Journal of the Nigerian Association of Mathematical Physics
Volume **25 (November, 2013), pp 239 – 250**
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Groundwater Exploration in Awa-Ijebu, Nigeria, Using the Resistivity Method.

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Abstract

A geophysical investigation was carried out in Awa- Ijebu, Nigeria to determine the groundwater potential and the geological structure of the area. The method employed in this study was the Vertical Electrical Sounding (VES) using the Schlumberger configuration. Ten soundings were carried out at different locations. Half- spacing in the range of 1- 100m with the aid of ABBEM TERRAMETER SAS (Signal Averaging System) 3000B and a booster SAS 2000 manufactured in Sweden was applied.The interpretation of the resistivity curves over the study area within geologic terrain often referred to as basement environment indicates that the area have groundwater potential.

***Keywords*:** Groundwater, electrical resistivity sounding, aquifer, water formation.

1.0 Introduction

This paper describes the geoelectric investigations undertaken in Awa-Ijebu in Ogun state with the aim of exploring groundwater potential of the area. Groundwater is a very important resource and it is also widely used as a source for the supply of drinking water and irrigation in food production. Naturally, about 53% of all population relies on groundwater as a source of drinking water. It is known to occur more widely than surface water. But, unfortunately, groundwater availability is limited by so many factors, hence, the urgent need for a thorough geophysical survey to determine amongst others the suitable the suitable ground point for borehole construction and determination of the hydrostratigraphic characteristics of the subsurface layers.

Work done by researchers [1] in Ago- Iwoeye, Oru, and Ijebu – Igbo; neighbouring communities to Awa- Ijebu showed that the flow of water above and below the ground surface in these areas and their environs are controlled by relief, weathered basement rocks, landform, and nature of the aquifer. Geophysical prospecting methods generally involve either direct or indirect use of physical parameters to study the part of the earth that is hidden from our direct views by measuring physical quantity at the surface. The choice of any method used therefore depends on the known and the anticipated physical properties of the target, details of instruments required, logistics, equipment and the purpose for which the survey is intended. While some physical methods are ideal for large anomalies only, others are most appropriate for small anomalies.

The superiority of the geoelectric method over others in the groundwater research is based on its ability to furnish information on the subsurface geology which is unobtainable by other methods in the groundwater studies. The resistivity techniques with Schlumberger array has been successfully utilized in assessing water supply potential in boundaries and in the assessment of groundwater resources potentials. It has greater penetration than the Wenner because Wenner configuration discriminates between resistivities of different geoelectric lateral layers while the Schlumberger configuration is used for depth sounding [2 - 5]. There is therefore an urgent need to have reliable water supply to the growing population of this community due to the erratic nature of the public water supplies in the country [6].

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2.0 Physical and geological setting of the study area

The study area is a part of South-western Nigeria, which lies within the longitudes N7°11' and N7°15' and latitudes E3°47' and E 3°55'. The topography map of the study area is shown in figure 1. The topography is undulating, and ranges from high to low relief. The drainage pattern is dendritic, and shows that surface water flows in northeast-southwest direction. The physiography of the study area results from the geomorphic processes that have shaped the terrain. Geologically, the study area lies within the basement complex of south western Nigeria. According to [7], the basement complex is underlain by crystalline, igneous and metamorphic rocks. However, the recent advances in the study of the basement complex of Nigeria, as presented by **[**8 - 9**]**, reveal that the Nigerian basement complex comprises six major rocks group. The rocks in the study area occur either directly exposed or covered by shallow mantle of superficial deposits. These are:

i. Coarse- Porphyritic Hornblende-Biotite-Granodiorite,
ii. Biotite Granite Gneiss,
iii. Pegmatite,
iv. Variably Migmatised undifferentiated Biotite and Biotite Hornblende Gneiss with inter calated Amphibolites,
v. Quartzite and Quartz Schist,
vi. Amphibole Schist and Amphibolites, and
vii. Undifferentiated Gneiss complex probably mainly Schist.

