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Groundwater Study in Irrua, Esan Central Local Government Area of Edo State, Using Electrical Resistivity Method

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***Abstract*— The Schlumberger electrode configuration was used to carry out Vertical Electrical Sounding (VES) at Irrua, Esan central, Edo State . A total of four (4) Vertical Electrical Soundings were carried out in the study area. The electrode spread was up to 450metres in almost all sites. The main equipment used for the electrical resistivity was the ABEM A.C. terrameter and its accessories. The data was interpreted qualitatively using the partial curve matching technique and quantitatively by computer iterative modelling. The results obtained from the VES stations showed five geoelectric layers made up of dry top soil, sand-clay, clayey-sand and sandstones which were interpreted using hand dug wells data as a control to detect various lithological boundaries and aquifer existence in the area. The thickness of near surface aquifer was found to be between 142m and ∞ while the depth to the deep fresh water aquifer was found to be between 27.5m and 267.5m. Some of the VES sites have good prospect for groundwater potential for shallow hand dug wells.**

***Index Terms*— Surface aquifer, vertical electrical sounding(VES), ABEM A.C Terrameter, Schlumberger electrode Configuration, Geoelectric layers.**

I. Introduction

Highlight Groundwater is water held within the interconnected openings of saturated rock beneath the earth's surface. Groundwater bearing formations which are sufficiently permeable to yield usable quantity of water are called aquifers. Thus, an aquifer is a rock unit that will yield water in usable quantities to wells or springs or other point of recovery. And the top of the saturated zone in such an aquifer is called the water table, (Garg, 2007). Water is one of the most consumed minerals at homes, in the industries and factories. One major source of obtaining portable water today is through boreholes and drilled wells. Ever since man began to live in communities, the problems of suitable and adequate water supply especially for domestic and farm use has always agitated the mind. Indeed, the Egyptian civilization could not have flourished without an adequate and reliable water supply, the River Nile.

In most parts of Irrua, Esan Central Local Government Area, Edo State, not all wells yield appreciable quantity of portable water since they are prone to variation groundwater characteristics. The existence of failed boreholes and dry wells has posed a great concern. This is however, traceable to sitting and drilling of boreholes without geophysical studies. Therefore, it is essential that a reliable geophysical study should be carried out in the study area. There are many methods of geophysical surveys. Some of these methods make use of naturally occurring field within the earth while others require the introduction of artificially generated current (field) into the ground.

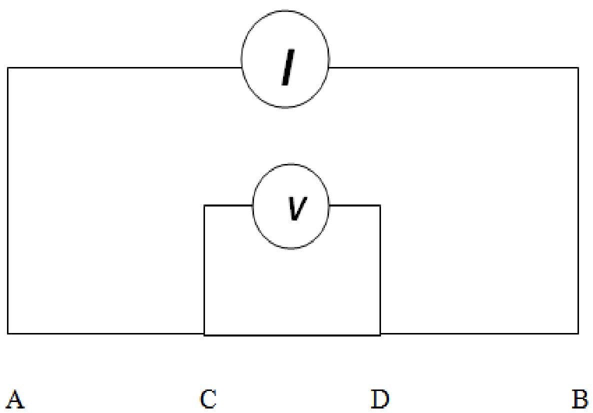
The method of geophysical survey employed in this research work is the electrical resistivity method. It involves the passing of electric current into the ground by means of two electrodes called current electrodes and measuring of potential drop through a second pair of electrodes called potential electrodes. The principle of operation depends on the fact that any subsurface variation in conductivity alters the form of current flow within the earth, and this in turn affects the distribution of electric potential. Thus, it is possible to have information about the subsurface formations from potential measurements made at the surface, (Osemeikhian and Asokhia, 1994).

The resistivity properties of the sub-surface can be explored by two main procedures often called Vertical Electrical Sounding (VES) and Horizontal Electrical Sounding (HES).

II. RESEARCH METHODOLOGY

The geophysical technique employed in this research was the electrical resistivity method using vertical electrical sounding (VES) conducted in Schlumberger configuration.

