efeoto *et al*, 1980, Ako and Osondu 1985, Egbai, 2011, 2012).

The VES method was chosen for the study because the instrumentation is simple, field logistics are easy and straight forward and the analysis of data is less tedious and economical (Zohdy *et al* 1974,Zohdy and Martin, 1993, Keller and Fristhenecht, 1996 and Egbai, 2011).

2. METHODOLOGY AND DATA ACQUISITION

The Schlumberger configuration was adopted with the maximum current electrode of 500m, which was sufficient in allowing depth penetration of 112m. The field procedure involves the expansion of the current electrodes successively while the potential electrodes remain fixed. Hence, there is a decreasing potential difference across the potential electrodes. At this point a new value for the potential electrodes separation is selected typically 2 to 5 times larger than the preceding value and survey is continued (Egbai, 1998). An increase in current electrode spacing results in a deeper penetration of the electric field and a different apparent resistivity is obtained.

The diagram for the Schlumberger arrangement is as shown in Fig 1. The Terrameter SAS 1000 model with inbuilt booster was used for data acquisition.

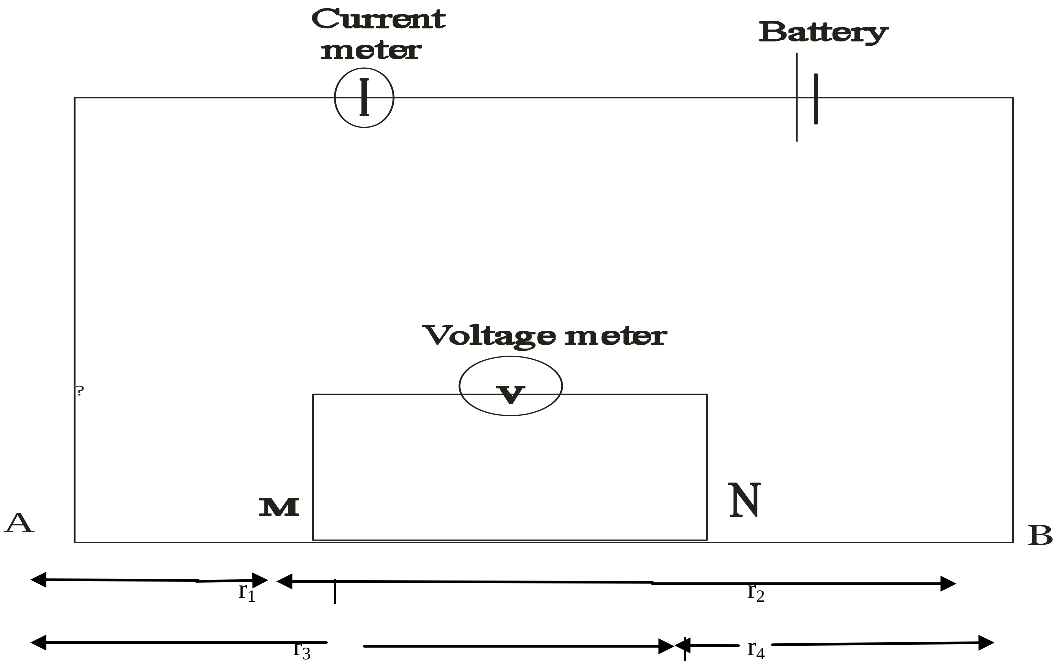

Figure 2: Schlumberger Configuration

The Schlumberger configuration has the potential electrodes close together. The apparent resistivity is given by

$$\rho_a = \frac{\pi(^L/_2)^2 - (^b/_2)^2}{b}\,\frac{V}{I}$$

where L= current electrodes

b= potential electrodes

theoretically, L>> b, but for practical application good results can be obtained if L ≥ 5b (Hague, 1963). When apparent resistivity is plotted against electrode spacing (L/2) for various spacing at one location, a smooth curve could be obtained. The data collected are shown in Table 1.

A total of seven VES data from seven locations at Idheze community were carried out.