Coarse- Porphyritic Hornblende-Biotite-Granodiorite is prominent in Oru. It displays a considerable variation in the amount of mafic and felsic minerals and in the degree of banding. It is a combination of three different rocks, i.e. Hornblende, Biotite and Granodiorite. The texture is coarse in nature. Biotite granite gneiss with foliation concomitantly shows affinities of the Gneiss Complex Rocks. They are common and widely occurring type of intrusive, felsic, igneous rock, usually of medium to coarsely crystalline. Biotite granite gneiss are characterized by alteration of mafic and felsic minerals which varies in width. Mineral content include biotite which is the most abundant, other accessory minerals associated with biotite granite gneiss are quartz, muscovite, orthoclase feldspar [8 - 9]. Pegmatites in the study area are coarse grained, and appeared to fall into two categories; the first stage is related to migmatisation and the second was related to the emplacement of granite bodies during the main phase or later phase of magmatism. The migmatites found in the study area are fine to coarse grained and are associated with quartzofelspathic veins that are concordant or discordant to strike direction. Migmatite occur as intrusion in the host rock, undifferentiated Gneiss complex probably mainly schist, which must have been emplaced during the period of Older granite. It is a heterogeneous group and comprises largely migmatitic and granitic gneisses, basic schist and gneisses, and relict metasedimentary calcareous, quartzitic and granulitic rocks, a grey foliated biotite acid / or biotite. Hornblende. Quartz, feldspathic gneiss of tonalitic to granodioritic composition which is now known as the grey gneiss or early gneiss **.** It is present in most outcrops. Quartzite which is a metamorphic rock usually formed by metamorphism of sandstone. They are foliated rocks in which quartz is a commonly mineral present. Metamorphism causes the quartz grains of sandstone to grow together to form one of the hardest and most resistant of common rocks. It's distinguished from sandstone by the indistinctness of its grains by the greater smoothness of its fracture surface. Variably Migmatised undifferentiated Biotite and Biotite Hornblende Gneiss with intercalated Amphibolites, here, gneiss represents the same intensity of metamorphism as the schist but less predominant in biotite. They are grey to almost white in colour and resemble granite very closely except for further alignment of biotite and hornblende. Best exposure as around Refugee camp in Oru. Amphibole is a silicate mineral which exhibits a vitreous uster and perfect cleavage. They occur commonly in igneous and metamorphic rocks. While amphibole exhibits schistocity which is foliation produced by deformation, Amphibolites is a non-foliated metamorphic rocks composed mainly of amphibole formed by the regional metamorphism of basic igneous rocks. Undifferentiated Gneiss complex probably mainly Schist group constitutes the schist belts of Nigeria features in most part of the study area. They show lithologic similarities to the schist belts from the other parts of the world [7] which are known to harbour important economic mineral deposits.The schist belts occupy N-S trending synformal troughs infolded into the migmatite – gneiss complex and which are the best developed in the western part of the country. Seventeen main belts have so far been identified . They define the structural grain of the basement. They are largely sediments dominated, and the most important lithologies are pelites and quartzites.

3.0 Methodology

Vertical Electrical Soundings (VES) were carried out in the study area with an ABEM TERRAMETER SAS (Signal Averaging System) 3000B with booster SAS 2000 manufactured in Sweden was used for taking surface resistivity readings. The equipment is light and powerful for deep penetrations. The resistivity survey was completed with three sounding stations. The VES was conducted by using the schlumberger array (AB) ranging from 2 metres to 200 metres (AB/2 was 1 – 100m). The field data acquisition was generally carried out by moving two or four of the electrodes used between each measurement [10].

The VES of the three sounding stations were obtained by plotting the calculated apparent resistivity against electrode spacing. Computer programs for reducing geoelectrical sounding curves into thickness and resistivity of individual layer were applied. The field curves were interpreted by the method of curve matching. The field curves and the results of the curve matching were then subjected to computer assisted iterative interpretation. The end result of the field measurement is the computation of the apparent resistitivity, using the equation

$$\rho_a = \frac{KV}{I} = KR \qquad (1)$$

where

$$K = \frac{\frac{\Pi}{2}\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{\left(\frac{MN}{2}\right)} \qquad (2)$$

and

ρ_a = Apparent Resistivity
K = Geometric factor
V = Volt; I = Current;
R = Resistance
AB = Current Electrodes Separation
MN = Potential Electrodes Separation.

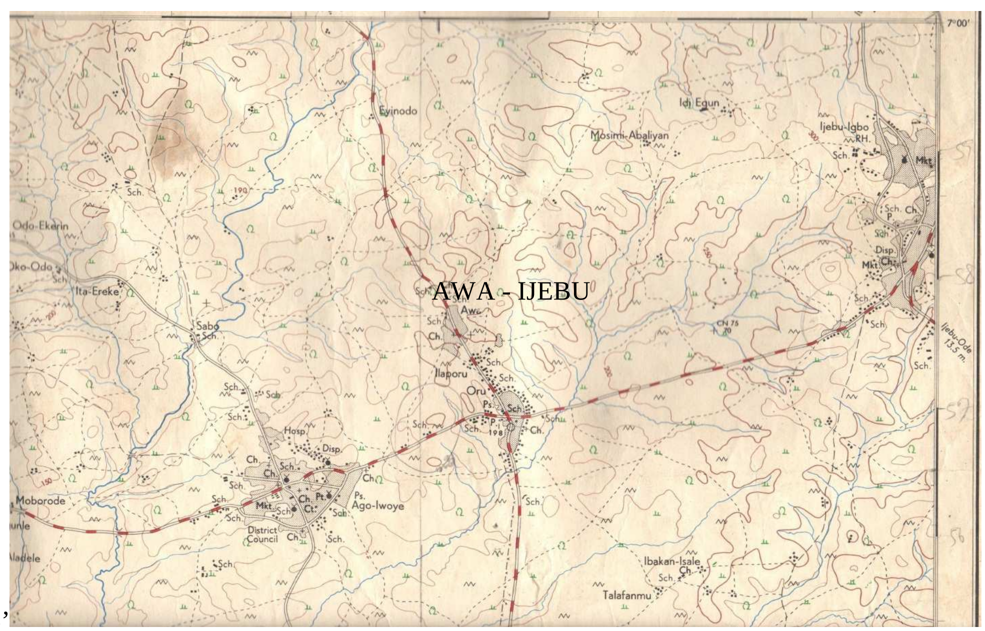

Figure 1. Map of Awa-Ijebu and environs.