Four electrode arrays was used at the surface, one pair introducing current to the earth, the other pair for measurement of potential drop associated with the current (Telford,1976). A schematic diagram of the Schlumberger configuration is shown in figure 1



The field procedure in the Schlumberger electrode array system is to expand the current electrode successively while

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the potential electrodes remained fixed. This process yields a rapidly decreasing potential difference across the measuring capabilities of the instrument. At this point, a new value for potential electrode separation was selected, typically 2 to 4 time lager than the preceding value and the survey continued. In this arrangement, it is required that the distance between potential electrode (CD) must never exceed two-fifth of the distance between the current electrodes (AB), i.e. CD $\leq \frac{AB}{5}$.

RESULT

The results of the vertical electrical soundings obtained from the field are shown in table 1.1, 1.2, 1.3 and 1.4 respectively. The geometric factor for the Schlumberger electrode array is calculated from the formula:

$$K = (\pi CD)\left((L/CD)^2 - \frac{1}{4}\right)$$

Where L = $\frac{AB}{2}$.

And the apparent resistivity is given by

$$\rho_a = K\frac{\Delta V}{I}$$

The value of apparent resistivity were plotted (as ordinates) against current electrode spacing $\frac{AB}{2}$ (as abscissa) using double logarithmic graph for necessary qualitative and quantitative interpretations

Table 1.1: Field Data for VES I

S/N	CURRENT ELECTRODE SPACING $\frac{AB}{2}$ or $L\ (m)$	POTENTIAL ELECTRODE SPACING $\frac{CD}{2} = l\,(m)$	RESISTANCE $R = \frac{\Delta V}{I}(\Omega)$	ELECTRODE GEOMETRIC FACTOR $K\ (m)$	APPARENT RESISTIVITY $\rho_a\ (\Omega m)$
1	2.00	0.80	61.08	6.597	403.0
2	3.00	0.80	23.45	16.415	385.0
3	4.00	0.80	12.30	30.159	371.0
4	6.00	2.00	16.30	25.134	410.0
5	8.00	2.00	9.57	47.120	451.0
6	12.00	2.00	5.05	109.956	556.0
7	15.00	6.00	12.15	49.480	601.0
8	25.00	6.00	5.32	154.200	820.0
9	32.00	6.00	4.00	258.658	1015.0
10	40.00	10.00	5.14	235.619	1211.0
11	60.00	10.00	2.58	549.779	1416.0
12	100.00	20.00	2.63	753.982	1984.0
13	150.00	20.00	1.20	1,735.730	2087.0
14	200.00	20.00	0.91	3,110.177	2817.0
15	250.00	20.00	0.66	4,877.323	3216.0
16	300.00	20.00	0.56	7,037.168	3958.0
17	350.00	20.00	0.41	9,589.712	3961.0

Schlumberger survey (VES)
Project: Groundwater study
Sounding location: Agua -Irrua

Computation formula: $\rho_a = K\frac{V}{I},\quad K = \frac{\pi}{2l}\left(L^2 - l^2\right)$ Or $K = \pi\, CD\left(\left(\frac{L}{CD}\right)^2 - 0.25\right)$

Table 1.2: Field Data For VES 2

S/N	CURRENT ELECTRODE $\frac{AB}{2} = L(m)$	POTENTIAL ELECTRODE SPACING $\frac{CD}{2} = l\ (m)$	ELECTRODE GEOMETRIC FACTOR, K (M)	RESISTANCE Ω	APPARENT RESISTIVITY $\rho_a\ (\Omega\, m)$
1	2.00	0.80	6.597	18.04	119.00
2	3.00	0.80	16.415	8.00	131.00
3	4.00	0.80	30.159	4.74	143.00

4	6.00	2.00	25.134	6.45	162.00
5	8.00	2.00	47.120	3.70	174.00
6	12.00	2.00	109.956	1.65	181.00
7	15.00	6.00	49.480	3.86	191.00
8	25.00	6.00	154.200	0.80	122.00
9	32.00	6.00	258.658	0.40	93.00
10	40.00	10.00	235.619	0.32	74.00
11	60.00	10.00	549.779	0.10	52.00
12	100.00	20.00	753.982	0.07	53.00
13	150.00	20.00	1735.730	0.05	84.00
14	200.00	20.00	3110.177	0.03	103.00
15	250.00	20.00	4,877.325	0.03	132.00

Project: Groundwater study
Sounding location: Shaka Momodu Rd, Akho Irrua

Computation formula: $\rho_a = K\frac{V}{I},\ K = \Pi CD\left((\frac{L}{CD})^2 - 0.25\right)$

