Delineation of Aquifers in parts of the Coastal Plain Sands of the Dahomey Basin of Central Lagos State Nigeria

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ABSTRACT

Delineation of aquifers in parts of the Coastal Plain Sands of Dahomey Basin of Central Lagos State was carried out using the Vertical Electrical Sounding (VES) technique of the electrical resistivity method of geophysics. The study revealed that the subsurface consists of four to five geoelectric layers of topsoil, sandy clay, clayey sand, sand and clay layers. The depth to sandy clay ranges from 2 to 4.79m while its thickness is from 6.4 to 53.4m. The clayey sand varies from 0.5 to 4.7m while its thickness varies from 4.20 to 19.3m. Finally, the clay layer shows thickness from 4.7 to 57.2m while its depth varies between 4.5m to 25m. The aquifer units show resistivity which ranges from 110 to 32023 Ohm-m. Depth to the water table for most of the area is between 2.0 m and 16.3m while freshwater can be obtained in the area at a depth of between 6.5 m and 61.7 m.

(Keywords: vertical electrical sounding, VES, geophysics, geoelectric layers, subsurface layers, aquifer units, coastal plain sands, Dahomey basin)

INTRODUCTION

From the beginning of time, man has always desired to conquer and improve his environment. This has led man to become specialized in different fields like geology, mathematics, engineering, physics and several other fields. For a better understanding of the subsurface, sub-disciplines like geophysics were developed. The applications of the methods of geophysics have wide range of application due to their use in reconnaissance, in-depth study tool, and their cost-effective application among several other advantages.

The methods of applied geophysics are aimed at obtaining information about the distribution of rock types and their attitude in the subsurface through physical measurements on the surface of the earth (Parasnis, 1986).

Soil surveys require quick and, when possible, non-disturbing estimations of numerous soil properties, such as salinity, texture, stone content, groundwater depth, and horizon sequence in soil profiles; however, conducting soil measurements with a high sampling density is costly and time-consuming. Conventional methods of soil analysis mostly require disturbing soil, removing soil samples, and analyzing them in a laboratory.

Electrical geophysical methods, on the contrary, allow rapid sub-surface measurement of soil electrical properties, such as electrical conductivity, resistivity, and potential, directly from soil surface without soil disturbance.

Literature Review

The electrical method of geophysical investigation is one of the methods which has found application in several ways. It is most widely used in groundwater investigation (Brooks and Keary,1988; Telford, *et al*., 1990). This might not be unconnected with its ability to provide rapid information on the geological structure and prevailing lithologies of a region without the high cost of an extensive drilling program (Zohdy., 1969; Ward, 1990; Koefoed, 1965, 1968; and Keller and Frischknecht,1966).

The *in-situ* methods of electrical conductivity (e.g. four-electrode probe and electromagnetic induction) are routinely used to evaluate soil salinity (Halvorson and Rhoades, 1976; Chang, *et al*.,1983; Rhoades, *et al*., 1989b). Some electrical geophysical methods were used to map groundwater tables (Arcone, *et al.*, 1998), preferential flow paths (Freeland, *et al*., 1997a), and perched water locations (Freeland, *et al*., 1997b); to outline locations of landfills (Barker,1990); and to evaluate water content, temperature, texture, and structure of soils.

Rabeh, *et al*. (2009) studied the detection of water aquifers and the delineation of subsurface structures predominant in the basement rocks, and their relationship with these aquifers, However, the relationships between electrical properties and other soil chemical and physical properties are very complex because many soil properties may simultaneously influence *in-situ* measured electrical parameters (Halvorson and Rhoades, 1976).

Significance of the Study

Due to the presence of different materials in the subsurface, it is imperative to carryout geophysical investigations prior to any drilling. Therefore, the aim of this study is to carry out some geoelectric investigation at Jjede in Ikorodu area of Lagos State in order to determine the nature of the subsurface geology.

While the objectives are – (i) The delineation of the geoelectric layers within the study area, (ii) To determine the thickness and resistivity of various geoelectric layers, and (iii) To provide appropriate recommendation for the exploitation of fresh groundwater.

The Geology and Location of the Study Area

The diverse rock types which make up the geologic constituents of Nigeria can in order of increasing age, be sub-divided into three main groups: the Basement Complex, the Younger Granites, and the Sedimentary series (Figure 1).

