ELECTRICAL RESISTIVITY SURVEY FOR GROUNDWATER POTENTIAL AND ESTIMATION OF CLAY DEPOSIT IN ARAGBA-OKPE, OKPE LOCAL GOVERNMENT AREA, DELTA STATE NIGERIA

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Abstract. Electrical resistivity survey employing Vertical Electrical Sounding techniques of Schlumberger arrangement were carried out at seven (7) fairly distributed stations with 154 Vertical Electrical Soundings in Aragba-Okpe. The data obtained from the field were plotted on a log-log graph and interpreted qualitatively by inspection and quantitatively by partial curve matching. The results obtained were improved with the aid of computer iteration using the Winresist Software to delineate the thickness and depth of each layers as well as the resistivity value. These layers were grouped together in to geologic depth intervals known as the Geoelectric sections for interpretations. Using knowledge of both the local geology of Aragba-Okpe and the resistivity of the layers, the Geoelectric sections were interpreted. The study revealed that boreholes for sustainable water supply could be drilled to a depth of 30 m in Aragba-Okpe, However, the fifth layer within Aragba Primary School, Aragba Secondary School and Oviri Aragba Road (VES 1, 5 and 7) are the best locations for sustainable water supply

The overburden protective capacities of the aquifer in Aragba-Okpe were evaluated using the Dar-zarrouk parameters. The result also revealed poor aquifer protection ratings of less than 0.1 in all the stations. The groundwater in Aragba-Okpe is therefore not protected and prone to contamination in the event of pollution.

Keywords: Aragba-Okpe, Vertical Electrical Sounding, Groundwater, Aquifer Protection Rating.

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Introduction

One of the direct ways geophysical exploration assisted the world economy is the delineation of Groundwater potential and estimation of the aquifer protective capacity *(Ezomo, & Aiyohuyin, 2012)*. Aquifer protection is essential for sustainable groundwater resources and protection of the dependent ecosystem. The amount of clay deposit can help to reduce the vulnerability and increase the protection capacity of aquifer. It is therefore of great importance to locate areas with high clay deposit for good borehole scheme *(Ezomo, 2012)*. Hence the use of geophysical method cannot be overemphasized since the earth electrical survey is capable of imaging both low and high resistivity formations and therefore a valuable tool for vulnerability studies *(Christensen, & Sorensen, 1998*; *Sørensen et al., 2005)*.

Egbai et al. *(2015)* investigated on the dumpsite in Ozoro to delineate the depth to the aquifer and determine the aquifer protective capacity. They concluded that the generated longitudinal conductance showed poor protective capacity and revealed the movements of leachate down toward the aquifer indicating that the aquifer is not protected.

Egbai J. C. *(2011)* also used the vertical electrical sounding to study the clay deposit in Orerokpe, Okpe Local Government Area of Delta State and revealed that the quantity of clay for both domestic and industrial purposes is very large.

Consequently, this investigation was carried out using electrical resistivity method Vertical Electrical Sounding specifically the Schlumberger Arrangement Configuration due to the following reasons; It made use of only two current electrodes at a time, thus is more convenient and faster than the Werner Arrangement; It saves time and manpower; It minimized the effects of the electrodes on the resistivity curve and errors due to shallow resistivity variations such as noise and made it a constant with fixed potential electrodes, hence is sensitive to heterogeneous surfaces in data acquisition.

The study therefore is aimed at not only establishing a baseline knowledge of the depth boreholes could be drilled for sustainable water supply, but investigate the presence, depth and thickness of clay in order to determine the protective capacity and vulnerability of the aquifer and avoid failures of buildings and roads within Aragba in Okpe Local Government Area of Delta State.

Location and geology of the study area (ARAGBA-OKPE)

Aragba- Okpe is in the Sombrero-Warri deltaic plain deposits characterized by silts, fine, and medium to coarse grained sand formations. It also has clay bands that are not uniform in thickness. It is within the Niger-Delta basin and lies within latitudes 05^0 36^1 N and 05^0 42^1N and Longitudes 05^0 30^1E and 05^0 31^1 E. The Niger Delta basin has three predominant formations (Benin, Agbada and Akata formations). The Benin formation is the youngest and prolific aquifer. The vegetative cover is of rain forest and has equatorial climate of two main seasons (Raining and Dry Seasons). The raining season begins in late March and extends to late September while the dry season starts in October and end in early March. Aragba-Okpe is close to Orerokpe which is the headquarter of Okpe Local Government Area and has an area of about 291.37 sq. km. Figure 1 is the base map of Aragba-Okpe and the locations of the Vertical Electrical Soundings.

The procedure involved the introduction of current through a pair of electrodes (AB/2) in to the earth and measuring the potential difference resulting from the applied current through another pair of electrode (MN/2). A fixed point was established and the potential electrodes were pinned to the ground at the opposite sides of the fixed point at a specified distance and connected to points "M" and "N" on the terrameter. The current electrodes were also pinned to the ground outside the potential electrodes and connected to the terrameter via points "A" and "B". Hence, the current electrodes, the potential electrodes and the fixed point are all in a straight line. When proper connections have been made, the terrameter was switched on and the averaged apparent resistivity value on the terrameter was recorded. After the reading has been taken, the current electrodes were moved step by step systematically to new points along the line that is equidistance from the fixed point and then the apparent resistivity values that is automatically averaged were also recorded. This procedure continued until considerable vertical electrical soundings data were taken each time varying the potential difference when the voltage of the potential falls below the reading accuracy of the Terrameter *(Oseji, 2011; Oseji et al., 2014; Oseji, 2013)*. The data obtained from the survey were plotted on a log-log graph paper manually with current electrode spacing (AB/2) on the abscissa and the apparent resistivity value on the ordinate.

