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Groundwater Prospecting Using Electrical Resistivity Profiles Over Jubilee Homes Parkland, Southwest, Nigeria

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Abstract
Urbanization is speedily catching on erstwhile fallow hinterland area of southwest Nigeria. Due to the various production companies springing up in the location adjoining area are experiencing influx of citizenry and accommodation and sustenance become a predominant challenge. Portable water is critical to the survival of man, hence the reason for this study. Electrical resistivity survey were carried out at Jubilee Homes Parkland, to delineate subsurface layers and determine the ground water potential, so as to make adequate provision of portable water supply for the settlements springing up within this area. The electrical resistivity method adopted for this study employed the use of ABEM SAS 1000 terrameter which worked on 16 vertical electrical sounding (VES) points within the area. A maximum distance of 550m current electrode (AB) spread was adopted for this purpose. The result shows the presence of four geoelectric layers with the resistivity of the first layer ranging from 25.54Ωm-619.45Ωm and thickness of 0.14-9.21m representing topsoil. The second geoelectric layer has a resistivity ranging from 20.94Ωm-706.82Ωm and thickness of 2.58-35.36m representing laterite, while the third geoelectric layer has a resistivity ranging from 12.29Ωm-598.93Ωm and thickness 3.33-58.06m representing sandy clay. Finally, the fourth geoelectric layer has a resistivity ranging from 12.10Ωm-1980.52Ωm and thickness of 11.4-45m representing sand. It can be concluded that the fourth layer is most prolific and attractive to be explored for groundwater. This thereby affords residents and potential settlers in the area a considerable confidence level in accessing sufficient groundwater for their various uses. Furthermore, construction purposes ongoing in the location could make use of this evaluation to satisfy their need of locating water for their operations.

Keywords: resistivity, groundwater, geoelectric layer, subsurface, terrameter, settlements, thickness,

INTRODUCTION

Water being the major source of life is required by all and sundry either in small or large quantity. The quality of water required for domestic and industrial use also needs to be taken into consideration. In view of these facts it became important to embark on this study for this location, being a residentially developing area; settlers here will require water for their day to day activities. Thus the study seeks to prospect for high yield ground water which is equally portable for consumption.

The electrical resistivity method used is aimed at studying the horizontal and vertical discontinuities in the electrical properties of the ground. This is targeted at investigating the shallow subsurface geology of the area (Tearpock and Bischke, 1991).
Conducting properties of the subsurface having anomalous values are a concern. The formations of the Eastern Dahomey basin are not an exception. The identified formations (earth layers) are as presented in table 1. They are a combination of both parallic and marine sediments underlain by undifferentiated crystalline basement (usually metamorphosed). Potential gradients are measured for a particular earth layer probing it with a known current. Possibility of measuring the spurious electrochemical potentials between the electrodes and electrolytes in the earth is the desire of survey programs. Difficulties arise because of simple horizontal layered models used as reference for theoretical formations. Ideally, this are perfect scenarios but are not geologically plausible. Near-surface rock formations <500m does not exhibit simple planar stratification both lithologically and also in electrical properties. Complex associations in subsurface lithological arrangements are directly responsible for variations in resistivity measurements laterally or vertically. However, in cases where we have clear-cut unconformities/non-conformities, resistivity measurements are capable of unraveling their boundaries and also respective depth of the layers. Discontinuities such as faults are resolvable from subsurface resistivity surveys. Almost all geological features have one or more diagnostic anomalous appearance in apparent resistivities over contrasting layers prospecting. Features like faults and joints serve as pathway or conduit for migration of groundwater within aquifers.