Table 1.3 field Data for VES 3

S/N	CURRENT ELECTRODE SPACING $\frac{AB}{2} = L\ (m)$	POTENTIAL ELECTRODE SPACING $\frac{CD}{2} = l\ (m)$	RESISTANCE (Ω)	ELECTRODE GEOMETRIC FACTOR, K	APPARENT RESISTIVITY ρ_a $(\Omega\ m)$
1	2.00	0.80	28.50	6.597	188
2	3.00	0.80	15.23	16.415	250
3	4.00	0.80	10.64	30.159	321
4	6.00	2.00	17.35	25.134	436
5	8.00	2.00	11.71	47.120	552
6	12.00	2.00	6.10	109.956	671
7	15.00	6.00	15.58	49.480	771
8	25.00	6.00	5.50	154.200	846
9	32.00	6.00	3.09	258.658	798
10	40.00	10.00	3.24	235.619	763
11	60.00	10.00	1.60	549.779	875
12	100.00	20.00	1.56	753.982	1178
13	200.00	20.00	0.53	3110.177	1636
14	300.00	20.00	0.28	7037.168	1959
15	350.00	20.00	0.20	9589.712	1816

Schlumberger survey (VES)
Project: Groundwater study
Sounding location: Idumuagbokhae Street, Equarre-Irrua
Date; 23rd July 2010

Computation formula: $\rho_a = K\frac{V}{I},\ K = \Pi CD\left((\frac{L}{CD})^2 - 0.25\right)$

Table 1.4: field Data for VES 4

1) S/N	CURRENT ELECTRODE SPACING $\frac{AB}{2} = L\ (m)$	POTENTIAL ELECTRODE SPACING $\frac{CD}{2} = l(m)$	RESISTANCE (Ω)	ELECTRODE GEOMETRIC FACTOR,K	PPARENT RESISTIVITY ρ_a $(\Omega\ m)$
1	2.00	0.40	115.58	15.08	1743
2	3.00	0.40	50.90	34.72	1767

3	4.00	0.40	27.34	62.20	1703
4	6.00	1.00	32.52	54.98	1788
5	8.00	1.00	15.14	98.96	1498
6	12.00	1.00	5.54	224.62	1245
7	15.00	2.00	7.20	173.57	1250
8	25.00	2.00	2.51	487.73	1225
9	32.00	2.00	1.69	801.11	1352
10	40.00	5.00	2.89	494..80	1428
11	50.00	5.00	1.89	777.54	1469
12	60.00	5.00	1.48	1123.12	1663
13	100.00	10.00	0.76	1555.09	1178
14	150.00	10.00	0.25	3518.58	897
15	200.00	10.00	0.1 3	6267.48	817
16	250.00	10.00	0.09	9,801.77	864
17	300.00	15.00	0.10	9401.22	905
18	350.00	15.00	0.08	12,804.61	1013
19	400.00	15.00	0.07	16,731.60	1139
20	450.00	15.00	0.06	21,182.19	1315

Schlumberger survey (VES)
Project: Groundwater study
Sounding location: Akhigbe Housing Estate, Akho-Irrua

Computational formula: $\rho_A = K \frac{\Delta V}{I}, \quad K = \pi \, CD \left(\left(\frac{L}{CD}\right)^2 - 0.25 \right)$

III. DISCUSSION OF RESULTS

Four vertical electrical soundings (VES) were carried out to cover the entire study area. These are along Agua road, Irrua (VES1); Along Momodu Street,Equare- Irrua (VES2); Udumuagbokhae Street, Equare-Irrua(VES3) and Akhigbe Housing Estate (VES4). The tables below show the various geoelectric layer parameters and analysis of the area.

VES 1 (Along Agua road, Irrua)

Geoelectric Layers	Resistivity (Ohm-m)	Thickness (m)	Cumulative Thickness (m)	Soil Lithology
1	439.7	1.577	1.577	Top soil
2	156.9	0.7864	2.363	Sandy clay
3	631	10.12	12.48	Sand
4	2596	86.09	98.57	Dry sand
5	8013	Infinity	Infinity	Dry sand