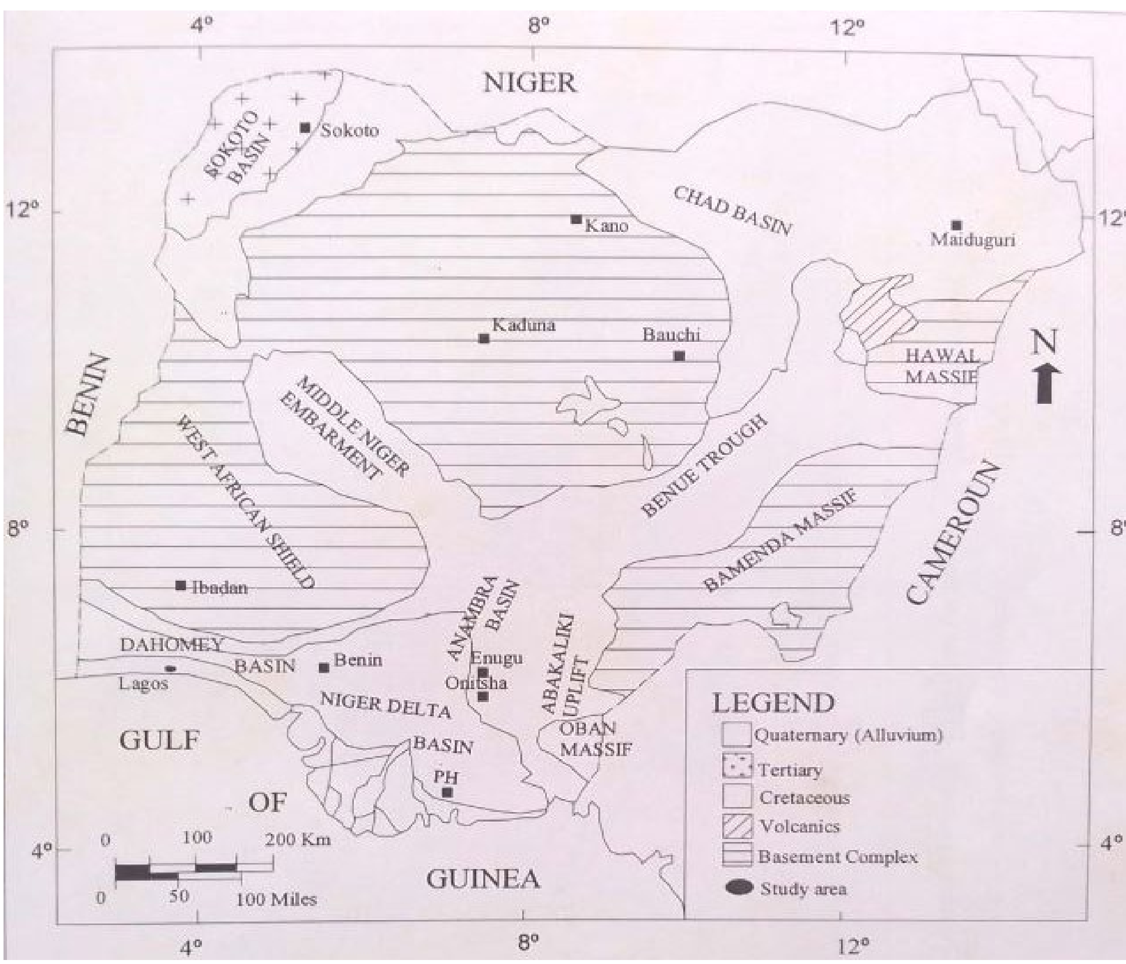

Figure 1: Geological Map of Nigeria showing Lagos the Study Area.