Further work on the aquifer and the lithology characterisation was estimated in terms of conductivity, longitudinal conductance and transmissivity. Transmissivity of aquifer expresses the ability of the aquifer material to transmit water (Egbai, 2013). Niwas and Singhai, 1981 established the relationships between transmissivity of aquifer and longitudinal conductance as

$$Tr = K\sigma R = \frac{KS}{\sigma}$$

where Tr = transmissivity, K = hydraulic conductivity ,σ = electrical conductivity, R= transverse resistance and S= longitudinal conductance. An average hydraulic conductivity of 10m/day MWT, 1974 is assumed for computing the transmissivity of boreholes in Idheze community.

3. DATA PRESENTATION

Table 1: Resistivity Sounding Field Data

Electrode Array : Schlumberger Array

Site location: Idheze Community

Observer: Dr. J.C Egbai.

Electrode Separation $C_1C_2/2$ m	**Potential Electrode** $P_1P_2/2$ M	**VES1** ρ_a Ωm	**VES2** ρ_a Ωm	**VES3** ρ_a Ωm	**VES4** ρ_a Ωm	**VES5** ρ_a Ωm	**VES6** ρ_a Ωm	**VES7** ρ_a Ωm
1	0.5	197	18980	40499	476	5696	188	18980
2	0.5	9957	39133	35638	435	8787	190	39284
3	0.5	12932	45626	32084	398	10776	161	45672
4	0.5	14846	47274	29168	326	202	143	43023
6	0.5	400	45490	715	287	260	113	38454
6	1.0	14856	47090	654	217	252	99	534
8	1.0	398	44853	694	268	212	56	736
12	1.0	410	1095	665	349452	164	63	500
15	1.0	465	1167	744	635	151	71	1110
15	2.0	496	1185	861	730	125	94	546
20	2.0	546	1217	939	851	106	147	834
25	2.0	566	1262	955	1091	72	202	318
32	2.0	591	1494	1051	1122	278	247	396
40	2.0	612	1523	1056	1423	164	361	357
40	5.0	550	1393	1129	1321	221	457	174
50	5.0	652	1517	1090	1252	299	622	
65	5.0	575	1840	1129	1102	101	821	559
80	5.0	552	1837	1090	1007	1020	722	483
100	5.0	630	2822	1324	976	458	622	2882
100	10.0	787	2822	1255	822	458	532	1699
120	10.0	1094	4336	923	823	3353	528	1794
150	10.0	1317	4034	2715	801			8536
200	10.0	1630	10351	7402				198
200	20.0	1393	6863	4409				4415
250	20.0	2840						

4. DATA ANALYSIS

The data obtained from the field are interpreted quantitatively and qualitatively. The data were plotted on a log-log graph paper with electrode separation and apparent resistivity on the abscissa and ordinate respectively.

The quantitative interpretation was done by partial curve matching and smoothening which enabled us to obtain the initial values of the resistivity and thickness of the subsurface.

The result obtained from the curve matching were used for a quantitative computer iteration using WinResist software (Vander Velpen, 1988).

5. RESULT AND DISCUSSION

The result obtained from the analysis is presented in Table 2 below. This shows the layer parameters, resistivity, thickness, lithology and curve types. Figures 2 to 8 show the sounding curve for the various VES locations. These parameters obtained from the iterated values are called the model parameters.

The geoelectric section of the seven VES are as shown in figure 9A and B.