RMS Error =1.09%

Ves1 is an HA (bowl ascending) type curve. The computer aided interpretation produced a best match that resulted in five geoelectric layers corresponding to five geologic layers. The first layer has a resistivity value of 439.7Ωm with a thickness of 1.577m representing a thin resistive top soil. The second layer has a resistivity of 156.9Ωm with a thickness of 0.7864m representing sandy clay. The third layer has a resistivity of 631.1Ωm with a thickness of 10.12m representing sand. The fourth layer has a resistivity of 2596Ωm and a thickness of 86.09m representing dry sand. The fifth layer has a resistivity of 8013Ωm with an infinite thickness representing dry sand. The total depth of current penetration is 98.57m. No aquifer is present in this station

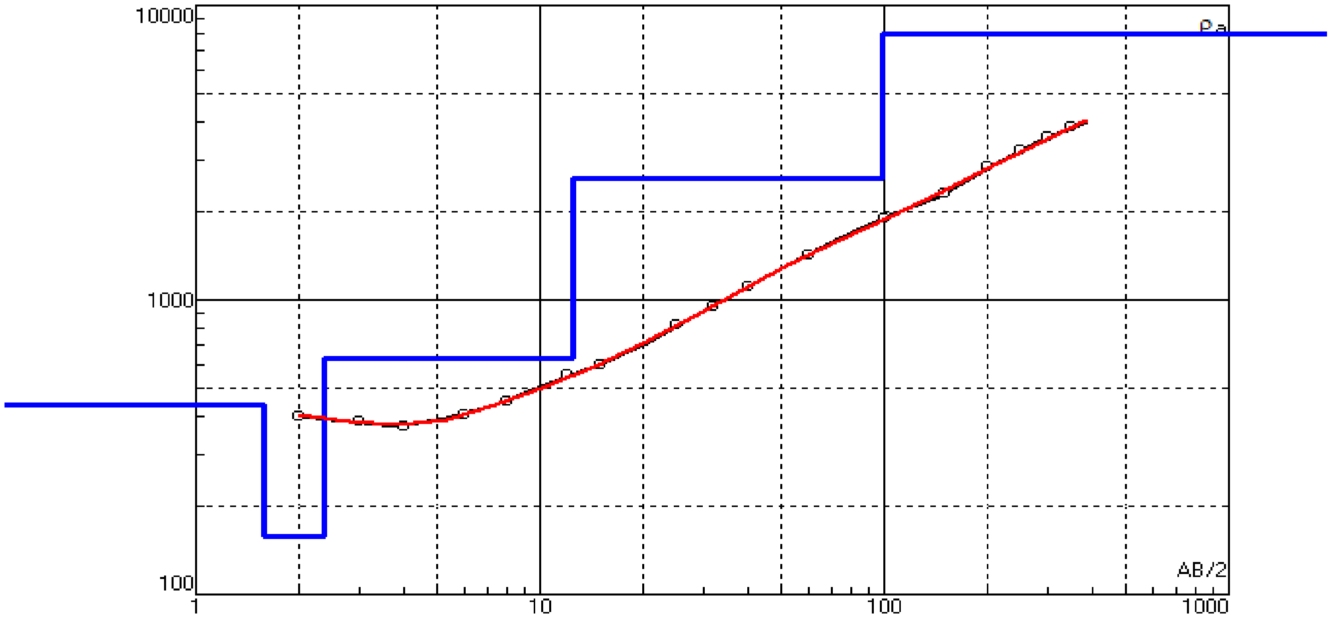

Fig 1.0: Geoelectric Interpretation Curve Section for VES1s

VES 2 (Shaka Momodu Street,Equare-Irrua.**)**

Geoelectric Layers	Resistivity (Ohm-m)	Thickness (m)	Cumulative Thickness (m)	Geologic Layers
1	113.3	2.265	2.265	Top soil
2	281.4	6.196	8.461	Sand
3	59.02	19.27	27.73	Sandy clay
4	18.19	27.43	55.16	Sandy clay
5	28998	Infinity	Infinity	Dry sand

RMS Error = 1.37%

A total of five geologic layers were interpreted from the HK(Bell-Bowl) type curve. Sounding at this site revealed that the first layer has a resistivity of 113.3Ωm and a thickness of 2.265m representing the top soil. The second layer has a resistivity of 281.4Ωm and thickness of 6.196m representing sand sequence. The third and fourth layer have resistivities of 59.02Ωm and 18.19Ωm and thickness 19.27m and 27.43m respectively. The fifth layer has a resistivity of 28998Ωm with an infinite thickness representing dry sand.

