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Research Article

Geoelectrical Investigation of the Groundwater Potential at Laniba, Akinyele Local Government area of Ibadan, Oyo State

Emmanuel Oluwagbemi Joshua[1,3,*], Benjamin Inalegwu Aboje[1], Emmanuel A. Ariyibi[2] and Olusegun Oladotun Adewoyin[3]

[1] *Department of Physics, University of Ibadan. Ibadan, Oyo State, Nigeria*
[2] *Department of Physics, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria*
[3] *Department of Physics, College of Science and Technology, Covenant University, Ota, Ogun State, Nigeria*
***Corresponding author:** eojoshua@yahoo.com

Abstract. Vertical Electrical Sounding (VES) was carried out at Laniba area, Ibadan, Oyo state, Nigeria in order to study the subsurface geologic layer with view of determining the depth to the bedrock and thickness of the geologic layers. The ABEM terrameter (SAS 300B) was used for data acquisition in twenty two (22) VES stations. The field data obtained has been analyzed using computer software (IPI2win) which gives an automatic interpretation of the apparent resistivity. The VES results revealed heterogeneous nature of the subsurface geological sequence. The geologic sequence beneath the study area is composed of hard pan topsoil (clayed and sandy lateritic weathered layer), partly weathered or fractured basement and fresh basement. The resistivity value for the topsoil layer varies from 36.1 to 185.0 Ωm with thickness ranging from 0.1 m to 1.4 m, the weathered basement has resistivity value ranging from 98.0 to 1098.8 Ωm and thickness of between 0.1 m to 1.4 m, the fractured layer has resistivity ranging from 51.5 to 1178.0 Ωm, the fresh basement (bedrock) has resistivity value ranging from 39.1 to 1010.2 Ωm with infinite depth. However, the depth from the earth surface to the bedrock surface varies from 3.1 to 35.5 m.

Keywords. Vertical electrical sounding; Iso-resistivity map; ABEM Terrameter; Basement

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1. Introduction

Surface water was the major source of drinkable water for earlier man and was improved upon in the early years of increasing populations, but unfortunately, surface water reservoirs which are historically cheaper and safer than groundwater as major portable water source have not been properly recharged and maintained to meet the population's need, the quality of water required for domestic and industrial use also need to be taken into consideration. The electrical resistivity method is a geophysical method widely in use presently to determine spatial distribution of quality groundwater suitable for exploitation [1, 2, 3, 4, 5, 6, 7]. This method has also been used by many authors to evaluate the relationship between acquifer electrical and hydraulic properties [8, 9, 10] and in environmental studies [11]. In Kaduna north central area of Nigeria, general hydrogeological condition and aquifer characterization was carried out using electrical resistivity method [12].

The area under study (Laniba) being a developing residential area with good surface sandy and laterite soil and considerable distance to the road needs all the amenities and infrastructures required to make the habitation conducive. Unfortunately there is no public water supply to the inhabitant but they depend on personal effort for domestic use, and can sometimes be inaccessible through digging of wells and sinking of boreholes which could be as a result of inadequate information from the subsurface or lack of technical "know how" among others which this research work stand to address. Since the area is developing and human habitation is springing up, the study therefore seeks to provide good portable water site for human and industrial use, also knowing the best possible location for sinking boreholes in order to access the quality and quantity of underground water.

Another issue that prompted this research is to determine the subsurface lithology which will help delineate depth to which boreholes can be sunk to obtain portable water and thus determines the depth to each layer.

2. Location and Geological Setting

The study area Laniba is located in the north eastern part of Ibadan, southwestern Nigeria within longitude E3°52′24.6″ and E3°52′59.3″ and latitude N7°28′44.7″ and N7°28′59.6″.

Laniba an area of about 150km square including the catchment area. The elevation ranging from 221 m to 241 m above sea level and surrounded by quartzite ridge hills towards north.

The area, falls under tropical hinter land climatic zone (about 150 km-240 km northward from the coast) with 1000 to 1500 mm annual rainfall, temperature range of 21-25°C and relative humidity range of 50-80%, the dry season range from 4-5 months between November to March, with December to January characterized by NE-SW dry Cold and dusty harmattan wind from the Sahara desert. For the study area Laniba, the hilly quartzite ridges are covered by forest, while the lowland area is dominated by light forest about one kilometer (1 km).