Therefore, in order to detect the ground water capacity of the study area electrical resisitivity method has been carried out independently using the

ABEM SAS 1000 terrameter for the profiling so as to determine the effective resistivity of the subsurface from the apparent resistivity given by the instrument (Telford *et al.,* 1976). Electrical sounding data are said to be influenced by both vertical and horizontal heterogeneities (Zohdy *et al.,* 1974). In view of this, plotting the resistivity values determined by the instrument against half the current electrode spread (AB/2) is done on the log-log graph to determine the depth to each layer depending on how many layers each vertical electrical sounding presents (Van Nostrand *et al.,* 1966). Probing which involves the adoption of the current and potential electrode spread is used to delineate the apparent resistivities, hence it follows that the deeper the probing the farther away from the current source is the measurement of the potential difference regardless of the electrode array utilized (Zohdy *et al.,* 1974).

In homogeneous ground therefore the current electrode depth of investigation increases with increasing separation of current electrodes. In view of this, the vertical electrical sounding is expected to be carried out in order to study the horizontal and near horizontal interfaces. In effect, this helps to determine the horizontal zones of porous strata. Southwestern Nigeria is distally bounded by coastal environment and the study area sharing this boundary tends to have a shallow depth to aquifer when compared with other basinal regions in Nigeria. This study intends to assess the subsurface for ground water resources, develop an understanding of the key physical properties of the subsurface horizontal strata and consider how the properties can be accessed from available resistivity data, employing the electrical resistivity method. An attempt will also be made to determine the precise depth to weathered basement and overburden thickness such that the different lithologies within the subsurface can easily be predicted (Tearpock and Harris, 1987). The study area covers about 1.2 Km^2. This is generally geared towards water assessment and use for various purposes in the location.

LOCATION

The study area is in the eastern Dahomey basin. It is in heart of Papa-Alanto express way along Shagamu interchange overhead bridge axis, Ogun State off Lagos-Ibadan expressway. The location is 5.3km off the Lagos Abeokuta express way, southeast of Ifo town on the outskirt of Lagos (figure 1). The study area is bounded in the south by Lagos State and the Atlantic Ocean, in the north by Oyo State, in the west by Benin Republic and in the east by Ondo State. Ogun state which harbors the study location has an area of 16,409.26km^2. The study area lies on a latitude of 6^0 51'N and a longitude of 3^0 27'E. It also lies westward to the Lagos-Ibadan expressway (figure 1).

GEOMORPHOLOGY OF STUDY AREA

The study of geomorphology helps to select suitable survey positions and invariably it serves as guide in interpreting the data acquired by electrical resistivity survey method (Ojelabi and Onuoha, 2002). The study area has a major geomorphological feature recognizable as the Lagos lagoon which serves as the drainage passing through Ofada, a neighboring town. This however has a dendritic drainage pattern. The area has mild surface erosion leading to a considerably flat land. Also on a large scale the area occupies lowland with flat undulating features. It has a steep relief in the NW-SE direction.

Figure 1: Location of Eastern Dahomey Basin and position of study area

Generally, the soil type associated with the area is sandy in nature with small amount of clay resulting from intense weathering causing leaching, this happens throughout the area. It is associated with the tropical climatic condition having 2 major seasons; the dry and rainy season. The average rainfall is between 40-60mm, peaking between May and August within the year. It can also be allotted an average temperature between 25^0C-27^0C (Odemerho and Onokerheraye, 1994). However, recent temperature recorded has a wider range between 24^0C-32^0C, probably due to the upsurge global temperature variation. The area is predominantly located within the equatorial rain forest of the world and it can be allotted guinea savanna vegetation for the tall grasses, shrubs and scattered trees which characterizes the area.