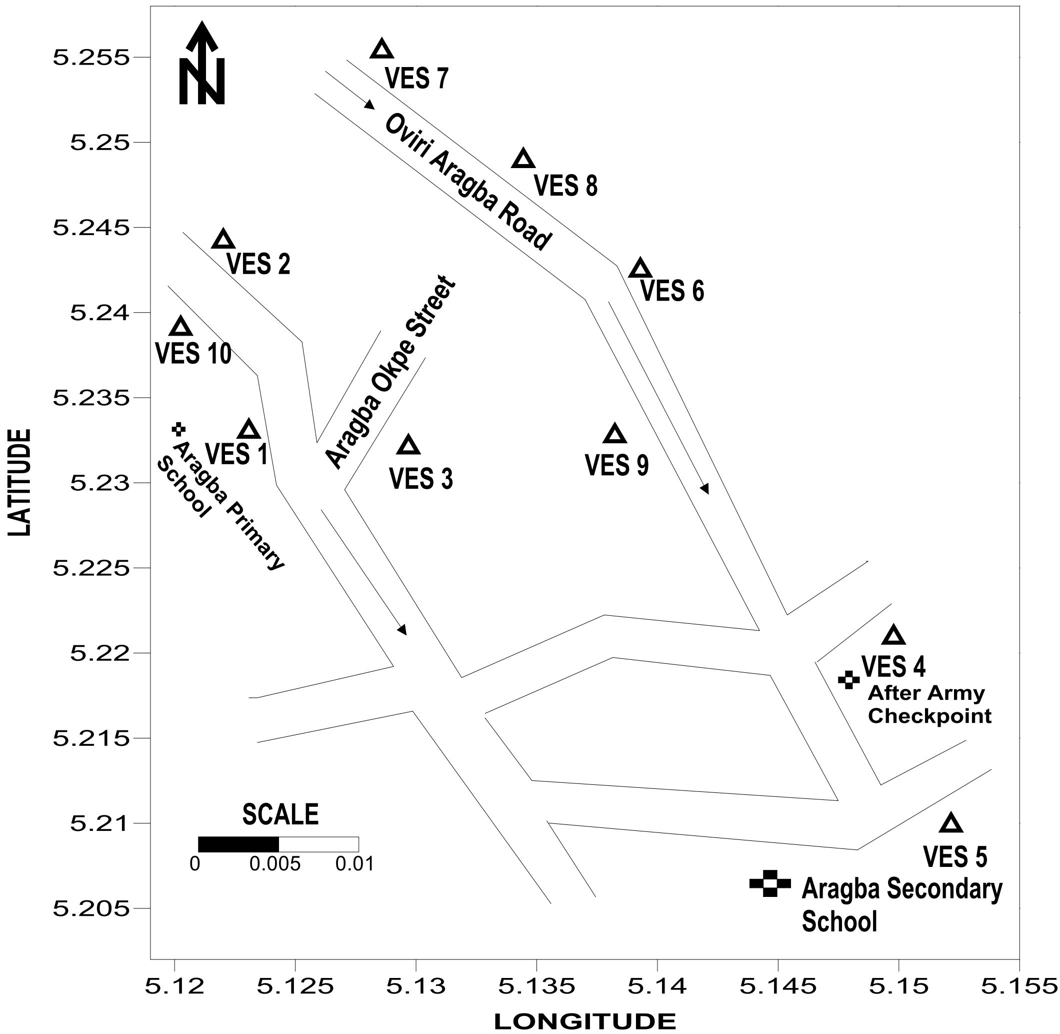

Fig. 1. Base Map of Aragba-Okpe Showing Locations of Vertical Electrical Soundings

Method

The partial curve matching technique using two layer standard curves (master curves) and the auxiliary curves were used to obtain the initial values of the resistivity and thickness of the subsurface layers *(Zohdy, 1974; Okolie et al., 2005; Zohdy et al., 1974)*. These values were fed into the winresist software for computer iteration (*Vande Velpen, 2004)*. The iteration process continued until the computer displays the final result of the iteration and the layer parameters with minimum root mean square error as shown in figures (2- 8).

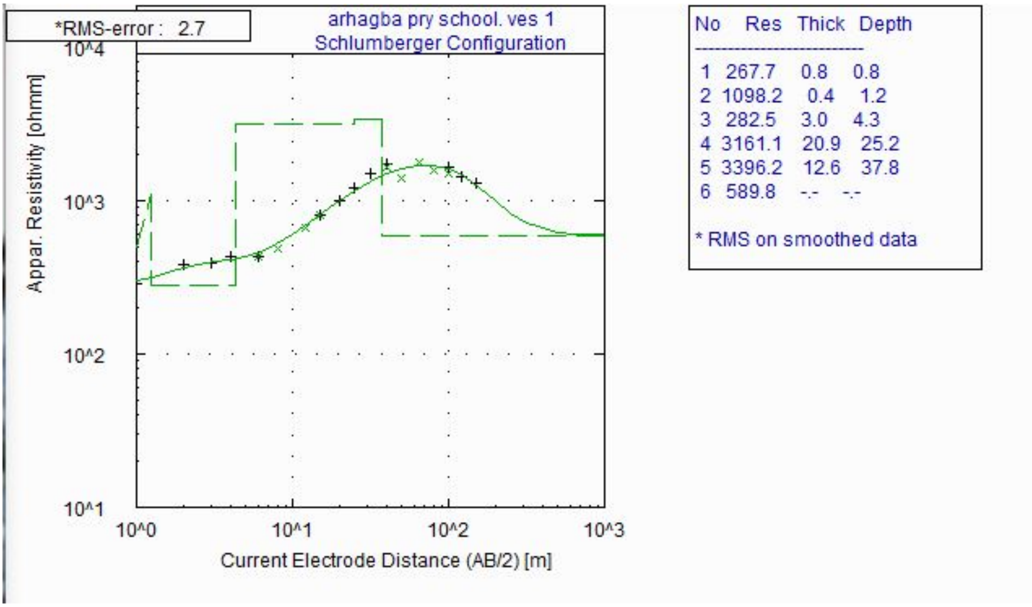

Fig. 2. Resistivity Sounding Interpretation for VES 1 (Aragba Primary School, Aragba-Okpe) Showing Resistivity Curves and Model Parameters

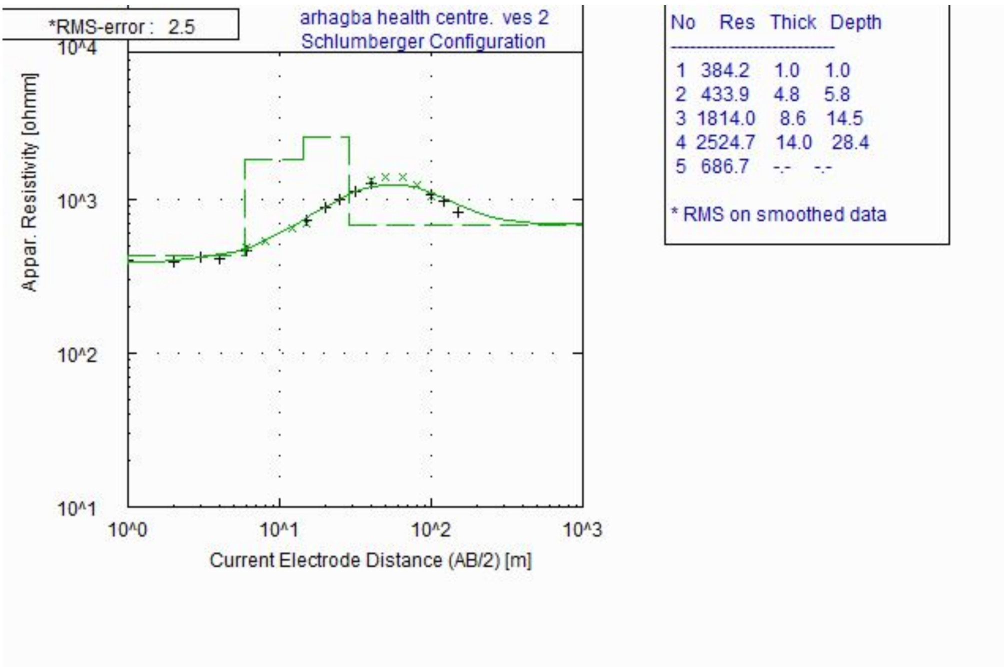

Fig. 3. Resistivity Sounding Interpretation for VES 2 (Aragba Okpe Health Center) Showing Resistivity Curves and Model Parameters