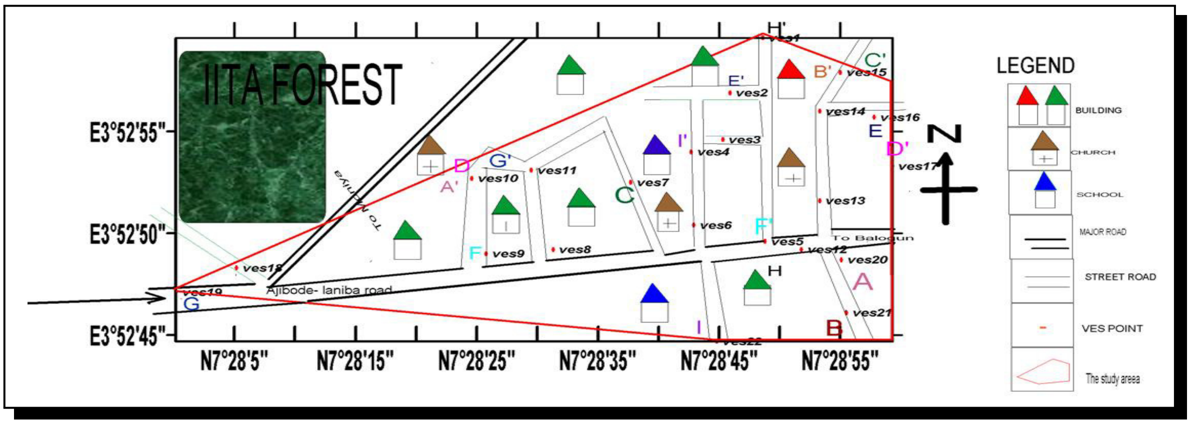

Figure 1. The base map of Laniba

3. Methodology

Nine traverses were worked on and vertical electrical sounding (VES) was carried out in twenty two different points. Data set were obtained with the use of ABEM terrameter (300B SAS) and the values of the apparent resistivity and the current electrode spacing (AB/2) were obtained, partial curve matching was carried out using the standard and auxiliary curves to give the insight to what is to be expected from computer iteration interpretation. The computer iteration was carried out on the data obtained, using the RESIST software. Consequently, different parameters were estimated, parts of which are the resistivity, the thickness of each layer and the number of each layers, depth to the bedrock. Iso-resistivity maps were generated.

4. Results and Discussion

The curve types obtained from the computer iteration are K, AK, KH, KQH and HKH type (Figures 2–6).