GEOLOGY OF STUDY AREA

The evolution of the Dahomey basin is attributed to the transcurrent movement of the oceanic fracture systems especially the Romanche chain and Charcot fractures during the drifting stages of separation of South American and Africa plates in the Campanian to Tertiary. The Dahomey basin constitute part of a system of West African pericratonic (margin sag) basin that developed during the commencement of the rifting, associated with the opening of the Gulf of Guinea in the early Cretaceous to Late Jurassic (Burke et al., 1971; Whiteman 1982; Omatsola and Adegoke, 1981)

Sediments are predominantly terrigenous clastics with clay/shale and sand intercalations. Bands of biogenic limestone and calcareous shaly beds developed on the highs. Sufficiently anoxic conditions prevailed leading to accumulations of dark-gray to bluish-green micaceous shales and clays containing glauconitic grains and biogenic pyrites all forming the upper Cretaceous sediments. Lower Cretaceous sediments range from feldspathic sandstone with admixture of ferrugenized conglomeratic sequence, comprising very coarse, sometimes pebbly to fine gritty clastic with partly weathered feldspar crystals (Slansky, 1962; Adegoke *et al.,* 1970; Ogbe, 1970; Kogbe, 1976). The entire Cretaceous succession has been grouped into 3 unconformable formational units. Some analogy includes the underlying Abeokuta group as the oldest consisting of coastal plain clastics with sleeves of fluvial-marine sands and clays (Table 1).

METHODOLOGY

Area Mapping

The study location has an area extent of 1.2 Km^2. The area was cut out into grid of about 200m per point which is equivalent to each station considered for survey as evident in the map of the area shown in figure 2. This grid system was adopted in order to appropriately investigate the length and width of the location.

Table 1: Regional generalized stratigraphic setting of the eastern Dahomey basin SW, Nigeria

AGE		FORMATION			LITHOLOGY
		Ako *et al.*, 1980	Omatsola and Adegoke, 1981		
TERTIARY	EOCENE	ILARO FORMATION	ILARO FORMATION		SANDSTONE
		OSHOSUN FORMATION/ AKINBO FORMATION	OSHOSUN FORMATION/ AKINBO FORMATION		SHALE
	PALEOCENE	EWEKORO FORMATION	EWEKORO FORMATION		LIMESTONE
CRETACEOUS	MASTRICHTIAN	ABEOKUTA FORMATION	ABEOKUTA GROUP	ARAROMI FORMATION	SHALE
	TURONIAN			AFOWO FORMATION	SANDSTONE AND SHALE
	BARREMIAN			ISE FORMATION	SANDSTONE
Undifferentiated Precambrian crystalline basement rocks					

The cutting of three different traverses to be worked on was done with the intention of opening the location for easy accessibility and then the profiles for the electrical resistivity was georeferenced using the global system positioning (GPS) instrument. Therefore the elevations and the longitude and latitude positions were determined as shown on table 1. In achieving adequate lateral coverage for the electrical resistivity survey, three traverses were worked on and Vertical Electrical Sounding (VES) was done for sixteen (16) different points as shown in the base map (figure 2). On each of the traverse, lines were cut, cables laid, electrodes injected into the earth. Traverse 1 cut across the culvert within the study area and the same is applicable to traverse 2 but traverse 3 only cuts across the major drainage which passes through the area as a consequent stream (figure 2). However, the 3 traverses all lie parallel to one another.

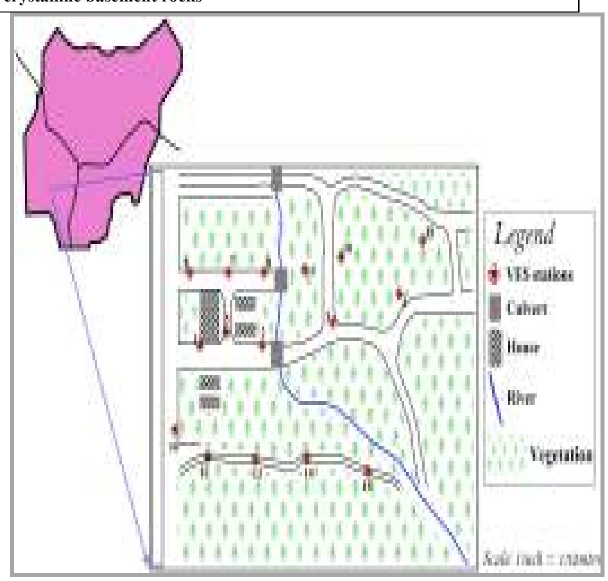


Figure 2: Location and survey area layout showing 3 parallel profiles with 16 VES stations