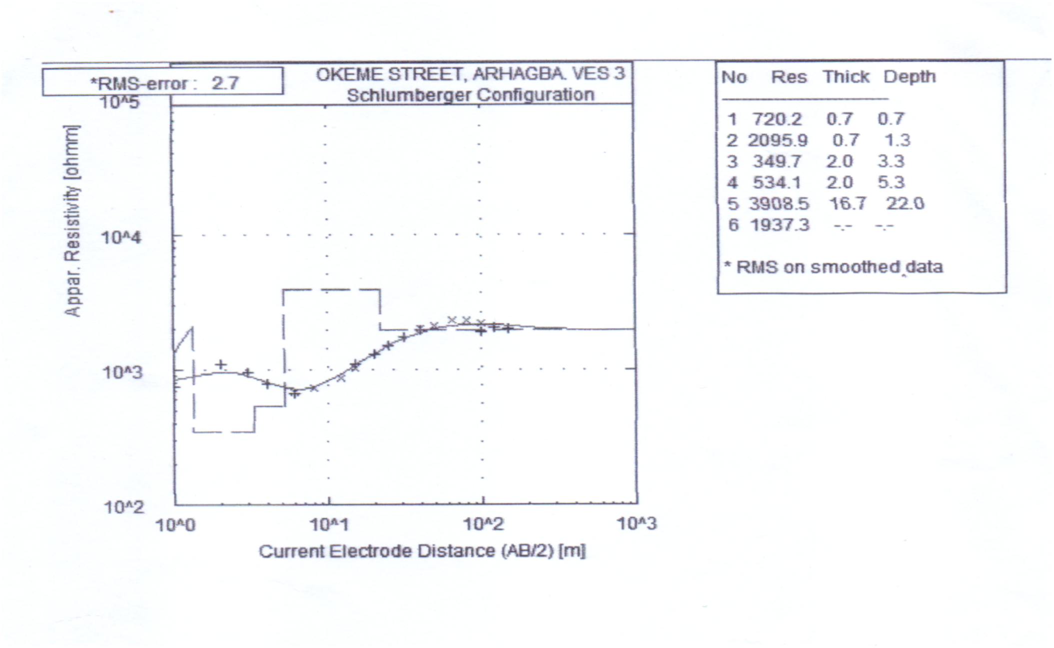

Fig. 4. Resistivity Sounding Interpretation for VES 3 (Okeme Street, Aragba-Okpe) Showing Resistivity Curves and Model Parameters

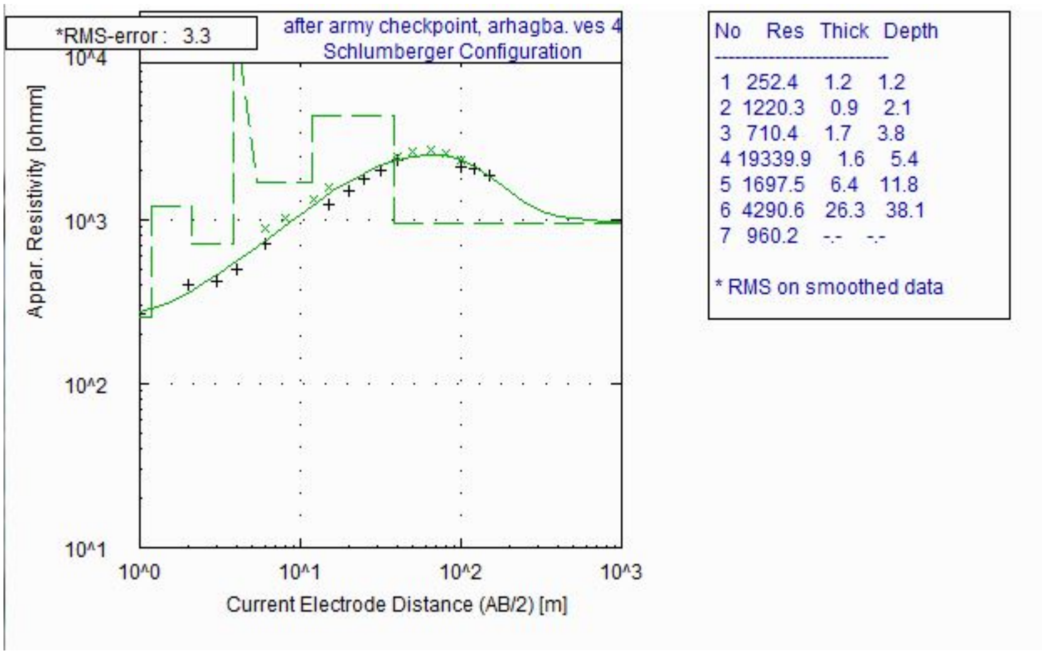

Fig. 5. Resistivity Sounding Interpretation for VES 4 (After Army Check Point, Aragba-Okpe) Showing Resistivity Curves and Model Parameters

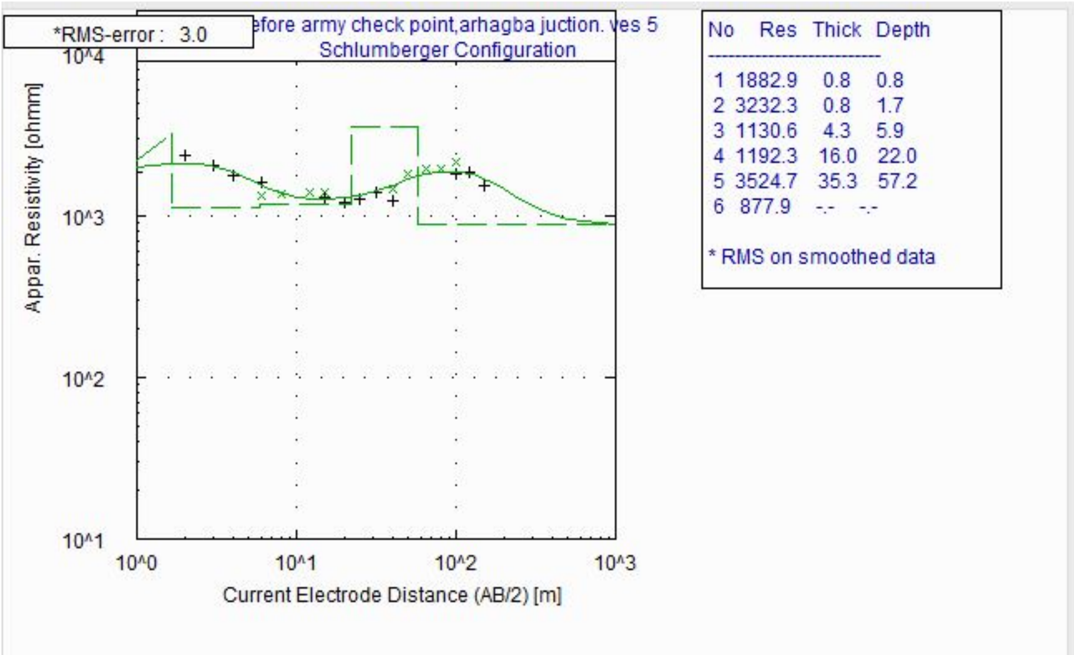

Fig. 6. Resistivity Sounding Interpretation for VES 5 (Before Army Check Point, Aragba-Okpe) Showing Resistivity Curves and Model Parameters