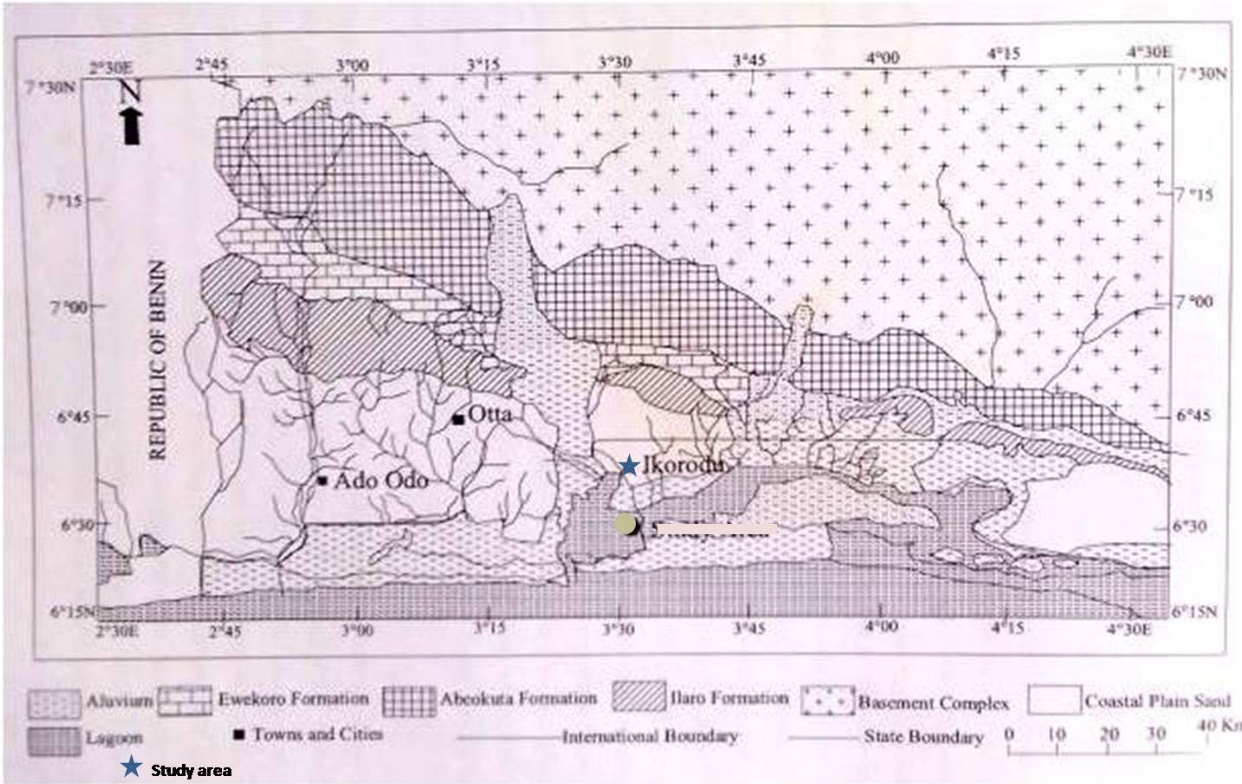

Figure 2: Geological Map of Lagos State showing the Study Area.

The sedimentary series include an interesting array of sedimentary rocks which occupy seven major sedimentary basins. These seven major sedimentary basins include: the Benue Trough, the Chad Basin, Southeast Iullemmenden (Sokoto) Basin, the Dahomey Basin, the Bida basin, the Anambra Basin and the Niger Delta Basin.

The study area is located in Ijede, Ikorodu, Lagos State. It is accessible from Ikorodu road, Ijebu Ode road and Shagamu access road. The location is between Northing 7° 25.000'-7° 35.000' and Easting 5° 50.250'-5° 70.250' (Figure 2).

Lagos lies within the Dahomey sedimentary basin (Figure 1 and Figure 2). It is made up of Coastal Plain Sands, clays and sandstone (Jones and Hockey, 1964).

This basin extends from Accra in Ghana through to the republic of Togo to the western flanks of Niger delta in the east. The basin is bounded on the west by fault and other tectonic structures associated with landwards extension of romanche fracture zone (Adegoke, *et al*., 1981). Its eastern limit is similar marked by the Benin hinge line which is a major flat structure marking the western limit of Niger delta basin (Omatsola and Adegoke, 1981).

The geological sequence in the Dahomey extends from the Precambrian to Recent (Table 1). The most recent detailed stratigraphy of Dahomey Basin is that of Omatsola and Adegoke (1981) in which they proposed three new easily recognized lithostatigraphic units of Formation rank. These Formation include: the Ise, Afowo and Araromi. They make up the Abeokuta group. Others are Ewekoro Formation, Oshosun Formation and Ilaro Formation.

MATERIALS AND METHODS

The data for this project were acquired using Vertical Electrical Sounding involving the Schlumberger electrode configuration. A total of twelve (12) VES were performed along three (3) traverses in the study area (Figure 3).

Table 1: Stratigraphic Relationship of Formation in the Dahomey Basin (Coode Blizzard, 1996).

Period	Geologic Age	Jones and Hockey (1964)	Omatsola and Adegoke (1981)
Quaternary	Recent Oligocene to Plio-Pleistocene	Alluvium Coastal Plain Sands	Alluvium Coastal Plain Sands
Tertiary	Eocene Palaeocene Lower Eocene	Ilaro Formation Ewekoro Formation	Ilaro Formation Oshoshun Formation Akinbo Formation
Cretaceous	Cretaceous	Abeokuta Formation	Araromi Formation Afowo Formation Ise Formation
Precambrian	Precambrian	Basement Complex	Basement Complex