Table 2: Geoelectric parameters and lithology delineation of study area

VES	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology	Rms % Error	Curve type
1	1	204.8	1.0	1.0	Lateritic top soil	2.5	$\rho_1>\rho_2<\rho_3<\rho_4$ HA
	2	147.0	9.5	10.5	Clayey sand		
	3	330.0	23.2	33.7	Medium grained sand		
	4	452.1			Coarse sand		
2	1	3117.7	1.1	1.1	Lateritic top soil	2.4	$\rho_1>\rho_2<\rho_3>\rho_4<\rho_5$ QQH
	2	2389.7	8.5	9.6	Coarse sand		
	3	1620.1	14.3	23.9	Fine sand		
	4	1450.0	17.1	41.0	Smooth medium sand		
	5	1722.1			Coarse sand		
3	1	4737.9	1.3	1.3	Lateritic top soil	2.1	$\rho_1>\rho_2>\rho_3<\rho_4$ QH
	2	3062.4	9.4	10.7	Coarse sand		
	3	2061.4	25.1	35.8	Fine sand		
	4	5033.0			Coarse sand		
4	1	469.5	1.0	1.0	Lateritic top soil	1.8	$\rho_1>\rho_2<\rho_3<\rho_4<\rho_5$ HAA
	2	324.7	8.2	9.2	Coarse sand		
	3	511.6	16.5	25.7	Fine sand		
	4	599.9	22.3	48.0	Medium grained sand		
	5	779.8			Coarse sand		
5	1	325.3	2.4	2.4	Lateritic top soil	1.2	$\rho_1>\rho_2<\rho_3>\rho_4$ HK
	2	134.5	4.8	7.2	Clay		
	3	520.6	19.5	26.7	Coarse sand		
	4	490.6			Fine sand		
6	1	204.2	1.5	1.5	Lateritic top soil	2.3	$\rho_1>\rho_2<\rho_3<\rho_4<\rho_5$ HAA
	2	91.0	14.4	15.9	Clay		
	3	291.1	15.6	31.5	Clayey sand		
	4	416.4	16.1	47.6	Fine sand		
	5	450.3			Medium grained sand		
7	1	716.0	1.0	1.0	Lateritic top soil	2.5	$\rho_1>\rho_2>\rho_3<\rho_4<\rho_5$ QHA
	2	643.0	8.0	9.0	Coarse sand		
	3	412.0	16.0	25.0	Fine sand		
	4	612.0	18.0	43.0	Medium grained sand		
	5	701.0			Coarse sand		