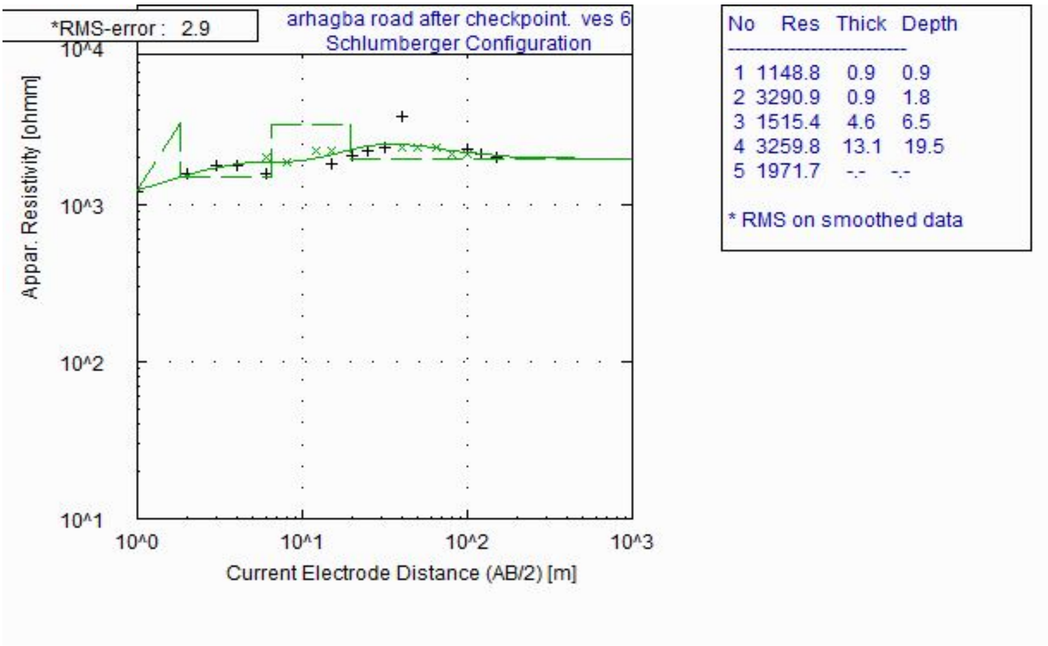

Fig. 7. Resistivity Sounding Interpretation for VES 6 (Aragba-Okpe after Check Point) Showing Resistivity Curves and Model Parameters

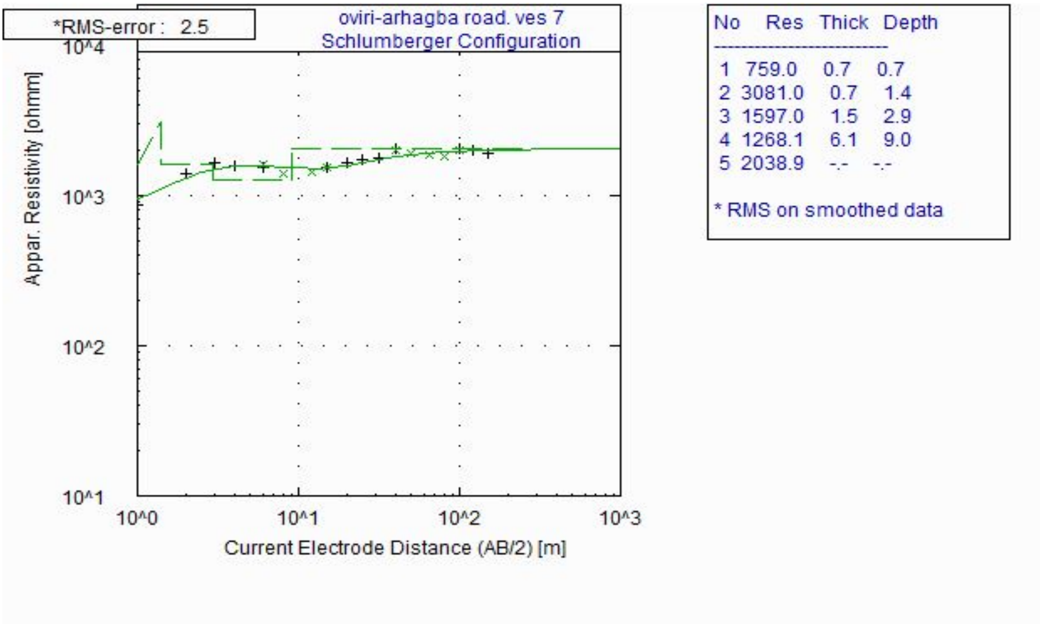

Fig. 8. Resistivity Sounding Interpretation for VES 7 (Oviri/Aragba Road, Aragba-Okpe) Showing Resistivity Curves and Model Parameters

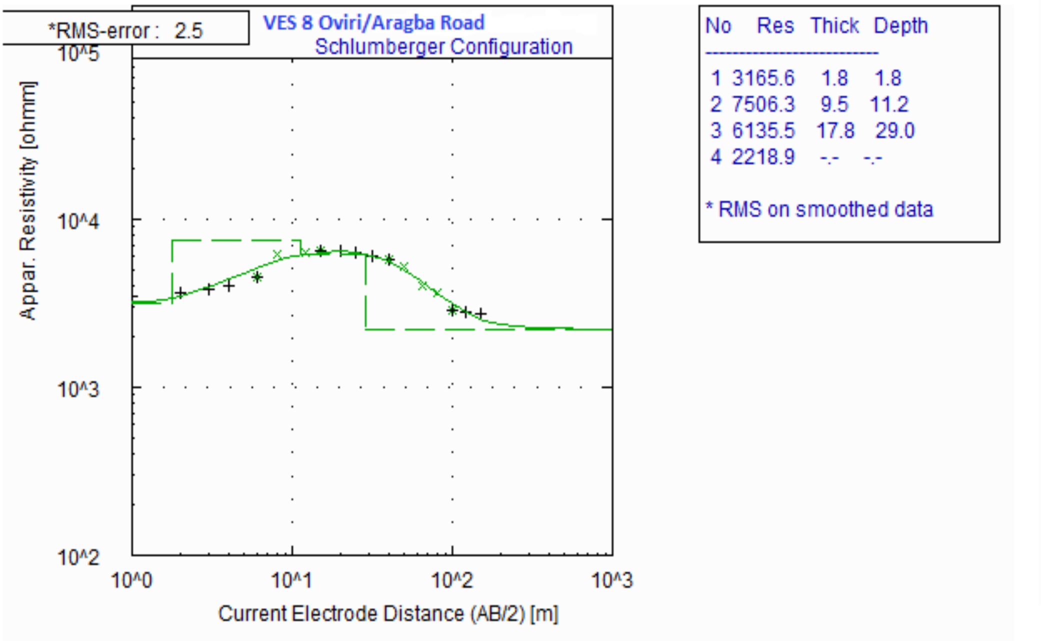

Fig. 9. Resistivity Sounding Interpretation for VES 8 (Oviri/Aragba Road, Aragba-Okpe) Showing Resistivity Curves and Model Parameters