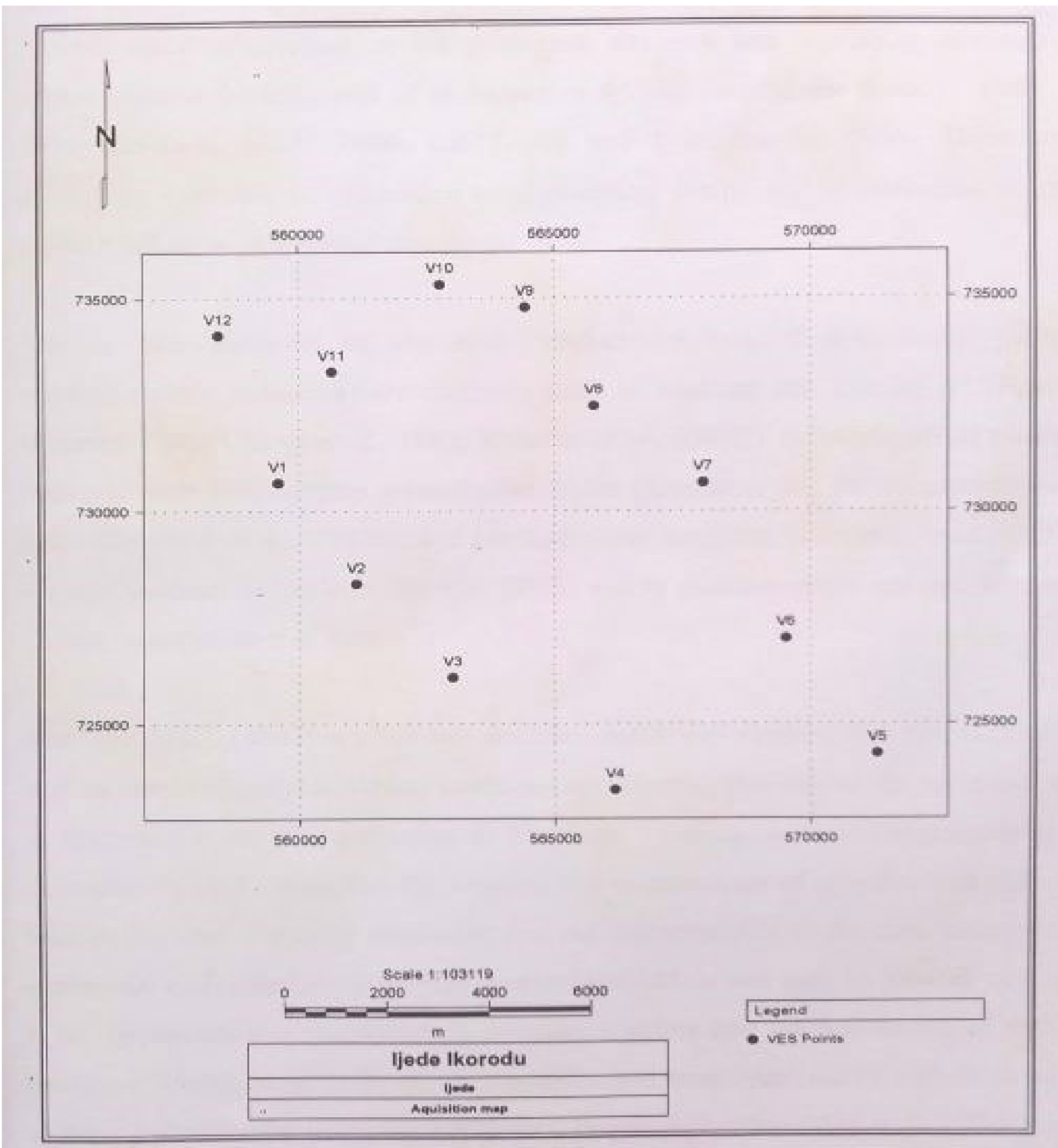

Figure 3: Acquisition Map of the Study Area.

ABEM Terrameter SAS 1000 was used to measure the apparent resistivity and induced polarization effect. A portable battery was used as the power source, while four metal steel rods were utilized as electrodes. Other equipment used include hammers, four reels of copper wire, Global Positioning System (GPS) and measuring tapes.

Measurement Procedure

The electrodes were arranged using the Schlumberger electrode array and were planted firmly in the ground to ensure good contact. The cables were connected to the electrodes using a cellotape and to the ABEM SAS 1000 Terrameter. For the first reading, the potential electrodes and current electrodes were at 0.25m and 1m respectively from the mid-point. The current electrodes were expanded subsequently symmetrically about the mid-point. The potential electrodes were only moved at specified distances so that the Terrameter could measure the voltage arising from the current injected into the subsurface.

Data Processing and Interpretation

Geophysical data acquired are normally processed to remove noise arising from instrumentation and environmental influence. Interpretation software for 1D inversion of apparent resistivity data called WINGLINK was used for processing the VES data. The program basically determines a resistivity model that approximates the measured data within the limits of data errors, and which agrees with all a prior information. The difference between the measured and calculated apparent resistivity values is given by the root-mean-square (RMS) error. The first step in the processing of the data was to enter the field data into the program; thereafter processing commenced to obtain the layer parameters.

RESULTS AND DISCUSSION

Twelve Vertical Electrical Soundings (VES) positions were occupied using Schlumberger array to obtain subsurface information in the study area. Some of the VES data results are presented as resistivity curves in Figures 4 and 5. The curves were interpreted qualitatively and quantitatively.