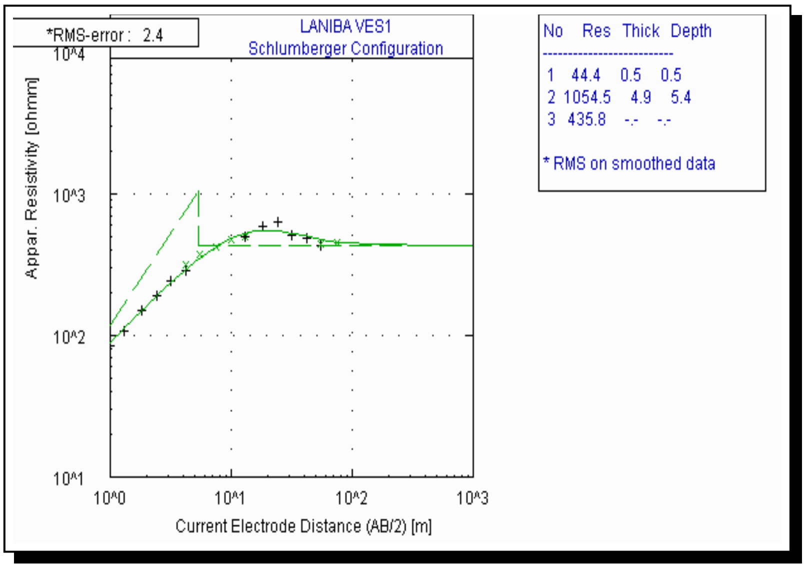

Figure 2. A typical K curve type

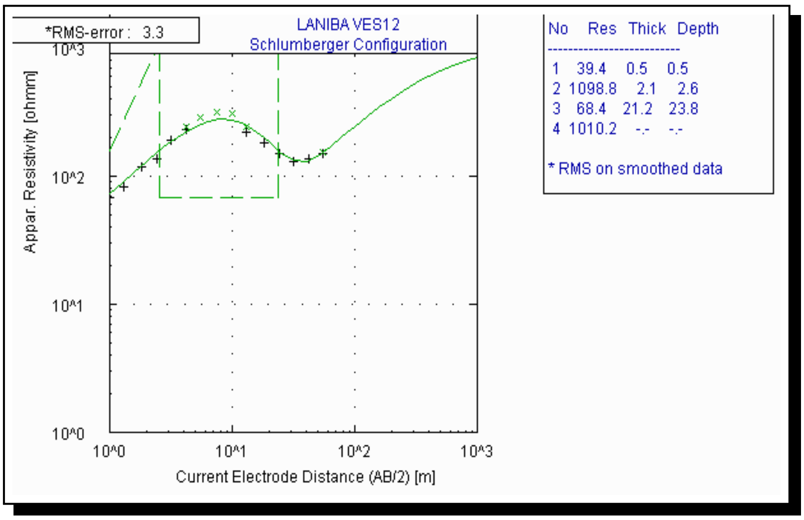

Figure 3. A typical KH curve type

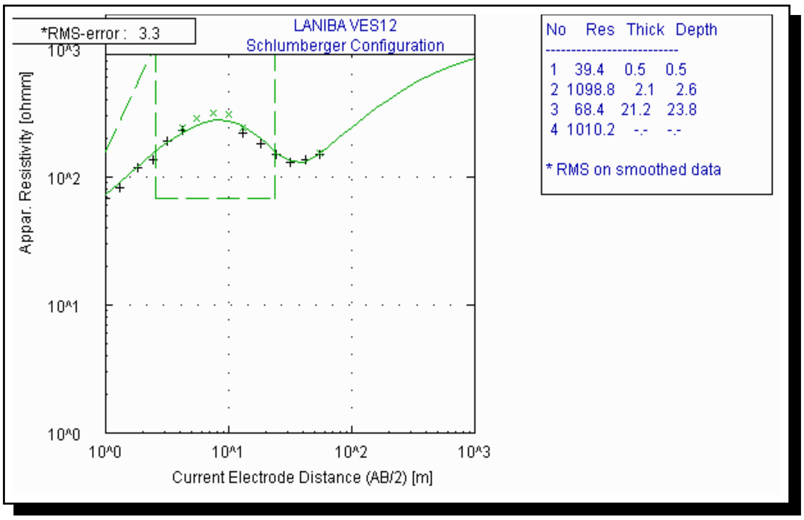

Figure 4. A typical AK curve type

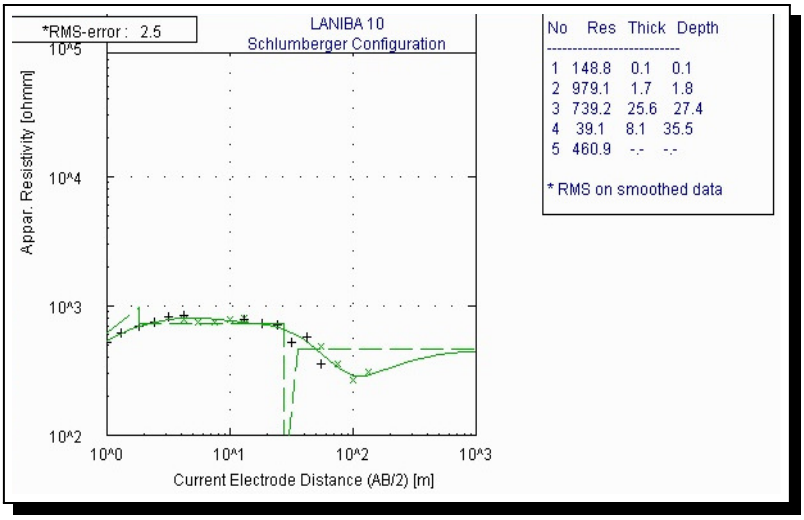

Figure 5. A typical KQH curve type

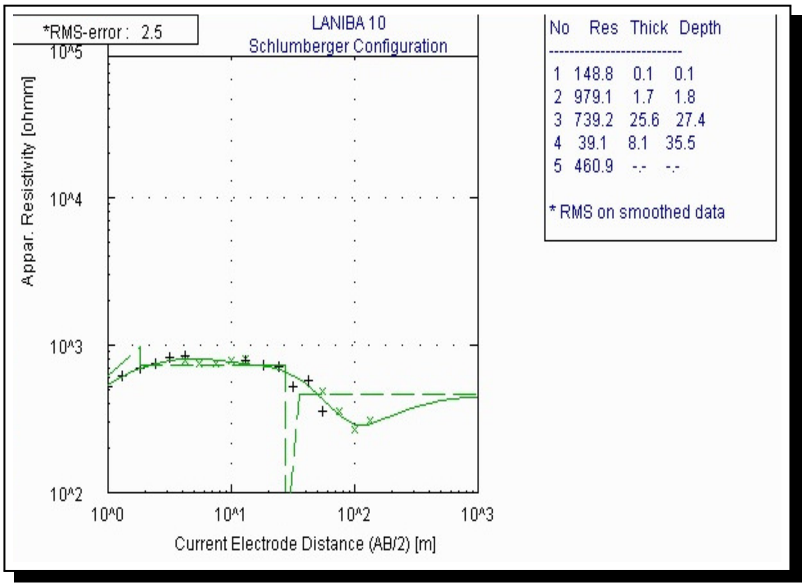

Figure 6. A typical HKH curve type

Therefore qualitatively, VES 1, 19, and 22 are the K type curves ($\rho_1 < \rho_2 > \rho_3$), while VES 2, 3, 4, 5, 6, 7, 8, 9, 12, 13, 14, 15, 17, 20 are AK type curves ($\rho_1 < \rho_2 < \rho_3 > \rho_4$), VES 11, 16, 18, are KH type curves ($\rho_1 < \rho_2 > \rho_3 > \rho_4$), VES 10 is KQH type curve ($\rho_1 < \rho_2 > \rho_3 > \rho_4 < \rho_5$) but VES 21 is HKH type curve ($\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5$) as indicated in Table 1. The KQH and HKH curves type consist of 5 layers, the K curves type consist of 3 layers, the KH and AK curves type are 4 layers.

4.1 Geoelectric Sections

The twenty two VES stations are grouped into nine geoelectric sections namely: AA′, BB′, CC′, DD′, EE′, FF′, GG′, HH′ and II′ (Figure 1). Layers 1, 2,3 and 4 for geoelectric section AA′ to II′ have different variation in resistivity and thickness as shown below in Table 2.

The geoelectric section AA′ encompasses VES 20, 12, 5, 6, 10, with the highest number of layers attributed to VES10 which has five different geoelectric layers, although only 4 different lithologies were delineated and include topsoil, weathered layer (laterite), fractured layer (comprises of clay) and the more fractured layer consist of sand. In effect therefore, the resistivity of this VES stations ranges from 39.1 Ωm to 460.9 Ωm such that the highest resistivity is identified as possible sand. For layer one in this section we have a thickness ranging from 0.5 m to 1.0 m and corresponding resistivity ranging from 36.1 Ωm to 148.8 Ωm. Layer 2 has thickness ranging from 1.6 m to 2.1 m and corresponding resistivity ranging from 311.5 Ωm to 1098.8 Ωm. For layer 3 the thickness ranges from 2.7 m to 25.6 m, while the corresponding resistivity ranges from 88.4Ωm to 1014.3 Ωm, for layer 4 therefore, the thickness is about 8.1 m and the corresponding resistivity ranges from 39.1 Ωm to 1010.2 Ωm, layer 5 has a resistivity of about 460.9 Ωm.