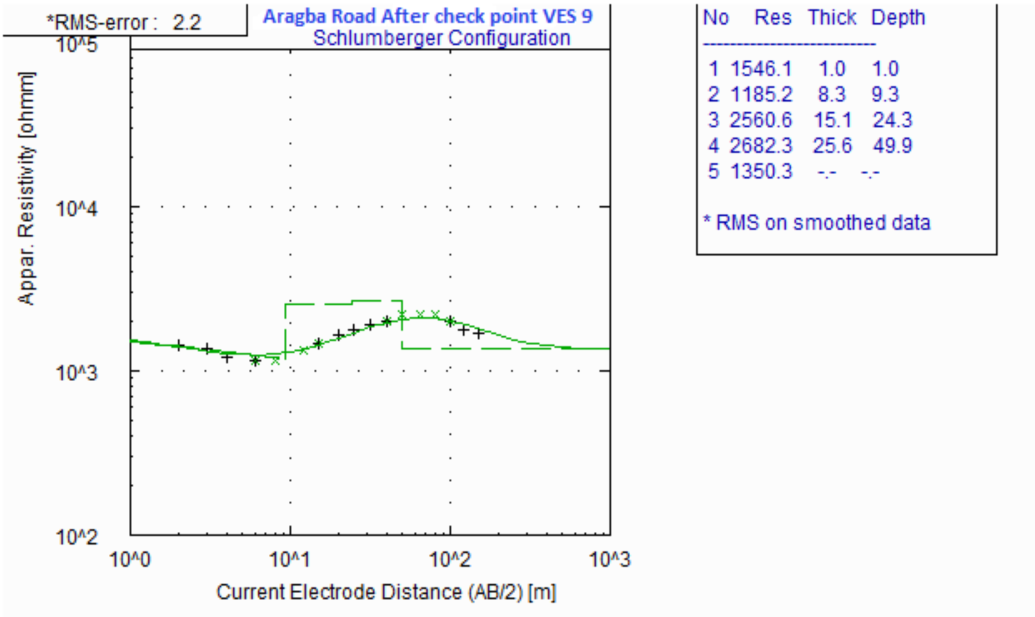

Fig. 10. Resistivity Sounding Interpretation for VES 9 (Oviri/Aragba Road, After Check Point) Showing Resistivity Curves and Model Parameters

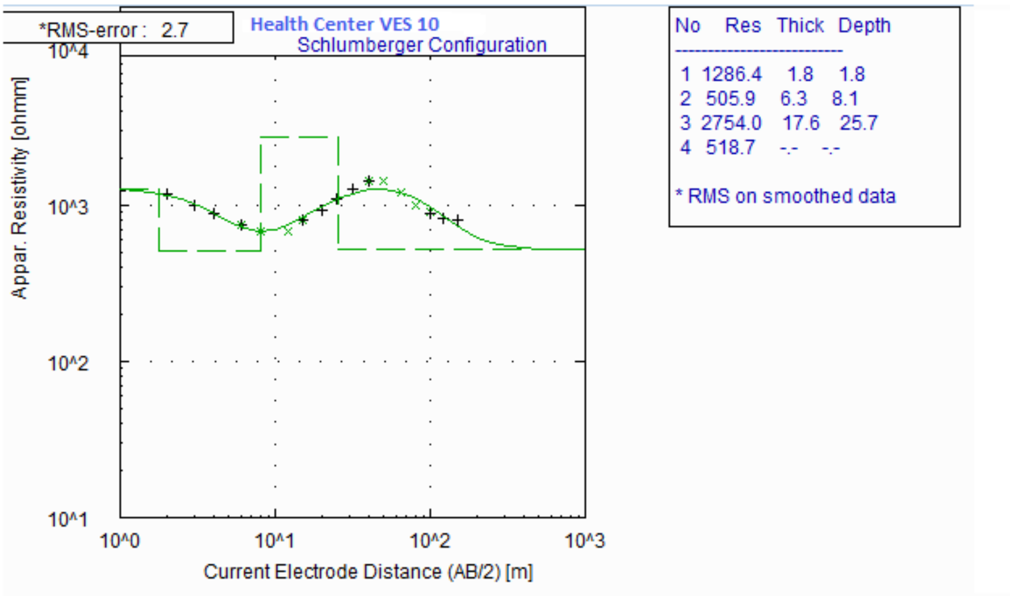

Fig. 11. Resistivity Sounding Interpretation for VES 10 (Health Center, Aragba-Okpe) Showing Resistivity Curves and Model Parameters