Quantitative interpretation of the curves involves using the WinGLink Software for 1D inversion to obtain layer parameters. The quantitative interpretation reveals three to five geoelectric layers. The qualitative interpretation shows that there are one QHK, two HK, KH, QH, QQH, and three KQH curves. The geoelectric sections beneath the VES points are shown in Figures 6, 7 and 8. The summary of the interpreted results are presented in Table 2. Isopach maps showing layer thickness and depth map of the identified lithologies, plus depth to water table is as displayed (Figure 9).

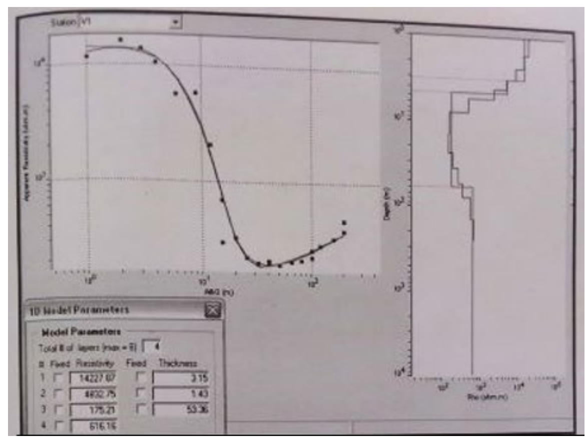

Figure 4: Computer Iterated Field Curve for VES 1.

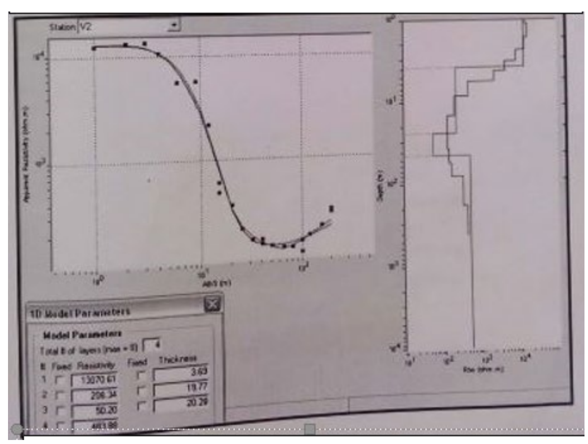

Figure 5: Computer Iterated Field Curve for VES 2.

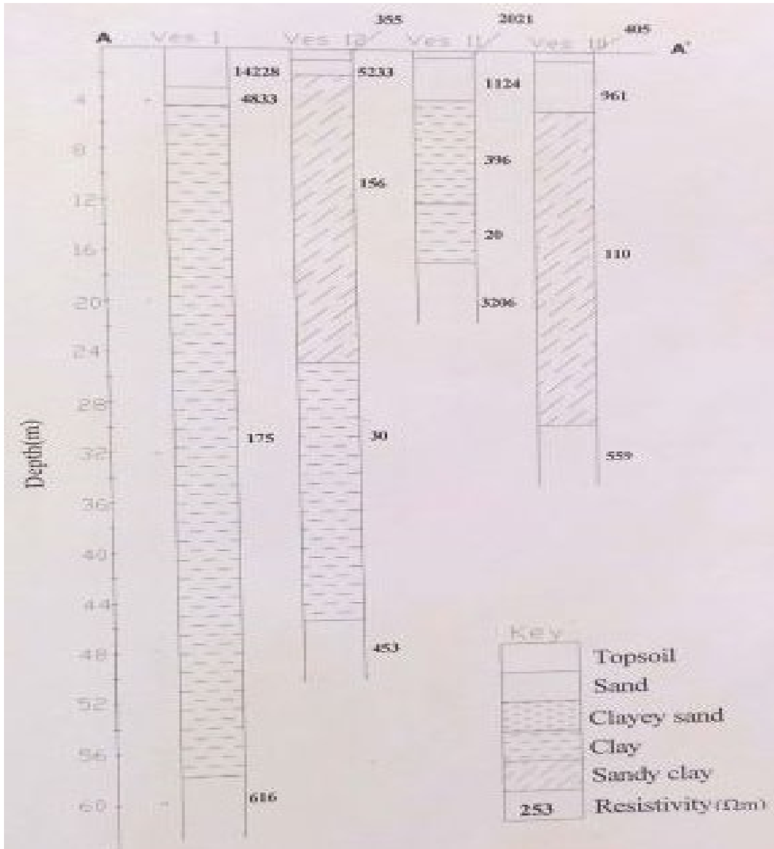

Figure 6: Geoelectric Section along Traverse AA'.