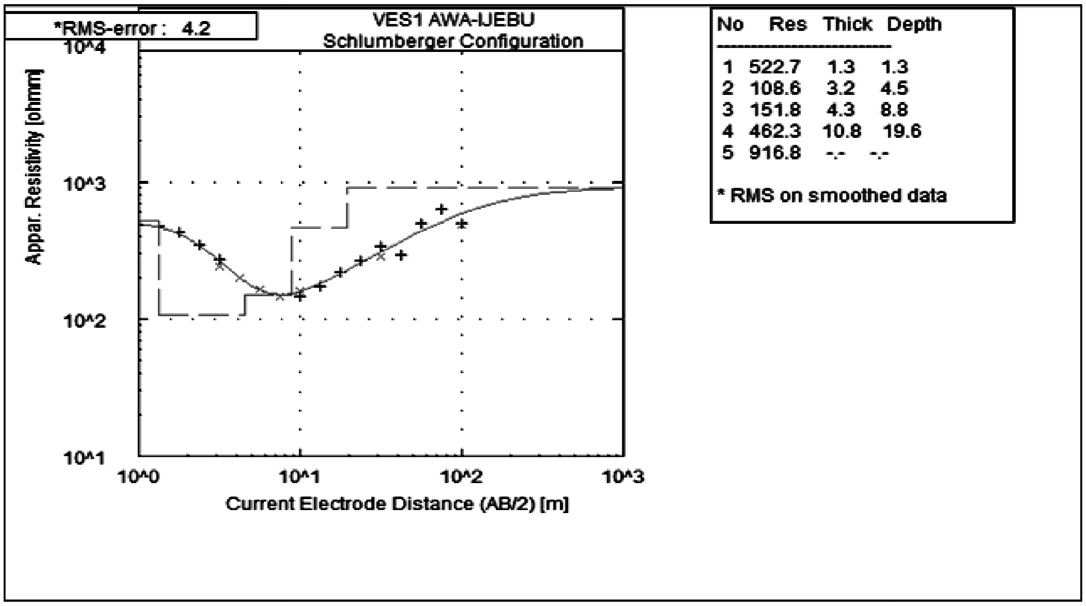

Figure 2: Field and theoretical curves for VES 1

Table 1: Geoelectric layer parameter analysis of VES No. 1

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	522.70	1.30	1.30	Top soil
2	108.60	3.20	4.50	Clayey sand
3	151.80	4.30	8.80	Sand clay
4	462.30	10.80	19.60	Shale
5	916.80	-	-	Oil shale

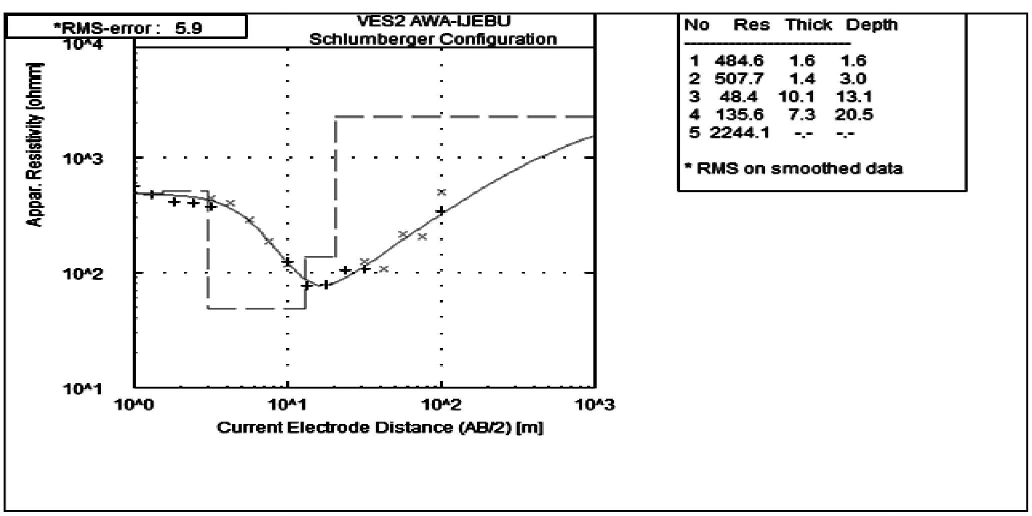

Figure 3: Field and theoretical cuves for VES 2

Table 2: Geoelectric layer parameter analysis of VES No. 2

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	484.60	1.60	1.60	Top soil
2	507.70	1.40	3.00	Sand
3	48.40	10.10	13.10	Clay
4	135.60	7.30	20.40	Shale
5	2244.10	-	-	Oil shale