The third and fourth layers are made of Sandy Clay/Clayey Sand horizons which is a signatory of a perched aquifer. The spread did not strike the aquifer which implies that it is very deep. The maximum depth reached is about 55.16m.

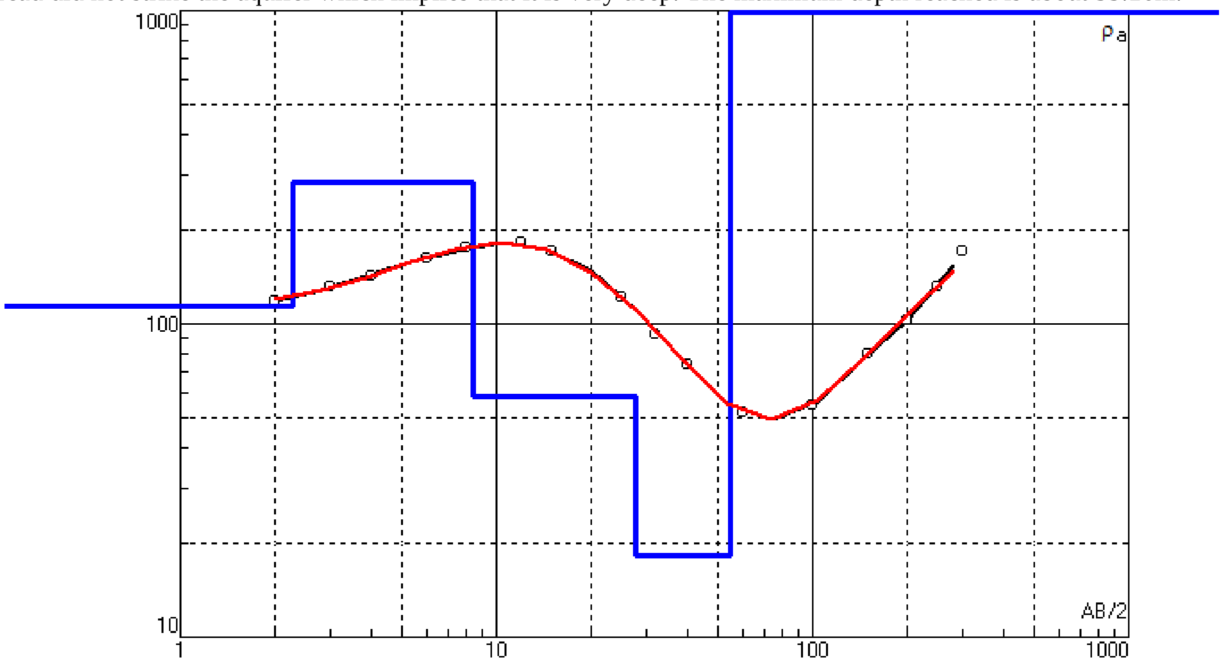

Fig 2.0: Geoelectric Interpretation Curve Section for VES2

VES 3 (Idumuagbokhae Street, Eguare-Irrua)

Geoelectric Layers	Resistivity (Ohm-m)	Thickness (m)	Cumulative Thickness (m)	Lithology
1	133.4	1.444	1.444	Top soil
2	225.4	5.432	6.876	Sandy Clay
3	299.4	13.25	20.13	Sandy clay
4	2920	247.4	267.5	Dry sand
5	115	Infinity	Infinity	Water bearing sand

RMS Error = 0.982%

The sounding produced a total of five geoelectric layers which was interpreted from the field data typified by an H.A (Bow-Ascending) type curve. The first geoelectric layer has a resistivity of 133.4Ωm and a thickness of 1.444m representing top soil. The second layer has a resistivity of 225.4Ωm and a thickness of 5.432m representing sandy clay. The third layer has a resistivity of 229.4Ωm and a thickness of 13.25m representing sandy clay. The fourth layer has a resistivity of 2920Ωm and a thickness of 247.4m representing dry sand. The fifth layer has resistivity of 115Ωm with an infinite thickness. This layer is composed of water bearing sand which signifies a high yielding aquifer. The water table is deep seated. The depth to the top of the aquifer is 267.5m. The aquifer is expected to be prolific. The maximum depth reached in this location is 267.5m.