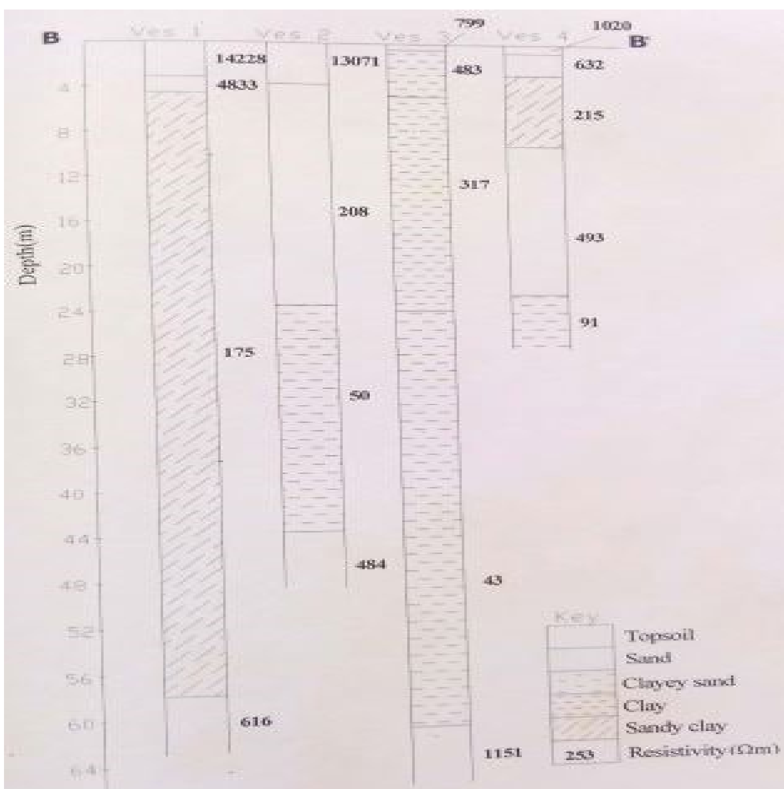

Figure 7: Geoelectric section along Traverse BB'.

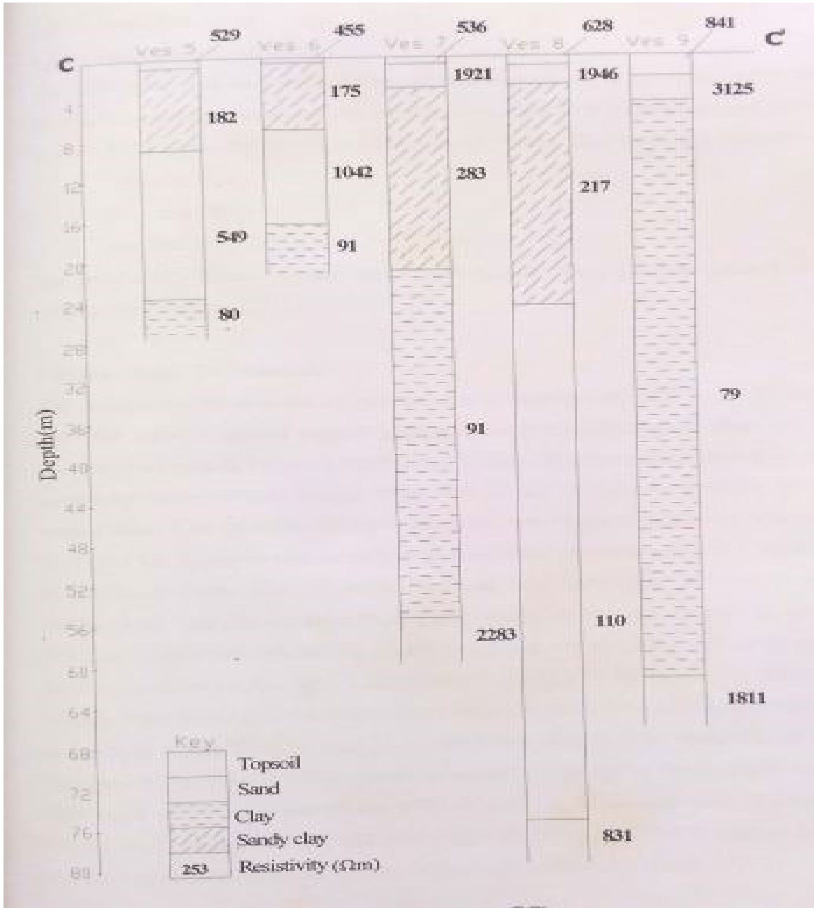

Figure 8: Geoelectric Section along Traverse CC'.