DATA ACQUISITION

Electrical Resistivity

The instruments adopted in the case of this method include: cables, steel electrodes, hammers, ABEM SAS 1000 Terrameter, D.C battery, GPS, measuring tapes, umbrella, and rain boots. The instruments were set up by connecting the ABEM SAS 1000 terrameter to the energy source being the battery, then employing the Schlumberger array of electrode which implies laying four different electrodes simultaneously with the ratio of current to potential electrode of 5:1.The cables were connected to the four electrodes, two of which represents the potential electrodes and the other two represents the current electrodes, then the other end of each electrode were connected appropriately to the terrameter, considering the fact that the terrameter bears the current and the potential terminals.

The terrameter is then switched on and readings taken as appropriate, noting that half the current lectrode spacing (AB/2) is measured in meters, the induced polarization (M) is measured in milliseconds, and the resistivity values (ρ) is measured in ohms. Then hammers were employed in driving the steel electrodes into the earth. The measuring tapes were used to measure out distances for the different electrode spacing. The GPS and the compass were used to know the elevations and the bearing of the location under observation with respect to the north.

RESULTS

Electrical Resistivity Results

From the 1D-layered model generated the resistivities associated with each layer were derived and their corresponding thicknesses presented in Table 2. These were observed to fall within the range documented in Kearey and Brooks, 2002 and presented in Table 3. There were sixteen different resistivity curves obtained from the computer iteration, a sample of this for VES station 1 is presented in figure 3. These results were used to generate three different geoelectric sections. It is from these sections alongside the resistivity values that the different lithologies presented in table 2 were delineated.

Qualitative Interpretation

Relatively, the curve types obtained from the computer iteration are AKQ type. Therefore qualitatively, VES 2, 3, 4 and 16 are the KH type curves with resistivity combination ρ1< ρ2> ρ3< ρ4, while VES 1, 7, 8, 13 and 14 are the QH type with resistivity combination ρ1> ρ2> ρ3< ρ4 but VES 5, 6, 9, 10, 11, 15 are the H type curves with resistivity combination ρ1> ρ2< ρ3 (Table 4). VES 12 on its part indicates a QHA type curve with resistivity combination ρ1> ρ2< ρ3> ρ4< ρ5 as indicated in Table 4 (figures 3, 4 and 5). Hence the QHA type curve consist of 5 layers, the H type curves has 3 layers and the QH type curves has 4 layers.