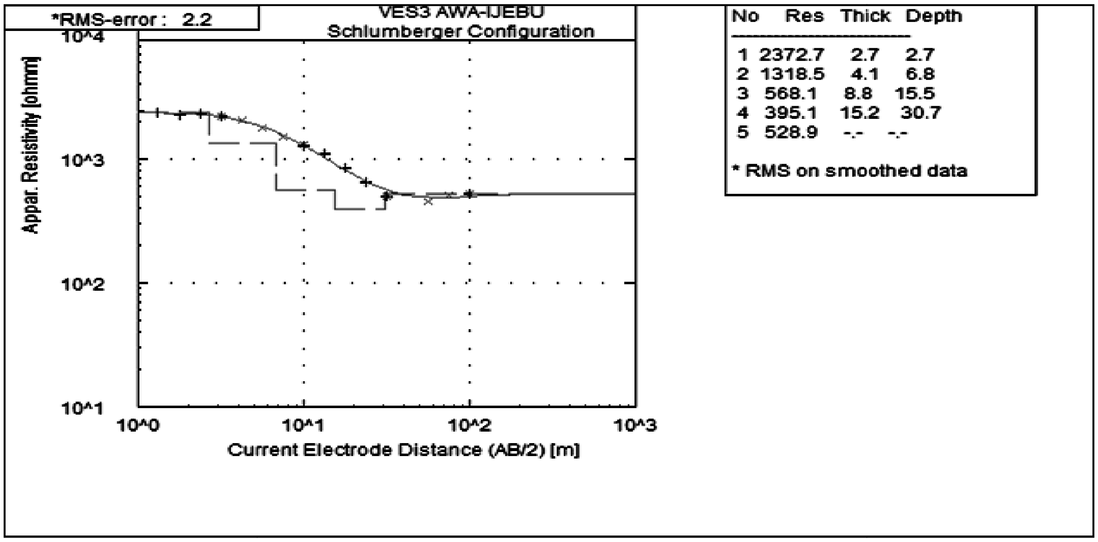

Figure 4: Field and theoretical curves for VES 3

Table 3: Geoelectric layer parameter analysis of VES No. 3

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	2372.70	2.70	2.70	Top soil
2	1318.50	4.10	6.80	Sand
3	568.10	8.80	15.60	Shale
4	395.10	15.20	30.80	Oil shale
5	528.90	-	-	Dry sand

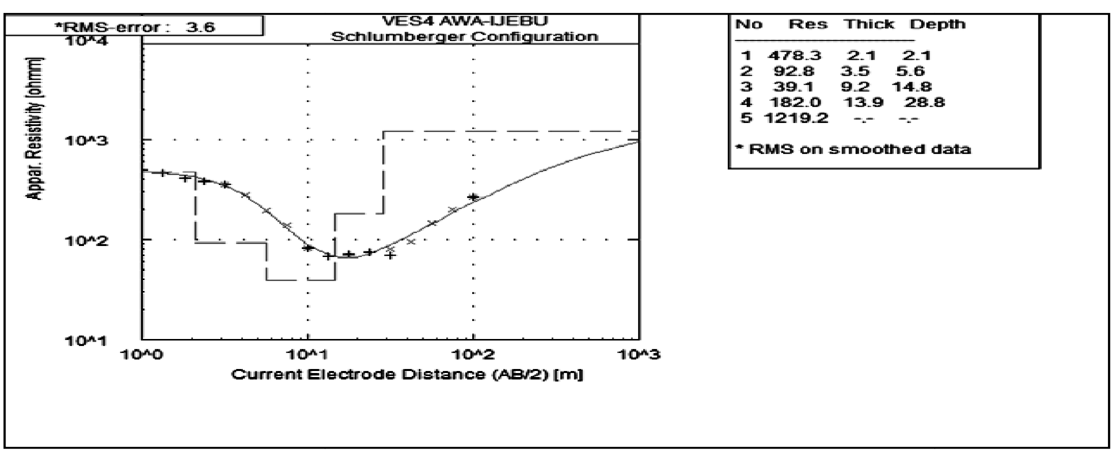

Figure 5: Field and theoretical curves for VES 4

Table 4: Geoelectric layer parameter analysis of VES No. 4

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	478.30	2.10	2.10	Top soil
2	92.80	3.50	5.60	Surface water
3	39.10	9.20	14.80	Shale
4	1820.00	13.90	28.70	Oil shale
5	1219.20	-	-	Dry sand