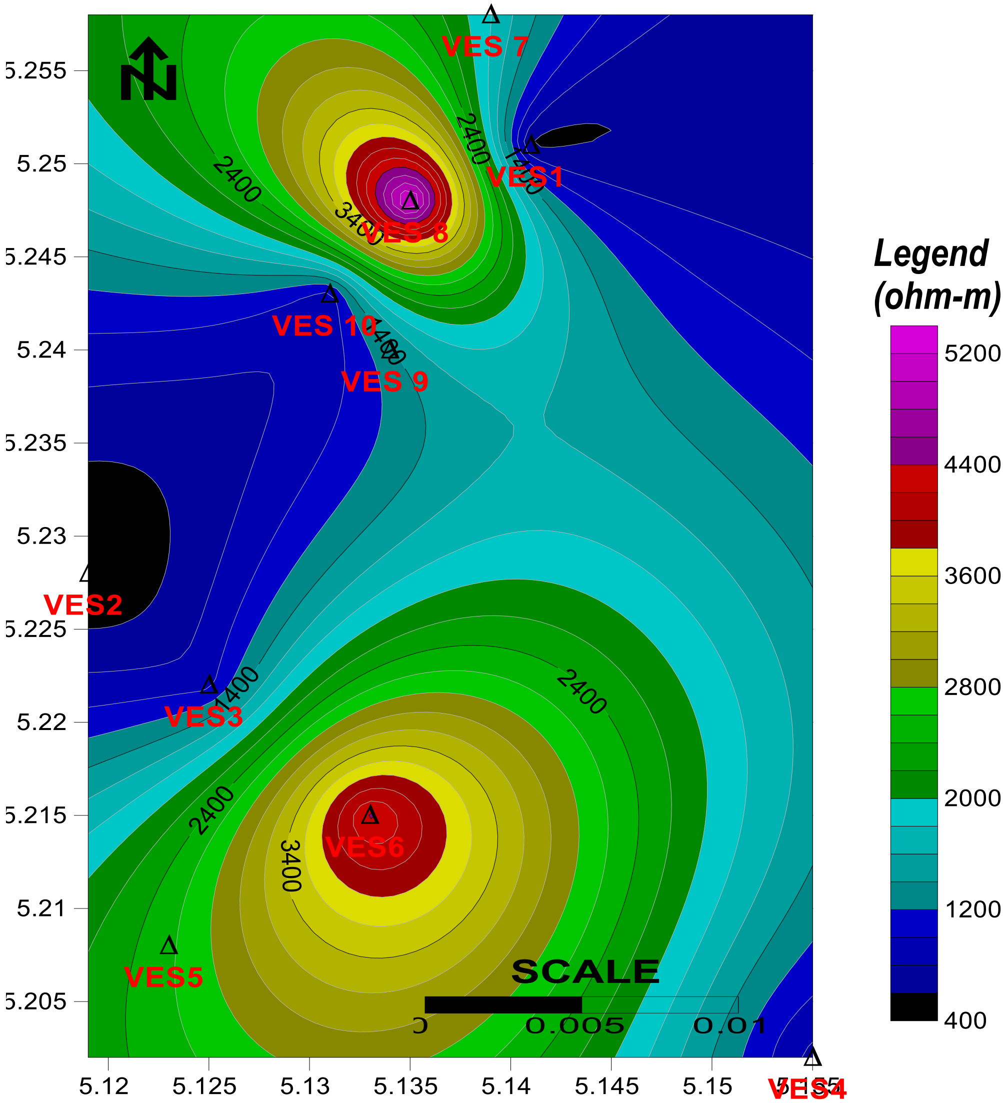

Fig. 12. Iso – resistivity contoured map of the Study area

RESULT

The results of the vertical electrical sounding were presented as Geoelectric section in figure 13 and the curve types and lithologic delineation are shown in Table 1. The aquifer protective capacity was obtained based on the values of the longitudinal unit conductance of the overburden formations. The areas with conductance of greater than 10 mhos are grouped as excellent protective capacity, where the conductance ranged from 5 to 10 mhos are classified very good. If the conductance value is between 0.7 and 4.9 mhos the protective capacity is good. When the conductance is between 0.2 and 0.69 then the area is moderately protected. The zones which have conductance values of between 0.1 and 0.19 mhos has weak protective capacity and that with less than 0.1 mhos is considered as poor aquifer protective capacity (*Egbai, Efeya, & Iserhien-Emekeme, 2015;Oladapo, & Akintorinwa, 2007)*.

The values obtained from longitudinal conductance in Aragba-Okpe revealed that the aquifer is not protected, since the protective capacity rating is generally poor (Table 2). Figure 12 shows the Iso- resistivity contour map of the aquifers in the locations at Aragba-Okpe.