Table 1. Results of the quantitative interpretation of the VES curves

VES Station	Curve Types	Apparent Resistivity (m)	Thickness (m)	Depth (m)	RMS Error (%)	Layer Description
1	K	44.4 1054.4 435.8	0.5 4.9 ...	0.5 5.4 ...	2.4	Topsoil Weathered layer Fresh basement
2	AK	171.6 283.9 1178.6 211.4	0.6 5.2 9.7 ...	0.6 5.8 15.6 ...	4.3	Topsoil Weathered layer Fractured layer Fresh basement
3	AK	159.7 180.4 822.8 178.9	0.6 2.2 8.2 ...	0.6 2.8 11.3 ...	4.2	Topsoil Weathered layer Fractured layer Fresh basement
4	AK	88.4 97.6 272.8 182.5	0.8 2.4 8.1 ...	0.8 3.2 11.3 ...	2.5	Topsoil Weathered layer Fractured layer Fresh basement
5	AK	36.1 611.1 766.5 172.2	0.7 1.6 4.8 ...	0.7 2.3 7.1 ...	2.3	Topsoil Weathered layer Fractured layer Fresh basement
6	K	57.5 311.5 208.5	1.0 2.1 ...	1.0 3.1 ...	2.5	Topsoil Weathered layer Fresh basement
7	AK	152.1 377.0 985.7 159.5	1.4 1.0 5.2 ...	1.4 2.5 7.7 ...	2.5	Topsoil Weathered layer Fractured basement Fresh basement
8	AK	72.9 100.7 308.3 155.4	0.2 2.9 4.2 ...	0.2 3.1 7.2 ...	4.0	Topsoil Weathered layer Fractured layer Fresh basement
9	AK	137.7 424.2 1403.9 214.0	0.5 1.7 3.5 ...	0.5 2.1 5.6 ...	2.6	Topsoil Weathered layer Fractured layer Fresh basement
10	KQH	148.8 979.1 739.2 39.1 460.9	0.1 1.7 25.6 8.1 ...	0.1 1.8 27.4 35.5 ...	2.5	Topsoil Weathered layer Fractured layer Fresh basement Fresh basement
11	AK	74.2 161.2 440.1 164.7	0.5 2.2 7.8 ...	0.5 2.7 10.5 ...	2.8	Topsoil Weathered layer Fractured layer Fresh basement
12	KH	39.4 1098.8 88.4 1010.2	0.5 2.1 21.2 ...	0.5 2.6 23.8 ...	3.3	Topsoil Fractured layer Clayed Fresh basement
13	AK	95.5 96.9 394.0 116.9	0.4 1.7 3.7 ...	0.4 2.0 5.4 ...	3.5	Topsoil Weathered layer Fractured basement Fresh basement
14	AK	89.6 150.1 204.1 153.9	0.4 2.1 9.0 ...	0.4 2.5 11.4 ...	2.5	Topsoil Weathered layer Fractured layer Fresh basement
15	AK	162.7 119.4 447.2 253.9	0.4 1.8 8.0 ...	0.4 2.1 10.2 ...	2.3	Topsoil Weathered layer Fractured basement Fresh basement
16	KH	45.6 203.9 55.9 146.9	1.2 6.5 12.3 ...	1.2 7.7 20.0 ...	2.5	Topsoil Fractured layer Clayed Fresh basement
17	AK	64.0 333.2 688.1 108.9	0.6 0.8 1.4 ...	0.6 1.4 2.8 ...	3.6	Topsoil Weathered layer Fractured layer Fresh basement
18	KH	143.4 277.6 51.5 218.3	0.4 4.8 9.7 ...	0.4 5.2 14.9 ...	1.7	Topsoil Fractured layer Clayed Fresh basement
19	K	96.0 300.6 226.7	0.9 3.9 ...	0.9 4.7 ...	2.6	Topsoil Fractured layer Fresh basement
20	AK	36.2 251.0 1014.3 157.0	0.6 1.0 2.7 ...	0.6 1.6 4.3 ...	4.4	Topsoil Weathered layer Fractured layer Fresh basement
21	HKH	185.0 98.0 272.0 86.7 557.0	0.6 1.9 5.2 20.8 ...	0.6 2.5 7.7 28.5 ...	1.7	Topsoil Weathered layer Fractured layer Clayed layer Fresh basement
22	K	60.6 1129.6 285	0.7 5.6 ...	0.7 6.3 ...	2.5	Topsoil Fractured layer Fresh basement

Table 2. Resistivity and thickness variations, for geo-electric section AA′ to II′

Geoelectric Section	VES	Layer 1 range in Resistivity (Ωm) and thickness (m)	Layer 2 range in Resistivity (Ωm) and thickness (m)	Layer 3 range in Resistivity (Ωm) and thickness (m)	Layer 4 range in Resistivity (Ωm) and thickness (m)	Layer 5 Resistivity (Ωm)
AA′	20, 12, 5, 10 and 6	(36.1-57.1) and (0.1-1.0)	(979.1-1098.8) and (1.0-2.1)	(88.4-766.5) and (2.7-25.6)	(172.2-2191.7) and 8.1	460.9
BB′	21, 13, 14, and 15	(95.5-185) and (0.4-0.6)	(96.9-150.1) and (1.7-2.5)	(204.1-447.2) and(3.4-11.4)	(86.7-253.9) and 8.1	557
CC′	7, 4, 3 and 15	(88.4-159.7) and (0.6-1.4)	(97.6-377.0) and (1.0-2.4)	(272.8-985.7) and (5.2-8.5)	(159.5-182.5)	...
DD′	10, 11 and 17	(64.0-148.8) and(0.8-2.2)	(440.1-739.2) and (0.8-2.2)	(440.1-739.2) and (1.4-25.6)	(39.1-164.7) and 8.1	...
EE′	9, 8 and 3	(72-159) and (0.2-0.6)	(100.7-424.2) and (1.7-2.9)	(308.3-1403.9) and (3.5-8.5)	(155.4-214)	...
FF′	19, 18 and 10	(96-148.8) and (0.1-0.9)	(277.6-979.1) and(1.7-4.8)	(51.5-739.2) and (9.7-25.6)	(39-218.3) and 8.1	460.1
GG′	5 and 1	(36.1-44.4) and (0.5-0.7)	(611.1-1054.5) and (1.6-4.9)	(435.8-766.1) and 4.6	172.2	...
HH′	16, 14 and 2	(45.6-171.6) and (0.4-1.2)	(150.1-283.9) and (2.5-6.5)	(55.9-1178.6) and (9.7-12.3)	1469-211.4	...
II′	22, 4 and 6	(57.5-88.4) and (0.7-1.0)	(97.6-1129.6) and (2.1-5.6)	(208.5-285.0) and (**??**)	182.5	...