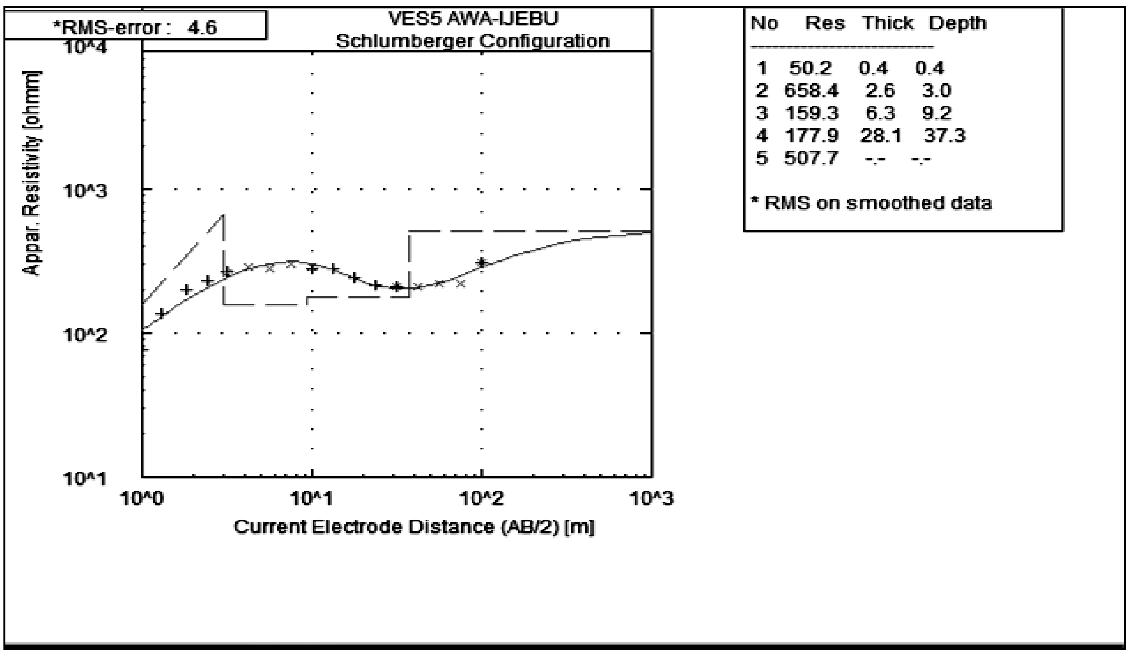

Figure 6: Field and theoretical curves for VES 5

Table 5: Geoelectric layer parameter analysis of VES No. 5

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	50.20	0.40	0.40	Top soil
2	658.40	2.60	3.00	Sand
3	159.30	6.30	9.30	Sandy Clay
4	177.90	28.10	37.40	Oil shale
5	507.70	-	-	Dry sand

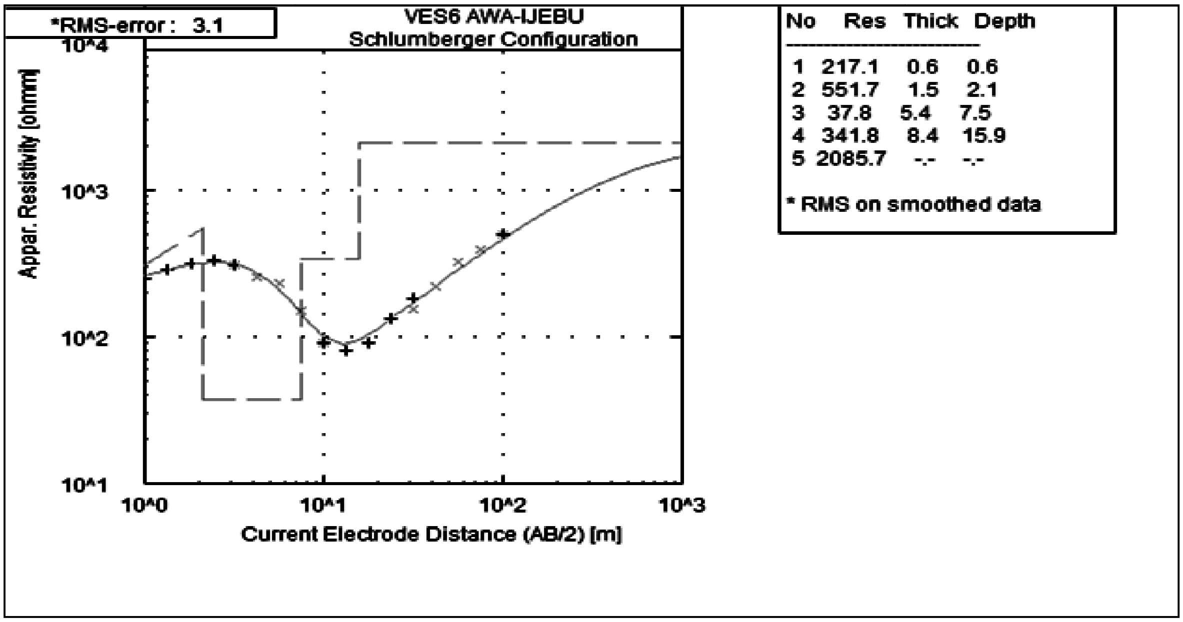

Figure 7: Field and theoretical curves for VES 6

Table 6: Geoelectric layer parameter analysis of VES No. 6

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	217.10	0.60	0.60	Top soil
2	551.70	1.50	2.10	Sand
3	37.80	5.40	7.50	Clay/Surface water
4	341.80	8.40	15.90	Shale
5	2085.70	-	-	Dry sand

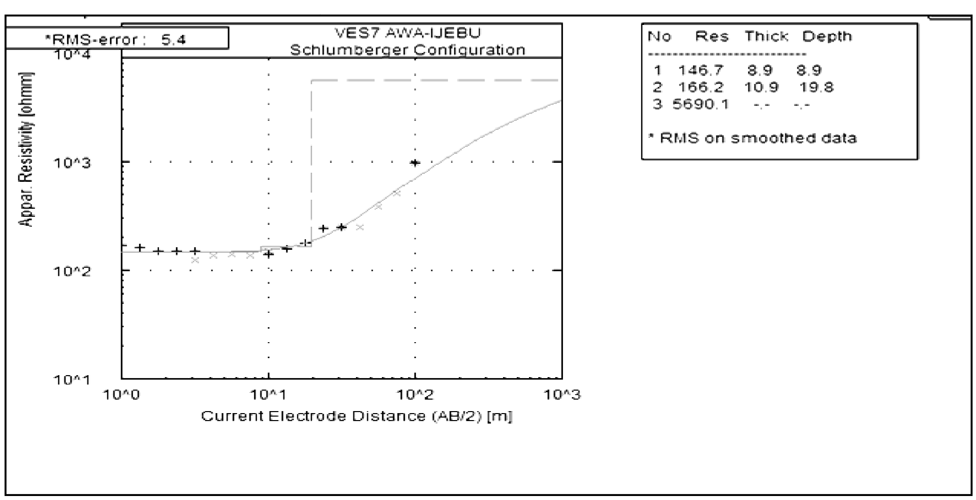

Figure 8: Field and theoretical curves for VES 7

Table 7: Geoelectric layer parameter analysis of VES No. 7

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	146.70	8.90	8.90	Top soil
2	166.20	10.90	19.80	Shale
3	5690.10	-	-	Dry sand