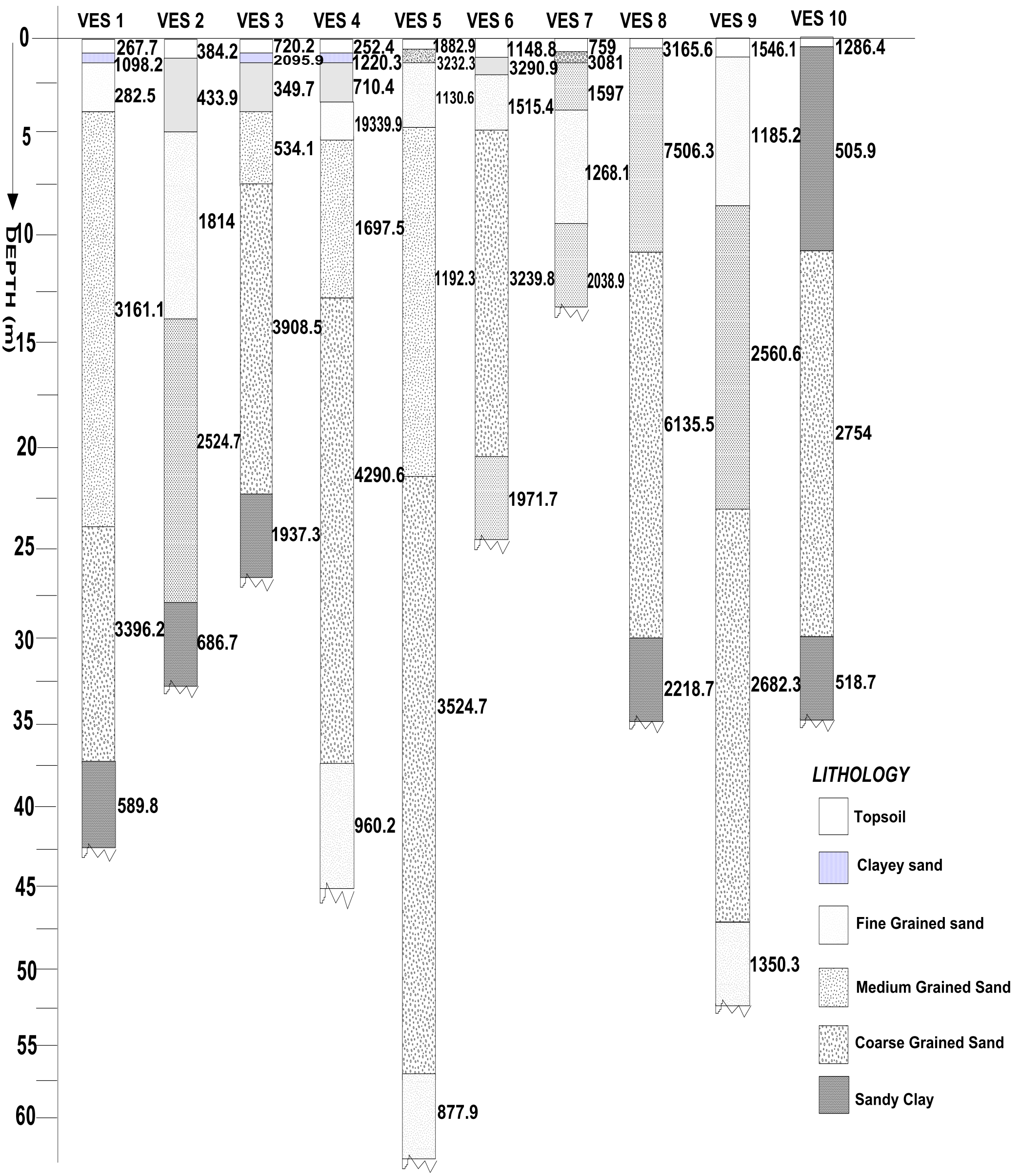

Fig. 13. Geoelectric section of Aragba-Okpe

Table 1

Curve types and lithologic delineation of Aragba-okpe

VES	LAYERS	RESISTIVITY (Ωm)	THICKNESS (m)	DEPTH (m)	LITHOLOGY	TYPE OF CURVE
1	1	267.70	0.80	0.80	Top Soil (Clayey Sand)	KHAK
	2	1098.20	0.40	1.20	Fine Grained Sand	
	3	282.50	3.00	4.30	Clayey Sand	
	4	3161.10	20.90	25.20	Medium Grained Sand	
	5	3396.20	12.60	37.80	Coarse Grained Sand	
	6	589.80	…….	…..	Sandy Clay	
2	1	384.20	1.00	1.00	Top Soil (Clayey Sand)	AAK
	2	433.90	4.80	5.80	Clayey Sand	
	3	1814.00	8.60	14.50	Fine Grained Sand	
	4	2524,70	14.00	28.40	Medium Grained Sand	
	5	686.70	…….	……	Sandy Clay	
3	1	720.20	0.70	0.70	Top Soil (Sandy Clay)	KHAK
	2	2095.90	0.70	0.70	Medium Grained Sand	
	3	349.70	2.00	1.30	Clayey Sand	
	4	534.10	2.00	3.30	Sandy Clay	
	5	3908.50	16.70	22.00	Coarse Grained Sand	
	6	1937.30	…….	……	Medium Grained Sand	
4	1	252.40	1.20	1.20	Top Soil (Clayey Sand)	KHKHK
	2	1220.30	0.90	2.10	Fine Grained Sand	
	3	710.40	1.70	3.80	Sandy Clay	
	4	19339.90	1.60	5.40	Coarse Grained Sand	
	5	1697.50	6.40	11.80	Medium Grained Sand	
	6	4290.60	26.30	38.10	Coarse Grained Sand	
	7	960.20	……	…….	Fine Grained Sand	
5	1	1882.90	0.80	0.80	Top Soil)	KHAK
	2	3232.30	0.80	1.70	Coarse Grained Sand	
	3	1130.60	4.30	5.90	Fine Grained Sand	
	4	1192.30	16.00	22.00	Medium Grained Sand	
	5	3524.70	35.30	57.20	Coarse Grained Sand	
	6	877.90	…….	……	Fine Grained Sand	
6	1	1148.80	0.90	0.90	Top Soil (Fine Grained Sand)	KHK
	2	3290.90	0.90	1.80	Coarse Grained Sand	
	3	1515.40	4.60	6.50	Fine Grained Sand	
	4	3239.80	13.10	19.50	Coarse Grained Sand	
	5	1971.70	…….	……	Medium Grained Sand	
7	1	759.00	0.70	0.70	Top Soil (Sandy Clay)	KQH
	2	3081.00	0.70	1.40	Coarse Grained Sand	
	3	1597.00	1.50	2.90	Medium Grained Sand	
	4	1268.10	6.10	9.00	Fine Grained Sand	
	5	2038.90	……	…..	Medium Grained Sand	
8	1	3165.60	1.80	1.80	Top Soil	KQ
	2	7506.30	9.50	11.20	Medium Grained Sand	
	3	6135.50	17.8	29.0	Coarse Grained Sand	
	4	2218.70	……	……	Medium Grained Sand	
9	1	1546.10	1.00	1.00	Top Soil	HAK
	2	1185.20	8.30	9.30	Fine Grained Sand	
	3	2560.60	15.10	24.30	Medium Grained Sand	
	4	2682.30	25.60	49.90	Coarse Grained Sand	
	5	1350.30	……	……	Fine Grained Sand	
10	1	1286.40	1.80	1.80	Top Soil	HK
	2	505.90	6.30	8.10	Sandy Clay	
	3	2754.00	17.60	25.70	Medium Grained Sand	
	4	518.70	……	……	Sandy Clay	

Table 2

First order Geoelectric Parameter and Dar Zarrouk Parameter of Aragba-Okpe

VES	Protec-ting Layers	Protecting Resistivity ρ (Ωm)	Thickness h (m)	$\frac{\sum \rho}{n} = \overline{R}$	$H_{T=h_1+h_2+....}$	Longitudinal Conductivity of Protecting Layers $H_T / \overline{R}$	Protective Capacity Rating
1	1 2 3	267.70 1098.20 282.50	0.80 0.40 3.00	549.47	4.20	0.0076	Poor
2	1 2	384.20 433.90	1.00 4.80	409.05	14.80	0.0036	Poor
3	1 2 3 4	720.20 2095.90 349.70 534.10	0.70 0.70 2.00 2.00	942.98	5.40	0.0058	Poor
4	1 2 3 4	252.40 1220.30 710.40 19339.90	1.20 0.90 1.70 1.60	727.70	3.80	0.0052	Poor
5	1 2	1882.90 3232.30	0.80 0.80	2557.60	1.60	0.0006	Poor
6	1 2	1148.80 3290.90	0.90 0.90	4439.70	1,80	0.0004	Poor
7	1 2 3	759.00 3081.00 1597.00	0.70 0.70 1.50	1812.33	2.90	0.0016	Poor
8	1 2	3165.60 7506.30	1.80 9.50	5335.95	11.30	0.0021	Poor
9	1 2	1546.10 1185.20	1.00 8.30	1365.65	9.30	0.0068	Poor
10	1 2	1286.40 505.90	1.80 6.30	896.15	8.10	0.0090	Poor

Discussion of result

The data obtained in Aragba Primary School (VES1) revealed six layers of KHAK type curve. The top soil is composed of clayey sand at a depth of 0.8 m with thickness of 0.8 m. Below this formation is fine grained sand at a depth of 1.2 m, thickness of 0.40 m and resistivity value of 1098.20 Ωm. Underlying the fine grained sand is another layer of clayey sand at a depth of 4.3 m, thickness of 3.0 m and resistivity of 282.5 Ωm. This is followed with two layers of coarse grained sand formations. This is the aquifer zone with an average resistivity value of 3278.65 Ωm at a depth of 53 m and thickness of 34 m, below these layers is a sandy clay formation with resistivity of 589.8 Ωm at an unknown depth and thickness since it is the last layer. Thus, the survey identified two continuous aquifer layers of thickness 33.5 m at an average depth of 32 m.

Aragba Health Center (VES 2) showed a characteristic AAK curve type. The thickness and depth of the top soil is 1 m each and characterized by clayey sand of resistivity 384.40 Ωm. Underlying the top soil is a clayey sand formation. It has a resistivity value of 433.9 Ωm with thickness and depth of 4.8 m and 5.8m respectively. Below this formation are the third and fourth layers of medium grained sand formations at an average depth of 25 m and thickness of 12 m with mean resistivity value of 2169 Ωm. This is one of the best regions for groundwater development in Aragba-Okpe. The last layer is a sandy clay formation.

The Location at Okeme Street (VES 3) is a KHAK type curve of six layers. The top soil is sandy clay with depth and thickness of 0.7 m each. This is followed by a thin layered medium grained sand of 0.7 m which is not a good aquifer. Underlying this layer are two layers of clayey sand and sandy clay formations respectively. The best aquifer is within the fifth and sixth layers that consist of coarse and medium grained sand formations. This layer has a minimum thickness of 17 m and extends from a depth of 22 m to infinity since it is the last layer.