Four different VES stations make up the geoelectric section BB′ which includes VES 21, 13, 14 and 15. The maximum number of geoelectric layer delineated was five which is VES10, though only four different lithologies were delineated which include the topsoil, laterite (weathered layer), clayed sand(fractured layer) and sand. Layer 1 has thickness which range from 0.4 m to 0.6 m and corresponding resistivity ranging from 95.5 Ωm to 185.0 Ωm, layer 2 has thickness ranging from 1.7 m to 2.5 m with corresponding resistivity values ranging from 96.9 Ωm to 150.1 Ωm, layer 3 has thickness ranging from 3.4 m to 11.4 m with resistivity ranging from 204.1 Ωm to 447.2 Ωm, therefore layer 4 has thickness of about 20.8 m and the corresponding resistivities ranges from 86.7 Ωm to 253.9 Ωm, layer 5 has resistivity of 557 Ωm.

The VES stations in geoelectric section CC′ are VES 7, 4, 3 and 15. the maximum number of geoelectric layer delineated at each VES station within this section are 4 layers and the lithologies delineated are topsoil, laterite, clayed sand and sand. Layer 1 has thickness ranging from 0.6 m to 1.4 m and corresponding resistivity between 88.4 Ωm and 159.7 Ωm, layer 2 has thikness ranging from 1.0 m to 2.4 m and resistivity between 97.6 Ωm to 377.0 Ωm, layer 3 has thickness ranging from 5.2 m to 8.5 m and corresponding resistivity ranging from 272.8 to 985.7 Ωm, the fourth layer has resistivity ranging from 159.5 Ωm to 182.5 Ωm.

The geoelectric section DD′ encompasses VES 10, 11 and 17 and the maximum number of geoelectric layers delineated is 5, which include topsoil, lateritic, clayed, sand clay and sand. Layer 1 in this section has thickness ranging from 0.5 m to 1.0m and resistivity between 64.0 Ω m and 148.8 Ωm, layer 2 has resistivity ranging from 161.2 Ωm to 333.2 Ωm and thickness between 0.8 m to 2.2 m, while the third layer has thickness between 1.4 m and 25.6 m with corresponding resistivity ranging from 39.1 Ωm to 164.7 Ωm and thickness of 8.0 m, layer 5 has resistivity of 460.9 Ωm.

Three different VES stations in geoelectric section EE′ are VES 9, 8 and 3, the maximum number of geoelectric layers delineated at each VES station within this section is 4, and the lithologies delineated are top soil, lateritic clay, sandy clay and sand. Layer 1has thickness ranging from 0.2 m to 0.6 m and corresponding resistivity between 72.0 Ωm and 159.7 Ωm, layer 2 has thickness ranging from 1.7 m to 2.9 m and resistivity values between 100.7 Ωm and 424.2 Ωm, layer 3 has thickness ranging from 3.5 m to 8.5 m and corresponding resistivity between 308.3 Ωm and 1403.9 Ωm, while the fourth layer has resistivity between 155.4 Ωm to 214.0 Ωm.

Three VES stations 19, 18 and 10 made up the geoelectric section FF′ with 5 maximum layers delineated, the highest number of layers attributed to VES 10, but only four lithologies delineated which include topsoil, laterite clayed, clayed sand and sand. The lithologies of VES 19, 18 varies with 19 having top soil, lateritic clay and sand while VES18 has topsoil, lateritic clay, clayed sand and sand. The variation in resistivity of the five layers in this section is shown in, the thickness of the first layer ranges from 0.1 m to 0.9 m, that of second layer range from 1.7 m to 4.8 m, the third layer thickness is between 9.7 m and 25.6, layer 4 has thickness of 8.1 m.

Only two different VES makes up the geoelectric section GG′ which include VES 5 and 1, maximum of four layers were delineated with highest layer attributed VES 1, it is obvious in this section to see the variation in resistivity of each layer from, maximum of four lithologies were delineated and it include topsoil lateritic clay, clayed sand and sand, the thickness of each layer starting with first layer are 0.5 m to 0.7 m, 1.6 m to 4.9 m and the third layer thickness of 4.6, the resistivity of the fourth layer is 172.2 Ωm.