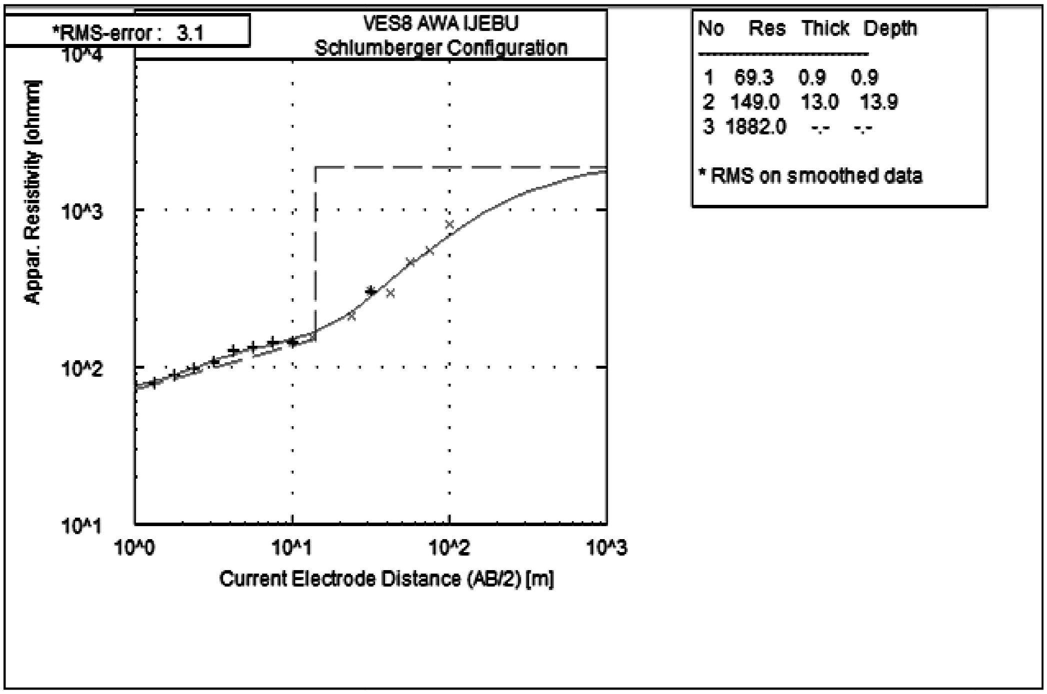

Figure 9: Field and theoretical curves for VES 8

Table 8: Geoelectric layer parameter analysis of VES No. 8

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	69.30	0.90	0.90	Top soil
2	149.00	13.00	13.90	Clayey sand
3	1882.00	-	-	Fresh basement

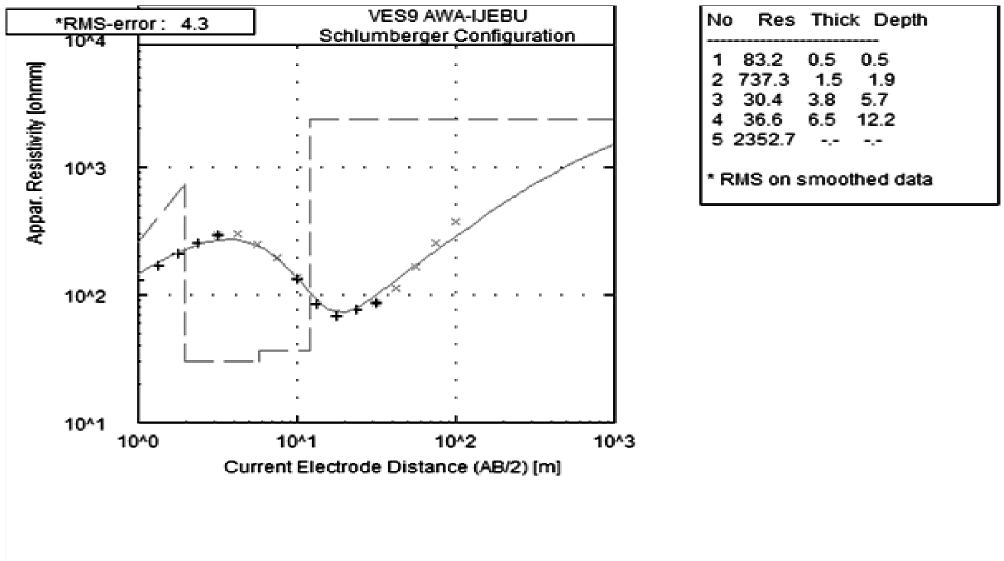

Figure 10: Field and theoretical curves for VES 9

Table 9: Geoelectric layer parameter analysis of VES No. 9

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	83.20	0.50	0.50	Top soil
2	737.30	1.50	2.00	Lateritic sand
3	30.40	3.80	5.80	Clay
4	36.60	6.50	12.30	Clay/weathered basement
5	2352.70	-	-	Fresh basement