VES 4 obtained after the Army check point in Aragba has seven layers of KHKHK type curve. The first layer which is the top soil is clayey sand of resistivity 252.4 Ωm and with thickness and depths of 1.2 m. The second layer is a fine grained sand formation of resistivity 1220.3 Ωm at a depth of 2.1 m with little thickness of 0.9 m. Underlying this layer are layers of coarse and medium grained sand formations of thickness 12 m and depth 20 m with a mean resistivity of 8842.47 Ωm. This is followed by extensive fine grained sand formation at the last layer.

VES 5 obtained from Aragba Junction before the Army check point close to Aragba Secondary School showed a characteristics KHAK curve type. The top two layers have high resistivity values with little thickness of about 0.8 m. This is followed by another two layers of fine grained sand. The best aquifer for sustainable water development is in the fifth layer at a depth 57 m and thickness of 35m with resistivity of 3524.70 Ωm signifying coarse grained sand formation. This is followed by fine grained sand at the last layer to an infinite depth.

The location at Aragba road after check point (VES 6) is a KHK type curve with six layers. Apart from the top which is fine grained sand, the entire station revealed alternation of fine to medium and coarse grained sand formations. The best aquifer is in the fourth layer with thickness of 13 m and at a depth of 20 m.

The station at Oviri-Aragba road (VES 7) showed a characteristics KQH type of curve indicating five layers. The resistivity of the top soil 759 Ωm implying sandy clay formation extends to a depth and thickness of 0.7 m respectively. This layer is followed by coarse grained sand formation with small thickness that cannot sustain appreciable water as an aquifer. The next two layers are of fine grained sand formations. The best aquifer is in 5^{th} layer with resistivity value of 2038.90 Ωm at a depth of 20 m and an infinite thickness since it is the last layer.

VES 8 taken along Oviri Aragba road is a KQ 4 layer type of curve. The aquifer is in the 3^{rd} layer with resistivity value of 6,135.50 Ωm at a depth of 29.00 m and thickness of 17.80 m.

VES 9 obtained also along Oviri Aragba road sfter the check point is an HAK type curve of 5 layers. The aquifer is in the 3^{rd} layer at a depth of 24.30 m and thickness of 15.10 m.

VES 10 located close to the health center is a 4 layered HK type curve. The aquifer is also in the 3^{rd} layer with resistivity of 2754.00 Ωm at a depth of 25.70 m and thickness of 17.10 m.

The low value of the protective capacity is as a result of the absence of significant quantity of clay which may enhance the percolation of contaminants into the aquifer.

Conclusion and recommendation

This study is aimed at delineating the groundwater potential and estimating the clay deposit in Aragba-Okpe using electrical resistivity method. The study revealed that boreholes for sustainable water supply could be drilled to a depth of 30 m in Aragba-Okpe, However, the third to the fifth layers within Aragba Primary School, Aragba Secondary School and Oviri Aragba Road (VES 1, 5, 7, 8 and 9) are the best locations for sustainable water supply

The study also revealed that there is no reasonable deposit of clay which will serve as protective capacity for aquifer. The absence of this solid mineral has adverse effect on the groundwater potentials as most aquifers are not overlain by very thick overburden material of deposit of clay to serve as a filter to underground water. The unavailability of significant clay deposit in Aragba-Okpe is also an advantage because buildings and roads in this area cannot easily fail due to enough fine sand, medium sand and coarse sand formations.

It is saving not only to recommend the dredging for sand in Aragba-Okpe for commercial purposes but to manage waste disposal properly and drill boreholes to a depth of 30 m within the third to the fifth layer for less contaminated groundwater because of the low protective capacity ratings as shallow aquifers are easily contaminated.

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References

Christensen, N. B., & Sorensen, K. I. (1998). Surface and borehole electric and electromagnetic methods for hydrogeological investigations. European Journal of Environmental and Engineering Geophysics, Vol. 3 (1), 75 – 90. [in English].

Egbai, J. C. (2011). Vertical Electrical Sounding for the investigation of clay deposit in Orerokpe. Delta State. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), No. 2 (2), 260 – 265. [in English].

Egbai, J. C., Efeya, P. & Iserhien-Emekeme, R. E. (2015). 2D Geoelectric Evaluation and Imaging of Aquifer Vulnerability of Dump Site at Ozoro Isoko South L.G.A of Delta State. Journal of Natural Sciences Research, Vol. 5, No. 10, 1 – 11. [in English].

Ezomo, F. O. & Aiyohuyin, E. O. (2012). Existence of sandstone deposit in Isihor Village Area of Edo State. Nigerian Journal of Science and Technology, Vol. 1, No. 8, 405 – 410. [in English].

Ezomo, F. O. (2012). Geophysical study of clay attributes in Iruekpen Village Area of Edo State Nigeria. Journal of Emerging Trends in Engineering and Applied Sciences (JETEAS), Vol. 3 (3), 563 -566. [in English].

Okolie, E. C., Osemeikhian, J. E. A., Atakpo, E. A., & Oseji, J. O. (2005). Geophysical Investigation of the source of River Ethiope in Ukwuani Local Government Area of Delta State. Nigeria Journal of Physics, Vol. 17, 21-26. doi.org/10.4314/njphy.v17i1.37987. [in English].

Oladapo, M. I. & Akintorinwa, O. J (2007). Hydrogeophysical Study of Ogbese Southwestern. Nigeria Global Journal of Pure and Applied Sciences, Vol. 13 (1), 55 -61. [in English].

Oseji, J. O. (2011). Surface Geoelectric Sounding for the Determination of Aquifer Characteristics in Aboh and Environs Delta State. International Journal of Research and Reviews in Applied Sciences (IJRRAS), Vol. 6 (2), 230 – 235. [in English].

Oseji, J. O. (2014). Application of Vertical Electrical Sounding Method to Decipher the Existing Sub-Surface Stratification and Groundwater Occurrence Status in Orogun Main Town, Delta State, Nigeria. Journal of the Nigerian Association of Mathematical Physics, Vol. 27 (July), 301 -314. [in English].
Otutu, O. J. (2013). Investigation of the Groundwater Resources and Aquifer Characteristics in Utagba-Uno Area, Delta State, Nigeria Using Surface Geoelectric Sounding. Journal of the Nigerian Association of Mathematical Physics, Vol. 25 (Nov.), 157-172. [in English].
Sørensen, K. I., Auken, E., Christensen, N. B., & Pellerin, L. (2005). An Integrated Approach for Hydrogeophysical Investigations: New Technologies and a Case History. In D. K. Butler (Ed.), Near-Surface Geophysics (Vol. 13, pp. 585-605). USA: Society of Exploration Geophysics. Investigations in Geophysics, Vol.. No. 13. [in English].
Vande Velpen, B. P. A. (2004). Win Resist Version 1.0 M. Sc Research project, ITC, Deft, Nertherlands. [in English].
Zohdy, A. A. (1974). Automatic Interpretation of Schlumberger Sounding Curves. Geological Survey Bulletin, Washington: 1313-E US Government Printing Office. [in English].
Zohdy, A. A., Eaton, C. P., & Mabey, D. R. (1974). Application of Surface Geophysics to Groundwater Investigation. Tech. Water resources Investigation. US Geological Survey, Washington D.C., 2401 – 2543. [in English].