Three different VES stations makes up this geoelectric section HH′ which include VES 16, 14, and 2 the maximum number of geoelectric layer delineated at each VES station within this section is 4 and the lithologies delineated are topsoil, lateritic clay, sandy clay, clay and sand. Layer 1 has thickness ranging from 0.4 m to 1.2 m and resistivity from 45.6 Ωm to 171.6 Ωm, layer 2 has thickness ranging from 2.5 m to 6.5 m and corresponding resistivity from 150.1 Ωm to 283.9 Ωm, layer 3 has thickness ranging from 9.7 m to 12.3 m and resistivity range of 55.9 Ωm to 1178.6 Ωm, the fourth layer resistivity range from 146.9 Ωm to 211.4 Ω.

Although some second layers are also made up of sand, but sand is prominent in the third layer and below due to the high resistivity values and this can be said to contain good quality groundwater.

4.2 Iso-resistivity Maps

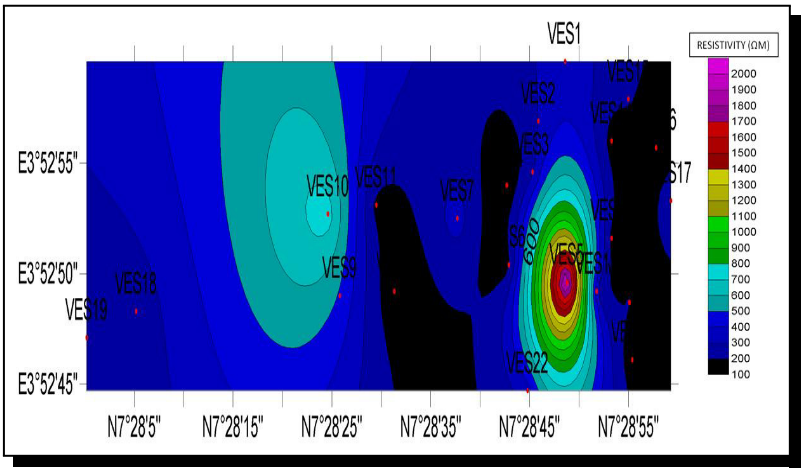

Figure 7a. Iso-resistivity at 5.5 m depth

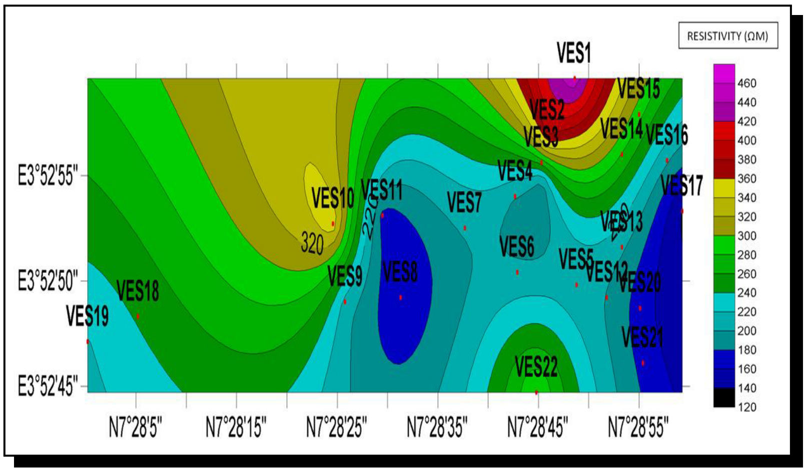

Figure 7b. Iso-resistivity at 13 m depth

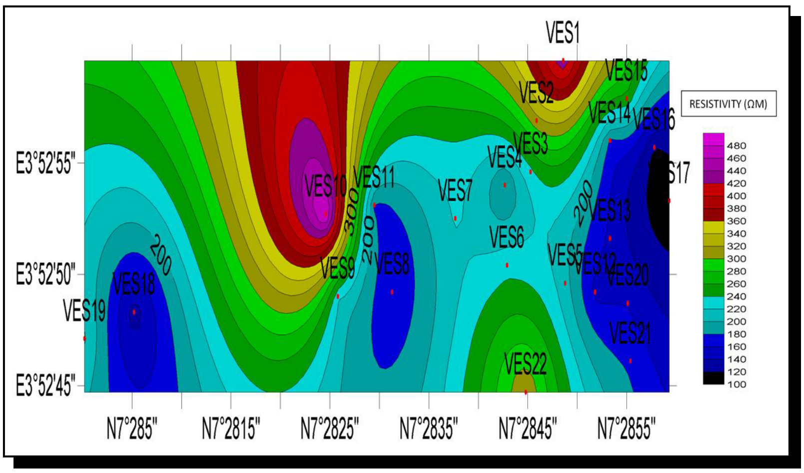

Figure 7c. Iso-resistivity at 55 m depth

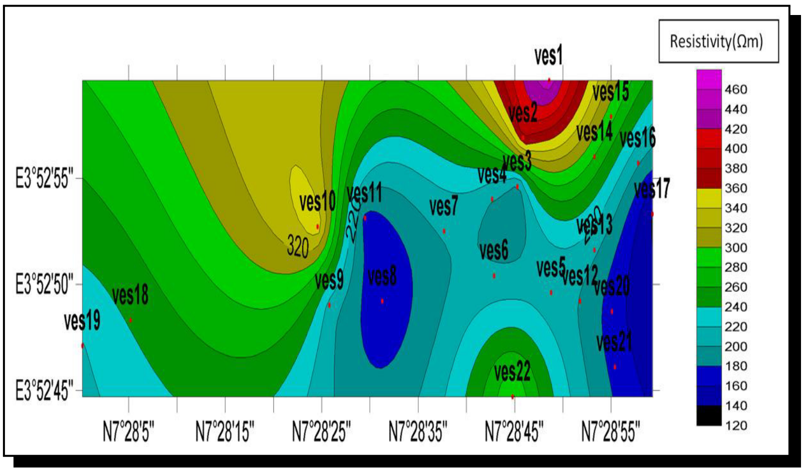

Figure 7d. Iso-resistivity at 75 m depth

The Iso-resistivity maps (Figures 7a-7d) denotes the correlation of resistivity information at depth of 5.5 m, 13 m, 55 m and 75 m. It is reveal in these maps that portion bearing colors green to purple has high resistivity values and those bearing colors black to cyan has low resistivity values. These contour maps help in viewing the subsurface to depth of 75 m over the area marked by the twenty two VES stations.