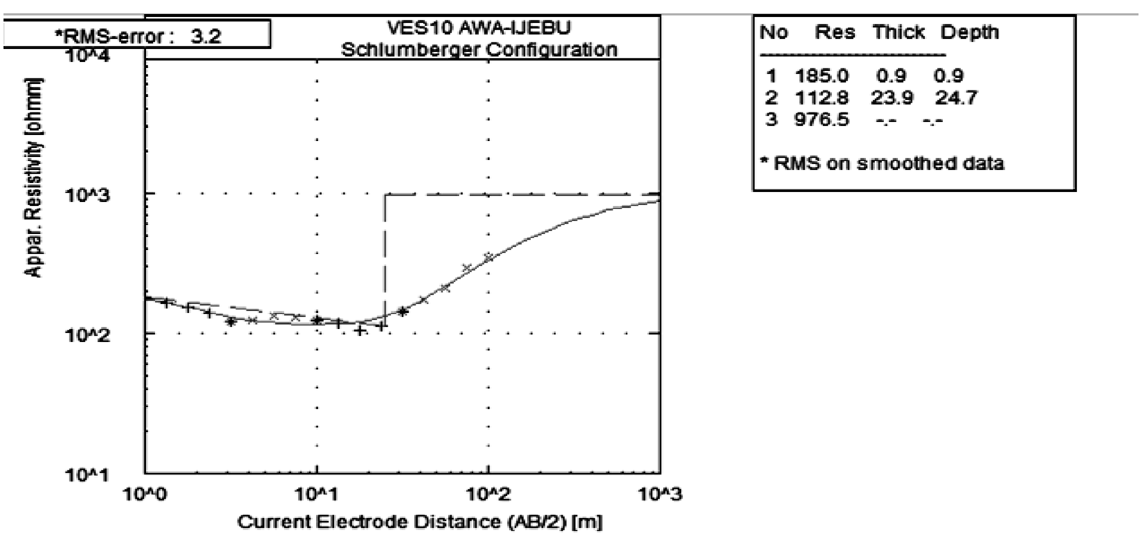

Figure 11: Field and theoretical curves for VES 10

Table 10: Geoelectric layer parameter analysis of VES No. 10

Geoelectric layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	185.00	0.90	0.90	Top soil
2	112.80	23.90	24.80	Clayey sand
3	976.50	-	-	Fresh basement

Table 11: Summary of results

Geoelectric Layer	Curve Shape	Depth to Aquifer(m)	Latitude	Longitude	Elevation (m)
1.	HAA	4.50	E003^0 56$'$ 01.4$''$	N06^0 57$'$ 127$''$	65
2.	KHA	Not penetrated	E003^0 55$'$ 58.2$''$	N06^0 57$'$ 06.9$''$	67
3.	QQH	15.60	E003^0 55$'$ 54.5$''$	N06^0 57$'$ 01$''$	67
4.	QHK	Below 28.70	E003^0 55$'$ 53.1$''$	N06^0 56$'$ 54.7$''$	72
5.	KHA	9.30	E003^0 55$'$ 56.9$''$	N06^0 56$'$ 56.5$''$	77
6.	KHA	Not penetrated	E003^0 56$'$ 05.6$''$	N06^0 57$'$ 20$''$	74
7.	Q	Not penetrated	E003^0 56$'$ 08.3$''$	N06^0 57$'$ 26.2$''$	82
8.	A	Not penetrated	E003^0 56$'$ 04.9$''$	N06^0 57$'$ 26.7$''$	86
9.	KH	Not penetrated	E003^0 56$'$ 21.6$''$	N06^0 57$'$ 20.08$''$	75
10.	H	24.80	E003^0 56$'$ 16.3$''$	N06^0 57$'$ 25$''$	75

4.0 Discussion and conclusion

The geoelectric section of VES 1 indicates five geoelectric layers and its apparent resistivity curve is the HAA-type, with $\rho_1 > \rho_2 < \rho_3 < \rho_4 < \rho_5$. The first layer has a resistivity value of 522.70Ωm with a thickness of 1.60m indicating the top soil. The second layer has a resistivity value of 108.60Ωm with a thickness of 3.20m and it shows the presence of clayey sand. The third layer with a resistivity value of 151.80Ωm and a thickness of 4.30m is suspected to be sandy clay. The fourth layers with a resistivity value of 462.30Ωm and a thickness of 10.80m is a shale deposit. The fifth layer has a resistivity value of 916.80Ωm and it is suspected to be oil shale. The second geoelectric layer of depth 4.50m is the aquifer.

The geoelectric section of VES 2 indicates five geoelectric layer and its apparent resistivity curve is the KHA- type, with $\rho_1 > \rho_2 < \rho_3 < \rho_4 < \rho_5$. The first layer has a resistivity value of 484.60Ωm with a thickness of 1.60m indicating the top soil. The second layer with a resistivity value of 507.70Ωm and a thickness of 1.40m is suspected to be sand. The third layer has a resistivity value of 48.40 Ωm with a thickness of 10.10m which might be clay. The fourth layer with a resistivity value of 135.60Ωm and a thickness of 7.30m is shale. The fifth layer has a resistivity value of 2244.10Ωm, and it is possibly composed oil shale.