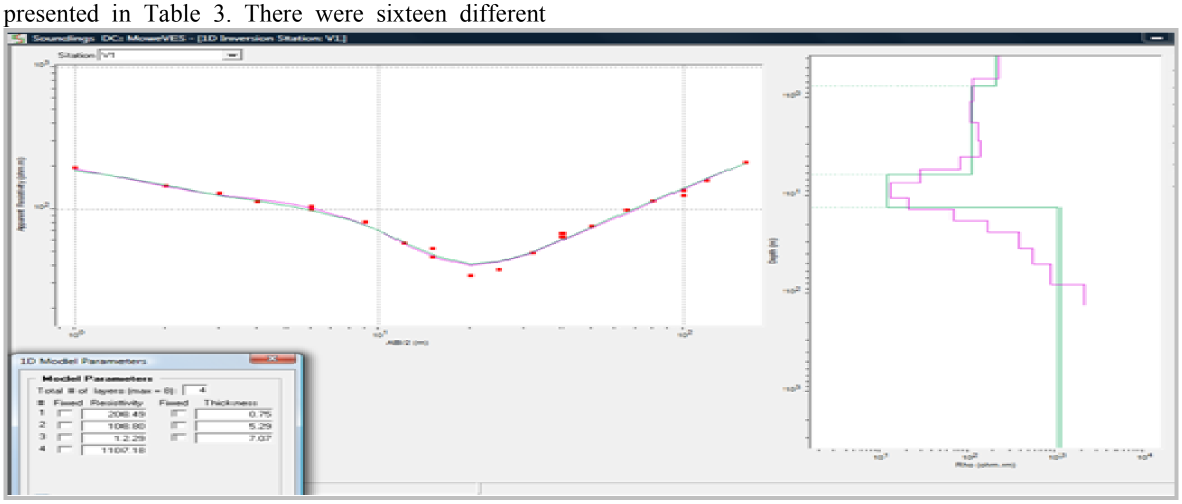


Figure 3: Computer Iterated 1D Layered Model for Electrical Resistivity showing VES station 1

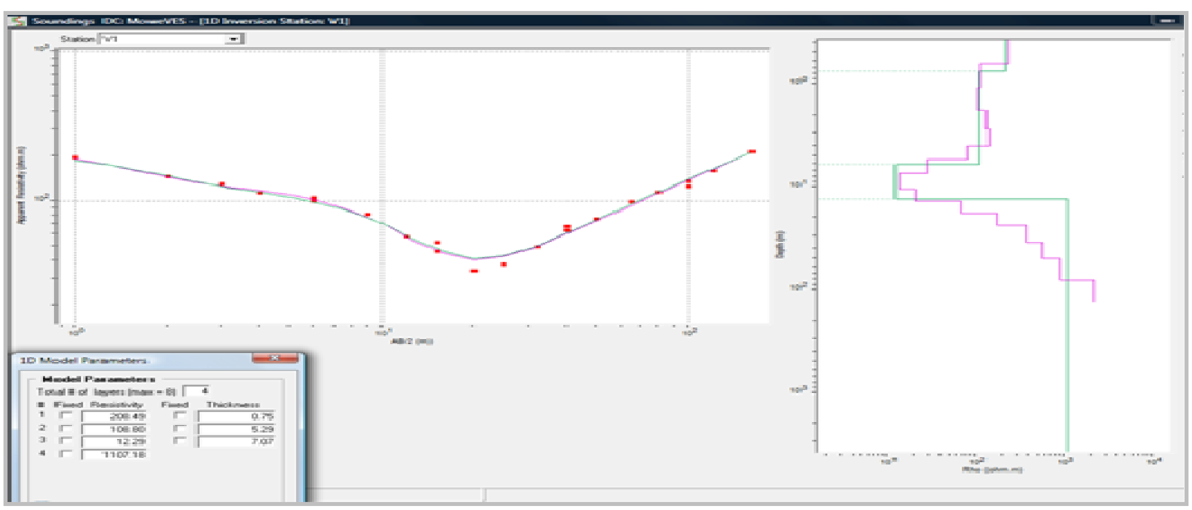


Figure 4: Computer Iterated 1D Layered Model for Electrical Resistivity showing VES station 2