5. Topgraphical Map

The bedrock beneath each VES points was determined to produce the bedrock relief map of the study area; this is the reflection of bedrock ridges and depression in the study area, the topographic contour map below shows the relief and depression with each VES point.

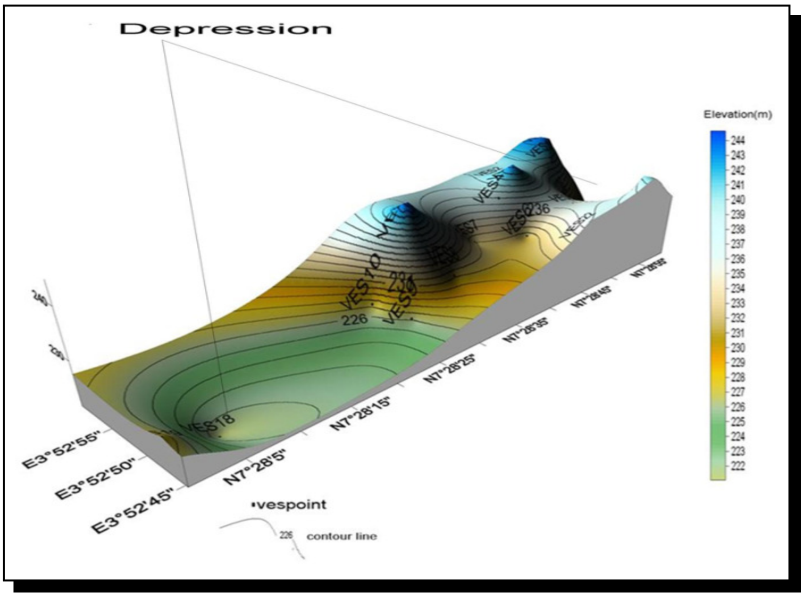

Figure 8. Bedrock topography of the study area

6. Conclusion

From these results two aquifer units were identified of which falls into the sandy region. Different aquifer units are embedded within the subsurface in the study area but only the depth to each of those aquifers could be delineated due to the spread used, such that electrical current terminated at within the aquifer zones. Depth wise, it can also be inferred from our iso-resistivity maps that when a borehole is sunk to a depth of about 35.5 m, area towards the North West down to south west and part of south east are generally a good site for location of boreholes with high tendency for good water.

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Competing Interests

The authors declare that they have no competing interests.

Authors' Contributions

All the authors contributed significantly in writing this article. The authors read and approved the final manuscript.

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