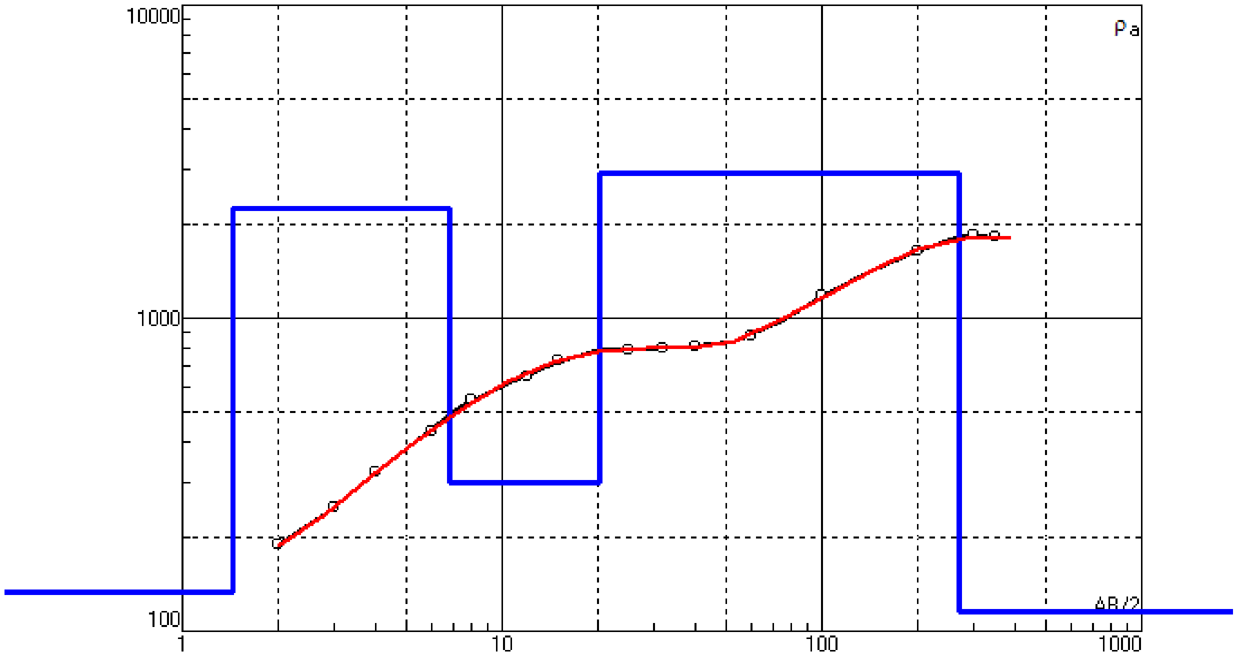

Fig 3.0: Geoelectric Interpretation Curve Section for VES3

VES 4 (Akhigbe Housing Estate, Akho-Irrua**)**

Geoeletric Layers	Resistivity (Ohm-m)	Thickness (m)	Cumulative Thickness (m)	Lithology
1	1781	5.34	5.34	Resistive top soil
2	729	9.39	14.73	Sandy clay
3	5215	12.8	27.53	Dry sand
4	442	142.2	169.7	Water bearing sand
5	140000	Infinity	Infinity	Highly resistive dry sand

RMS Error =1.60%

The sounding produced a total of five geoelectric layers which was interpreted using the curve matching of HKH (Bell-Bowl-Bell) type curve. It revealed a high resistive top soil in the first layer with resistivity of 1781Ωm and a thickness of 5.34m. The second layer has resistivity of 729Ωm and a thickness of 9.39m representing sandy clay. The third layer has a resistivity of 5215Ωm and a thickness of 12.8m representing dry sand. Below this layer is the fourth layer low resistivity of 442Ωm and thickness 142m.This layer is composed of water bearing sand. This implies that there is presence of aquifer in this layer. The depth to the top of the high yielding aquifer is 27.53m while the depth to the bottom of the aquifer is 169.7m. The aquifer is confined and prolific. The fifth layer has a high resistivity of 140000Ωm with an infinite thickness. This layer is composed of highly resistive dry sand.