The geoelectric section of VES 3 indicates five geoelectric layers and its apparent resistivity curves is the QQH-type, with $\rho_1 > \rho_2 > \rho_3 > \rho_4 < \rho_5$. The first layer has a resistivity value of 2372.70Ωm with a thickness of 2.70m indicates the top soil. The second layer with a resistivity value of 1318.50Ωm and a thickness of 4.10m shows the presence of sand. The third layer has a resistivity value of 568.10Ωm with a thickness of 8.80m and it is made up of shale. The fourth layer has a resistivity value of 395.10Ωm and a thickness of 15.20m is composed of oil shale. The fifth layer of resistivity value 528.90Ωm contains dry sand. The third layer of depth 15.60m is the aquifer.

The geoelectric section of VES 4 indicates five geoelectric layers and its apparent resistivity curve is the QHK –type, with $\rho_1 > \rho_2 > \rho_3 < \rho_4 > \rho_5$. The first layer has a resistivity value of 478.30Ωm with a thickness of 2.10m and it indicates the top soil. The second layer with a resistivity value of 92.80Ωm is of thickness 3.50m, and it is suspected to be surface water. The third layer has a resistivity value of 39.10Ωm with a thickness of 9.20m is made up of shale. The fourth layer with a resistivity value of 1820Ωm and thickness 13.90m contain oil shale. Also, the fifth layer which has a resistivity value of 1219.20Ωm contain dry sand and it is the aquifer.

The geoelectric section of VES 5 indicates five geoelectric layers and its apparent resistivity curve is the KHA-type, with $\rho_1 < \rho_2 > \rho_3 < \rho_4 < \rho_5$. The first layer of apparent resistivity value 50.20 Ωm and thickness 0.40m describes the top soil. The second layer has a resistivity value of 658.40 Ωm and a thickness of 2.60m contains sand. The third layer of resistivity 159.30 Ωm and thickness 6.30m contain sandy clay. The fourth layer with a resistivity value of 177.90 Ωm and thickness 28.10m contain oil shale and the fifth layer has a resistivity value 507.70 Ωm indicating the presence of dry sand. The third layer of depth 9.30m is the aquifer.

The geoelectric section of VES6 indicates five geoelectric layers and its apparent resistivity curve is the KHA-type, with $\rho_1 < \rho_2 > \rho_3 < \rho_4 < \rho_5$. The first layer has a resistivity value of 217.10 Ωm and a thickness of 0.60m indicating the top soil. The second layer which has a resistivity value of 551.70 Ωm with a thickness of 1.50m contains sand. The third layer has a resistivity value of 37.80 Ωm with a thickness of 5.40m and it is believed to contain clay or surface water. The fourth layer has a resistivity value 341.80 Ωm and thickness of 8.40m indicating the presence of shale. The fifth layer with a resistivity value of 2085.70 Ωm is suspected to be made up of dry sand.

The geoelectric section of VES 7 indicates three geoelectric layers and its apparent resistivity curve is the Q-type, with $\rho_1 > \rho_2 > \rho_3$. The first layer has a resistivity value of 146.70 Ωm with a thickness of 8.90m represents the top soil. The second layer has a resistivity value of 166.20 Ωm and a thickness of 10.90m is made up of shale. The third layer which has a resistivity value of 5690.10 Ωm is composed of dry sand.

The geoelectric section of VES 8 describes three geoelectric layers and its apparent resistivity curve is the A-type, with $\rho_1 < \rho_2 < \rho_3$. The first layer has a resistivity value of 69.30 Ωm with a thickness of 0.90m indicating the top soil. The second layer has a resistivity value of 149.00 Ωm and a thickness of 13.00m and it is composed of clayey sand.. The third layer with a resistivity value of1882.00 Ωm is a fresh basement

The geoelectric section of VES 9 contained five geoelectric layers and its apparent resistivity curve is the KH-type, with $\rho_1 < \rho_2 > \rho_3 < \rho_4$. The first layer with a resistivity value of 83.20 Ωm and a thickness of 0.50m is the top soil. The second layer which has a resistivity value of 737.30 Ωm and a thickness of 1.50m contains lateritic sand. The third layer of resistivity value of 30.80 Ωm and a thickness of 3.80m is made up of clay. The fourth layer which has a resistivity value of 36 .60 Ωm and a thickness of 6.50m is suspected to be made up of clay/weathered basement. The fifth layer of apparent resistivity value 2352.70 Ωm is a fresh basement.

The geoelectric section of VES 10 indicates three geoelectric layers and its apparent resistivity curve is the H-type, with $\rho_1 > \rho_2 < \rho_3$. The first layer has a resistivity value of 185.00 Ωm and a thickness of 0.90m indicating the top soil. The second layer has a resistivity value of 112.80 Ωm with a thickness of 23.90m and it is suspected to be clayey sand. The third layer is a fresh basement with apparent resistivity value of 976.50 Ωm . The second layer of depth 24.80m is the aquifer.

Conclusively, geophysical exploration techniques based on the notion of vertical electrical sounding (VES) have demonstrated its usefulness for achieving reliable results that enable the researcher to delineate sequence of aquifers in all the VES locations in Awa- Ijebu.

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