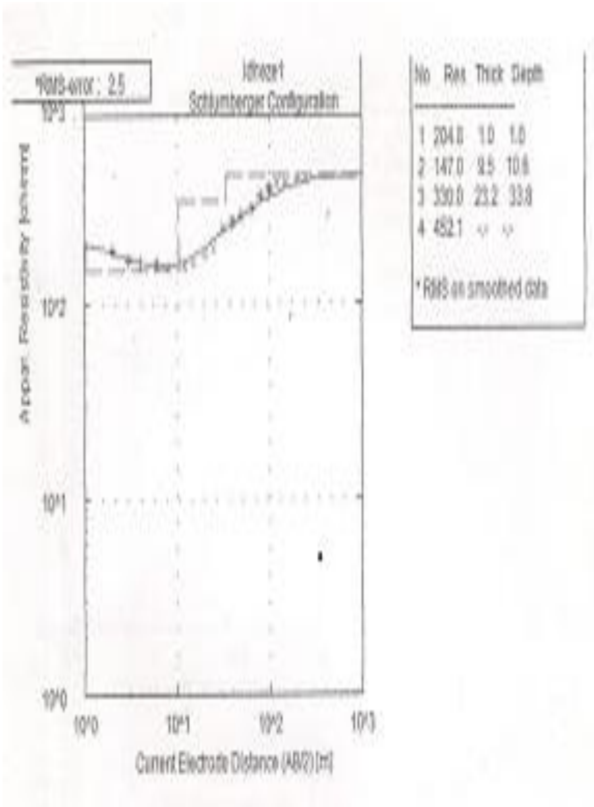

Figure 2: VES for location 1

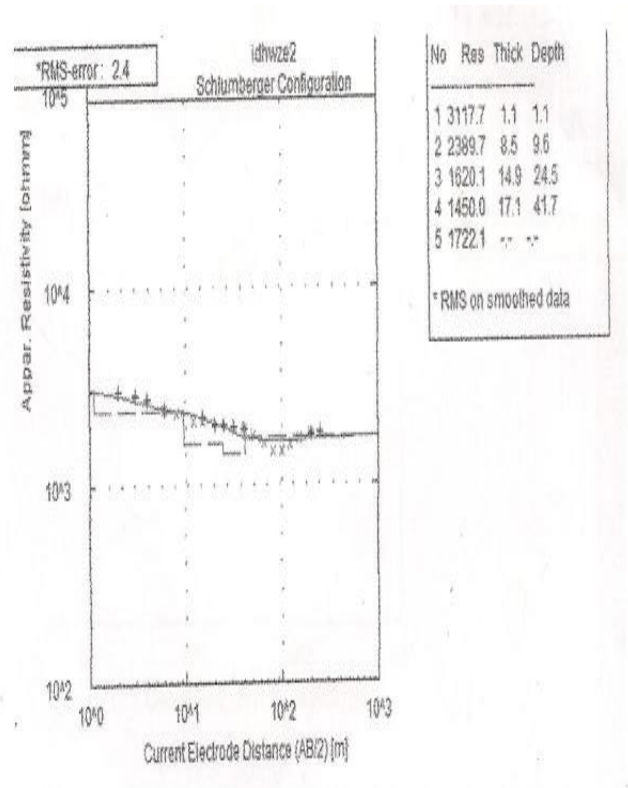

Figure 3: VES for location 2

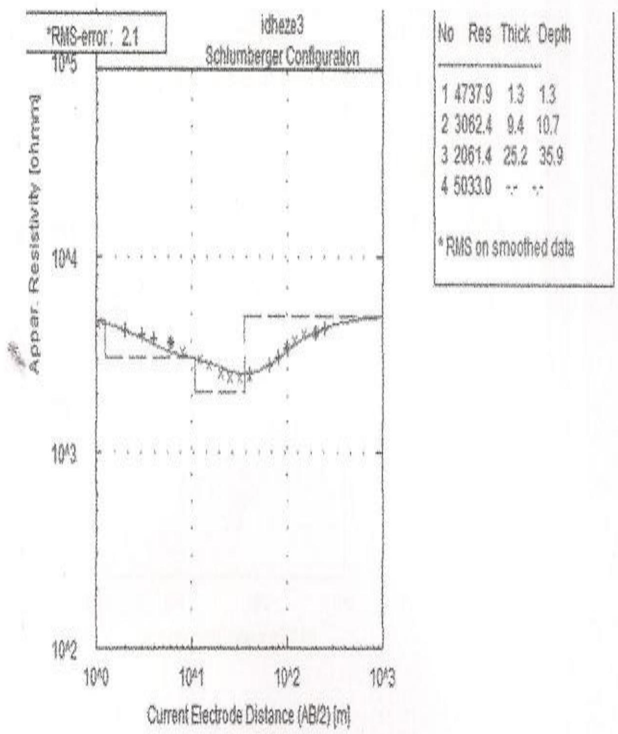

Figure 4: VES for location 3

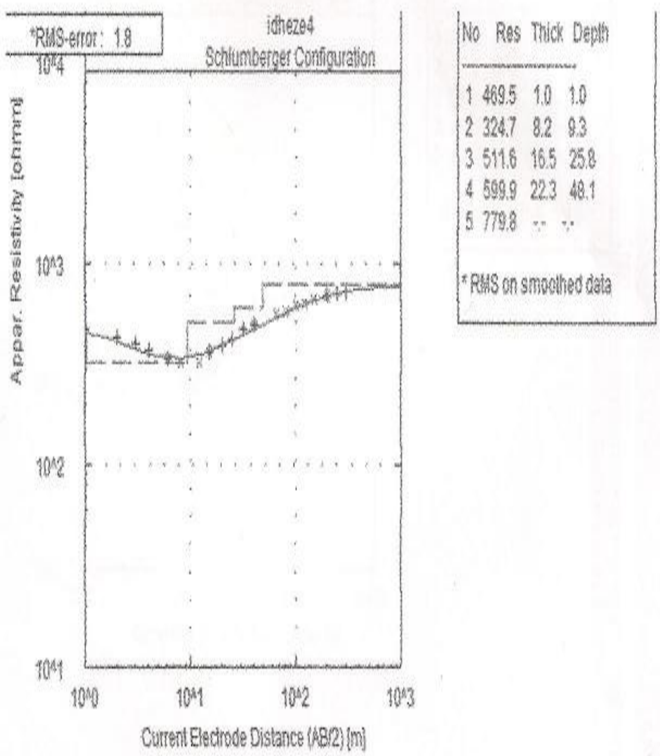

Figure 5: VES for location 4

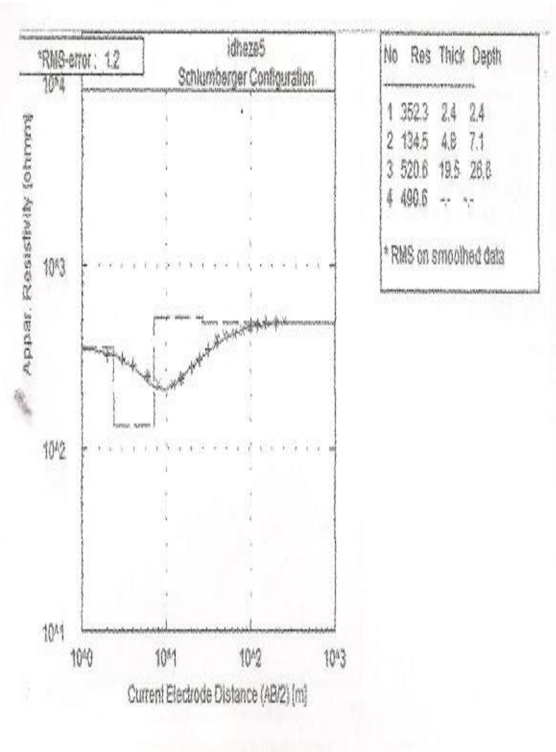

Figure 6: VES for location 5

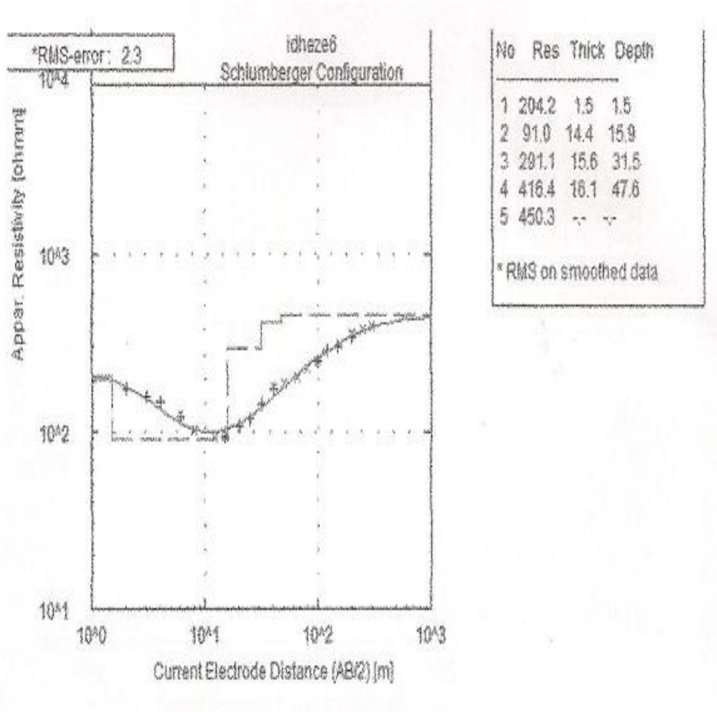

Figure 7: VES for location 6

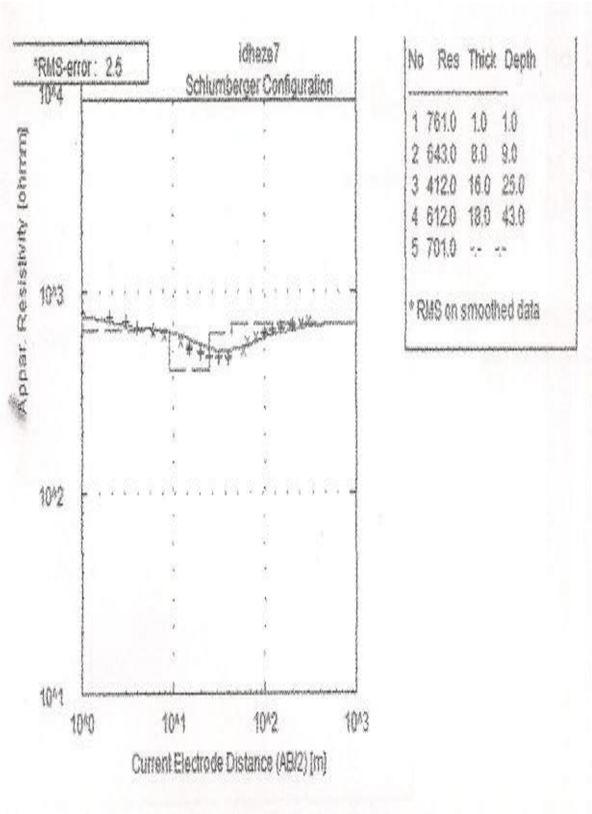