The maximum depth of current penetration is 169.7m

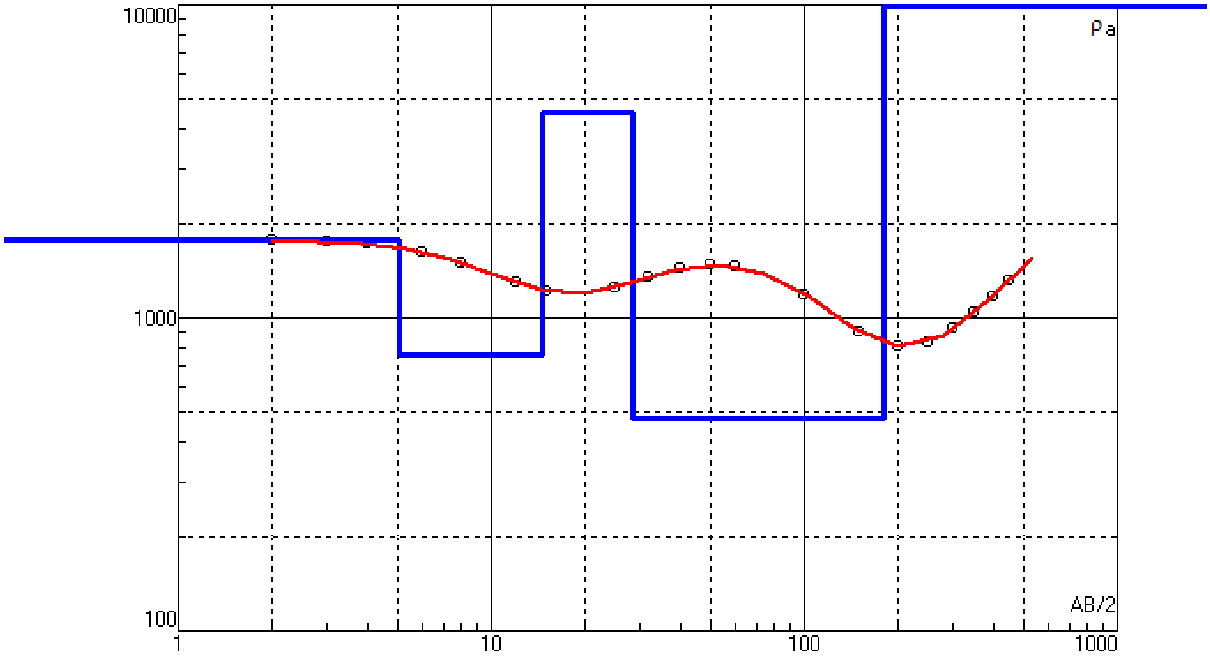

Fig 4.0: Geoelectric Interpretation Curve Section for VES4

Summary of VES results along sedimentary environs

VES no/Location	Maximum AB/2 (m)	Curve Shape	No of Layers	Thickness of near surface aquifer (m)	Total Depth Penetrated (m)	Existing borehole data (m)
1 Along Agua road, Irrua	350	HA	5	Not penetrate	98.57	140
2 Shaka Momodu street, Eguare-Irrua	300	HK	5	Not penetrate	55.16	73
3 Idumuagbokhae Street, Eguare-Irrua	350	HA	5	Infinite	267.5	80
4 Akhigbe Housing Estate, Akho-Irrua.	450	HKH	5	142.2	169.7	95

IV. CONCLUSION

The study revealed the presence of near surface fresh water aquifer at Irrua which is the main source of fresh water for the inhabitant. At Agua-Irrua, the depth to the aquifer was not penetrated which means that the water table is very deep. At Eguare-Irrua, Momodu Street, although the aquifer was penetrated at the depth between 27.73m to 55.16m, it was a perched aquifer which implies that it may not stand the test of time. Also, at Equare-Irrua Idumuagbokhae Street, the aquifer was penetrated at the depth of 267.5m which means that the aquifer was deep-seated. At Akho quarter,the aquifer was penetrated at the depth between 27.53m to 169.7m.

In general, Irrua has a good prospect for pure water industry. Aquifer in the study area is located at the depth that is not less than 27.53m to 169.7m below the surface which may not dry up for a long time after borehole completion. Detection of aquifers aids the general economy by setting up ventures for the production of sachet and bottled water arising from hand dug borehole at Irrua. This study demonstrated the usefulness of VES using Schlumberger array for the delineation of aquifer types in the study area.

V. RECOMMENDATION:

It is recommended that future researchers in this study area and its environs should use a combined VLF and VES so as to obtain the actual depth of the aquifer. It is also recommended that a similar study should be carried out during the dry season to know the variation in the depth and thickness of the aquifers. SP logging should be carried out to confirm the lithology of the area

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