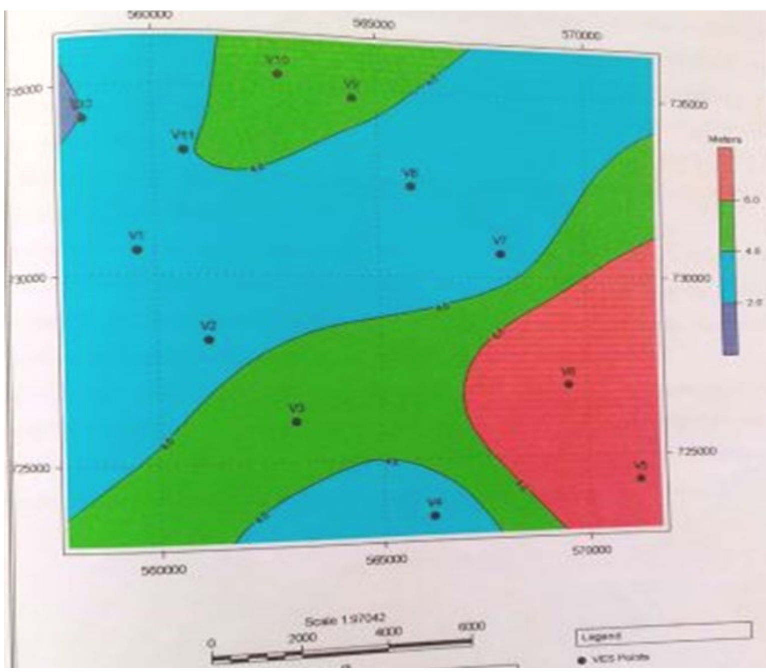

Figure 9: Depth to Water – Ijede Ikorodu.

Table 2: Summary of the Interpreted VES Data Showing Layer Parameters.

VES	Layer	Resistivity (Ωm)	Thickness (m)	Depth (m)	Inferred Lithology
1	1	14227.87	3.15	3.15	Topsoil
	2	4832.75	1.43	4.58	Sand
	3	175.21	53.36	57.94	Sandy clay
	4	616.16	-	-	Sand
2	1	13070.61	3.69	3.69	Topsoil
	2	208.34	19.77	23.46	Sand (wet)
	3	50.20	20.28	43.74	Clay
	4	483.88	-	-	Sand
3	1	798.98	0.51	0.51	Topsoil
	2	482.87	4.20	4.71	Clayey sand
	3	316.47	19.26	23.97	Clayey sand
	4	43.44	37.37	61.34	Clay
	5	1150.69	-	-	Sand
4	1	1019.62	0.74	0.74	Topsoil
	2	631.51	2.02	2.76	Sand
	3	215.25	6.38	9.14	Sandy clay
	4	492.64	13.47	22.61	Sand
	5	90.85	-	-	Clay
5	1	528.78	0.85	0.85	Topsoil
	2	182.28	8.14	9.99	Sandy clay
	3	549.13	14.59	23.58	Sand
	4	79.55	-	-	Clay
6	1	455.19	0.47	0.47	Topsoil
	2	175.27	6.48	6.95	Sand clay
	3	1042.14	9.32	16.27	Sand
	4	91.05	-	-	Clay
7	1	535.49	0.67	0.67	Topsoil
	2	1920.98	2.30	2.97	Sand
	3	282.70	17.89	20.86	Sandy clay
	4	91.04	34.58	55.44	Clay
	5	2283.07	-	-	Sand
8	1	627.53	0.90	0.90	Topsoil
	2	1945.95	1.87	2.77	Sand
	3	216.98	21.62	24.39	Sandy clay
	4	109.59	51.35	75.74	Sand
	5	831.27	-	-	Sand
9	1	840.49	2.11	2.11	Topsoil
	2	3124.73	2.42	4.53	Sand
	3	79.32	57.15	62.64	Clay
	4	1810.77	-	-	Sand
10	1	404.73	0.79	0.79	Topsoil
	2	961.30	4.00	4.79	Sand
	3	110.09	25.41	30,20	Sandy clay
	4	558.78	-	-	Sand
11	1	2020.99	0.57	0.57	Topsoil
	2	1124.18	3.38	3.95	Sand
	3	396.40	8.22	12.17	Clayey sand
	4	20.36	4.71	16.88	Clay
	5	3202.94	-	-	Sand
12	1	335.29	0.85	0.85	Topsoil
	2	5233.22	1.18	2.03	Sand
	3	156.43	22.96	24.99	Sandy clay
	4	29.63	20.77	45.76	Clay
	5	452.52	-	-	Sand

Geoelectric Sections

The VES data was acquired along three traverses. The traverses were used to obtain a geoelectric representation of the subsurface. The VES data along the traverses was used to draw the geoelectric sections along the traverses. The traverses include Traverse AA', Traverse BB', and Traverse CC'.