Figure 8: VES for location 7

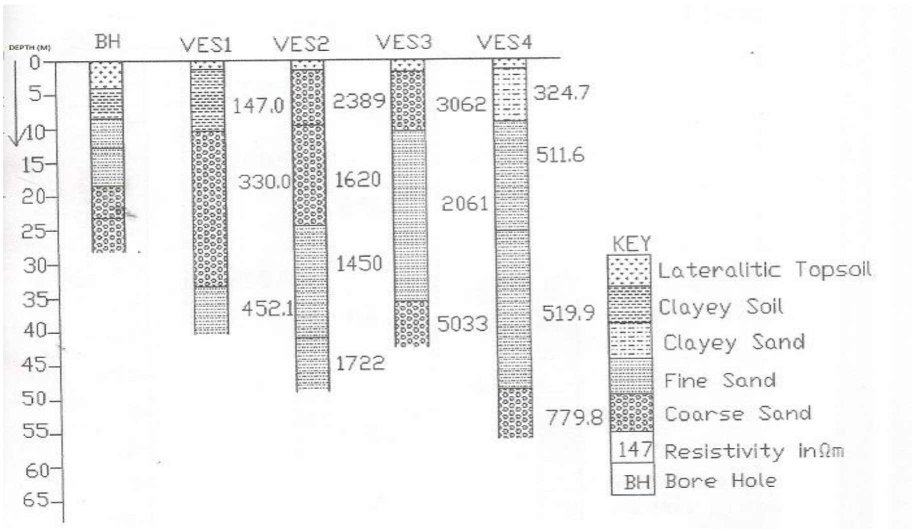

Figure 9A: Geo-electric section for VES 1 to 4.

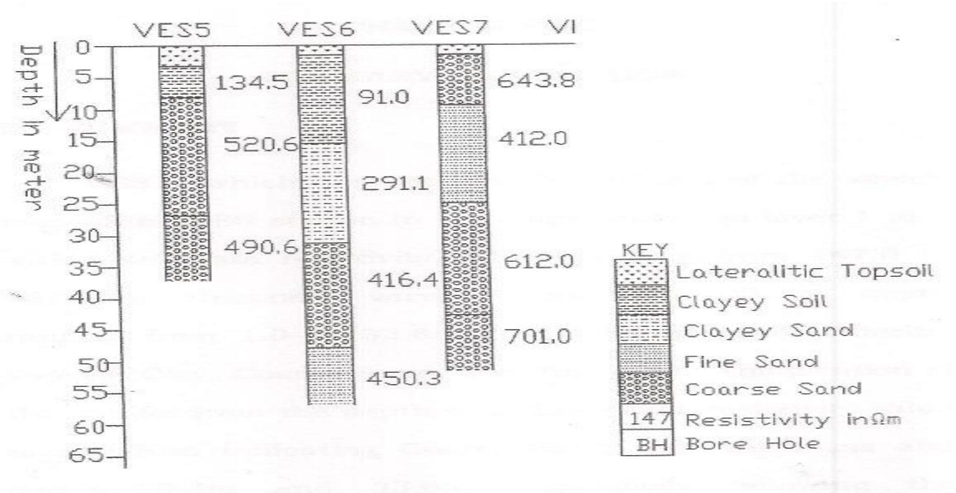

Figure 9B: Geo-electric section for VES 5 to 7.

Table 3: Aquifer electrical properties for all VES locations

VES	Resistivity	Thickness m	Conductivity $\sigma(\sigma \times d)^2$	Longitudinal Conductance $(\sigma \times d)$	Transmissivity Tr
1	330.0	23.2	3.03×10^{-3}	7.03×10^{-2}	232.0
2	1450.0	17.1	0.69×10^{-3}	1.18×10^{-2}	171.0
3	2061.4	25.1	0.46×10^{-3}	1.22×10^{-2}	251.0
4	599.9	22.3	1.67×10^{-3}	3.72×10^{-2}	223.0
5	520.6	19.5	1.92×10^{-3}	3.75×10^{-2}	195.0
6	416.4		2.40×10^{-3}	3.87×10^{-2}	161.0
7	612.0	18.0	1.63×10^{-3}	2.94×10^{-2}	180.0

The model parameters for the whole locations show four and five distinct geoelectric layers with VES 1, 3 and 5 having four layers while VES 2, 4, 6 and 7 have five geoelectric layers.

VES 1 (Location 1) has four layers having resistivity ranging from 147.0 Ωm to 452.12 Ωm, thickness varying from 1.0m to 23.2m at a depth of 33.7m. The lithology is made of lateritic top soil, clayey sand, medium grained soil and coarse sand. The aquiferous layer is within the third layer having resistivity 330.0 Ωm, thickness 23.2m at the depth of 33.7m.

VES 2 (location 2) has five geoelectric layers with resistivity values ranging from 1450.0 Ωm to 3117.7 Ωm, thickness varying from 1.1m to 17.1m at depth of 41.0m. The lithology shows that of lateritic top soil. Coarse sand, fine sand, smooth medium sand and coarse sand. The fourth layer is the aquiferous zone with thickness 17.1m at a depth of 41.0m.

VES 3 (location 3) is made of four layers with resistivity ranging from 2061.4 Ωm to 5033.0 Ωm with thickness varying from 1.3 to 25.1m at a depth of 35.8m. The lithology varies from lateritic top soil, coarse sand, fine sand and coarse sand. The third layer is made of fine sand representing the aquiferous unit with resistivity of 2061.4 Ωm, thickness 25.1m at a depth of 35.8m.

Location 4 (VES 4) is of 5 layers model with resistivity ranging from 324.7 Ωm to 779.8 Ωm with thickness varying from 1.0m to 22.3m at a depth of 48.0m. The lithology is made of lateritic top soil, coarse sand, fine sand, medium grained sand and coarse sand. The fourth layer is the aquiferous unit with resistivity of 599.9 Ωm with thickness 22.3m at a depth of 48.0m.

VES 5 (location 5) is of four layer earth models with resistivity ranging from 134.5 Ωm in the second layer to 520.6 Ωm in the third layer. Thickness varies from 2.4m to 19.5m at a depth of 26.7m. The lithology is made of lateritic top soil, clay coarse sand and fine sand. The aquifer of this location is within the third layer with resistivity of 520.6 Ωm, thickness 19.5m at a depth of 26.7m.

Location 6 (VES 6) is a five layer earth with resistivity values ranging from 91.0 Ωm to 450.3Ωm with lithology made of lateritic top soil, clay, clayey sand, fine sand and medium grained sand. The thickness varies from 1.5m to 16.1m with aquiferous layer in the fourth layer at a depth of 47.6m.

Location 7 (VES 7) is a five layer earth model having resistivity of values ranging from 412.0 Ωm in the third layer to 716.0 Ωm in the first layer. The lithology is lateritic top soil, coarse sand, fine sand, medium grained sand and coarse sand with aquifer located in the fourth layers with thickness of 18m at a depth of 43.0m.

The transmissivity of aquifer in the seven locations are shown in 3. The table shows a survey of Aquifer electrical properties for all VES locations.

The study shows that the seven locations have good aquifer transmissivity. Borehole construction could be sited in any of the locations without failure. Location 3 (VES 3) has the best aquifer transmissivity of 251m^2/day , follow by VES 1 with transmissivity of 232m^2/day and lastly VES 6 with transmissivity of 161.0m^2/day.

6. CONCLUSION

Seven vertical Electrical Soundings (VES) were carried out using the Schlumberger configuration in Idheze Community, Isoko North Local Government Area of Delta State. The result revealed four to five geoelectric layers, HA, QQH, QH, HAA, HQ, HAA and QHA curve type. The geoelectric parameters lithology and geoelectric section are in agreement with the borehole logs in the study area. The locations are good for borehole construction with VES 3 having the best aquifer transmissivity of 25m^2/day while VES 6 has the least with aquifer transmissivity of 161.0m^2/day.

7. ACKOWLEDGEMENT

We wish to thank my final year Physics students (2012/2013 Academic session) for the part played during the field work where the data were collected from the research. We also wish to acknowledge the part played by Mr Pius Efeya during the field work.

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