Section Under Traverse AA'

The geoelectric section along traverse AA' comprises of VES 1, 12, 11 and 10 (Figure 6). The first layer is named topsoil with resistivity values ranging from 335.29 to 14227.87 Ωm. Its thickness is between 0.57m and 3.15m. The second identified layer is sand. It has resistivity value which ranges from 961.30 to 5233.22 Ωm while its layer thickness ranges from 1.18 to 4.00m. The third geoelectric layer is made up of sandy clay in VES 1, 10 and 12. It shows layers resistivity between 110.09Ωm and 175.21Ωm.The thickness of this layer varies from 22.96 to 53.36 m.

The third layer in VES 11 is inferred to be clayey sand. The clayey sand shows 396.40Ωm as its layer resistivity while its thickness is 8.22m. The fourth identified geoelectric layer under VES 1 and 10 is composed of sand having resistivity value which ranges between 558.78 Ωm and 616.16 Ωm. The thickness of this layer could not be determined because current terminated within this layer. The same layer under VES 11 and 12 is composed of clay. The thickness of this layer ranges between 4.71m and 20.77m while its resistivity range is from 20.36 to 29.63 Ωm. The fifth layer is only present under VES 11 and 12. It is composed of sand with resistivity values with range between 452.52Ωm and 3202.94Ωm.The thickness of this layer could not be determined because current terminated within this layer.

Section Under Traverse BB'

Geoelectric section along traverse BB' is made up of VES 1-4 (Figure 7). The first identified layer is the topsoil with resistivity values ranging between 798.982m and 14227.87Ωm.The topsoil thickness ranges from 0.51 to 3.69m. The second geoelectric layer observed under VES 1, 2, and 4 is composed of sand with layer resistivity between 208.34 Ωm and 482.872 Ωm. The layer thickness varies from 1.43 to 19.77m. The same layer under VES 3 is composed of clayey sand. Its layer resistivity is 482.8792 Ωm while its thickness is 4.20m.

Section Under Traverse CC'

Traverse CC' used to obtain information about the subsurface consist of VES 5-9 (Figure 8). The topsoil, the first geoelectric layer, has resistivity values between 455.192m and 840.49Ωm.The layer thickness ranges from 0.47-2.11m. The second layer under VES 5 and 6 corresponds to sandy clay having resistivity which ranges from 175.27 to 182.28 Ωm while the layer thickness is between 6.48m and 8.14m. The same layer under VES 7 -9 shows sand with thickness ranging from 1.87m and 2.42m; while its resistivity ranges from 1920.98 to 3124.73Ωm.

The third identified geoelectric layer under VES 5 and 6 is shown to be sand. Its resistivity value is between the range 549.132m and 1042.14Ωm while its thickness ranges from 9.32 to 14.59m.The same layer under VES 7 and 8 is made up of sandy clay. The layer resistivity is between 216.98 S2m and 282.70Ωm while it shows thickness which varies from 17.89 to 21.62m.The third layer under VES 9 is made up of clay which a resistivity value of 79.32 Ωm while its thickness is 57.15m. The fourth layer under VES 5-7 is made up of clay with a resistivity range from 79.55 to 91.05Ωm. The thickness of this layer is only obtainable under VES 7 where it is 34.58m. The fourth layer under VES 8 and 9 shows sand. The resistivity of this layer is between 109.59 Ωm and 1810.77 Ωm with thickness of 51.35m for VES 8 and while its thickness is undetermined for VES 9 because current terminated within the layer. The fifth layer is only present under VES 7 and 8.Its composition is sand. Its resistivity range is from 831.27 to 2283.07 Ωm. The thickness of this layer is unknown because current terminated in this layer.

Aquifer units are found in VES 1-8 and 10-12.The resistivity of the aquifer ranges from 109.59 to 32023 ohm-m; this aquifer contains fresh water. Depth to the water table for most of the area is between 2.03 m and 16.27m while freshwater can be obtained in the area at a depth of between 6.45 m and 61.68 m (Figure 9).

CONCLUSIONS

The Delineation of Aquifers of part of Ijede area in Ikorodu Local Government Area of Lagos State, employing Vertical Electrical Sounding technique of Electrical resistivity method shows that the subsurface is made up of four to five geoelectric layers consisting of topsoil, sandy clay, clayey sand, sand, and clay layers. Results show that the near surface layers underneath the topsoil consist essentially of sand and sandy clay. The depth to the sand layer is from 0.57 to 9.14m, with sand thickness ranging from 1.18 to 51.35m. The sand layer is mostly underlain by sandy clay. The depth to sandy clay ranges from 2.03 to 4.79m while its thickness is from 6.38 to 53.36m.The clayey sand varies from 0.51 to 4.71m while its thickness varies from 4.20 to 19.26m. Finally, the clay layer shows thickness from 4.71 to 57.15m while its depth varies between 4.53m to 24.99m.

The aquifer units show resistivity which ranges from 109.59 to 32023 Ohm-m. Depth to the water table for most of the area is between 2.03 m and 16.27m while freshwater can be obtained in the area at a depth of between 6.45 m and 61.68 m.

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