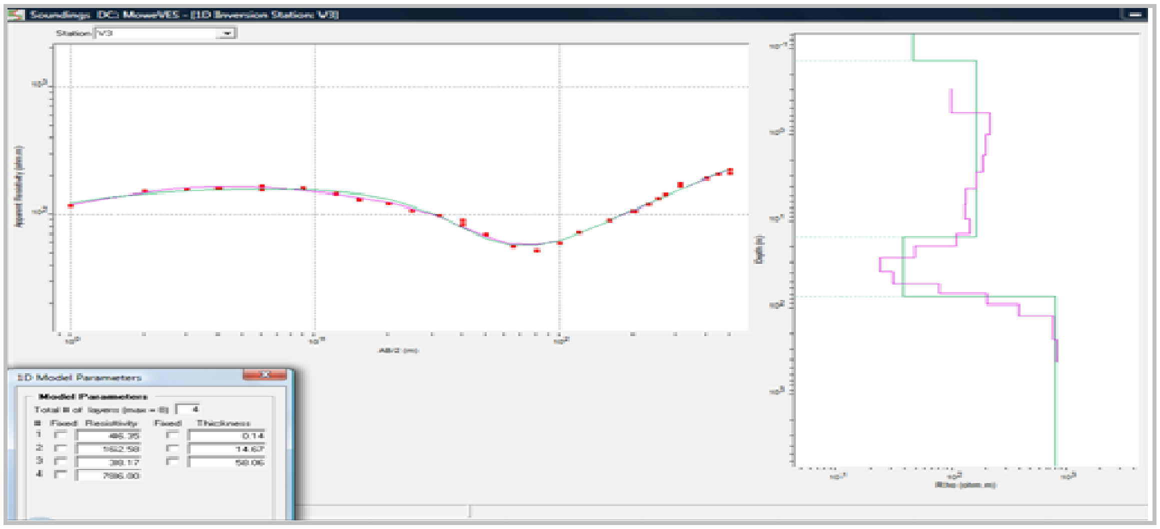


Figure 5: Computer Iterated 1D Layered Model for Electrical Resistivity showing VES station 3

Table 2: Results showing lithology of each layer, resistivity and thickness

VES Station	Layer	Resistivity (Ohm-m)	Thickness (m)	Depth (m)	Lithology
1	1	208.49	0.75	0.75	Topsoil
	2	108.8	5.29	6.04	Laterite
	3	12.29	7.07	13.11	Clay
	4	1107.18	-	-	Sand
2	1	80.9	1.14	1.14	Topsoil
	2	222.21	8.54	9.68	Laterite
	3	25.07	45.63	55.31	Clay
	4	760.25	-	-	Sand
3	1	46.35	0.14	0.14	Topsoil
	2	162.58	14.67	14.81	Laterite
	3	38.17	58.06	72.87	Clay
	4	786	-	-	Sand
4	1	118.65	2.92	2.92	Topsoil
	2	173.55	5.75	8.67	Laterite
	3	45.92	28.57	37.24	Clay
	4	64.42	45	82.24	Sand
	5	290.19	-	-	Sand
5	1	291.31	0.98	0.98	Topsoil
	2	29.44	8.13	9.11	Laterite
	3	496.58	-	-	Sand
6	1	487.87	0.44	0.44	Topsoil
	2	142.26	2.58	3.02	Laterite
	3	27.57	3.33	6.35	Clay
	4	713.84	-	-	Sand
7	1	239.94	1.41	1.41	Topsoil
	2	154.3	4.2	5.61	Laterite
	3	13.24	8.68	14.29	Clay
	4	351.71	-	-	Sand
8	1	303.26	9.21	9.21	Topsoil
	2	37.13	35.36	44.57	Clay
	3	417.49	-	-	Sand
9	1	549.7	0.82	0.82	Topsoil
	2	165.67	9.74	10.56	Laterite
	3	64.57	39.72	50.28	Clayey Sand
	4	1980.52	-	-	Sandy Clay
10	1	378.57	0.59	0.59	Topsoil
	2	174.39	5.54	6.13	Laterite
	3	29.96	8.73	14.86	Clay

Table 3: Approximate range of resistivity values of common rock types (Keary and Brooks, 2002)

Resistivity(Ωm)	Rock Type
$10\text{-}10^3$	Alluvium
1-10	Clay
$20\text{-}10^4$	Shale
$1\text{-}10^9$	Sandstone
$10\text{-}10^8$	Quartzite
$20\text{-}10^4$	Schist
$10^3\text{-}10^6$	Gabbro
$500\text{-}10^6$	Granite

QUALITATIVE INTERPRETATION

Relatively, the curve types obtained from the computer iteration are AKQ type. Therefore qualitatively, VES 2, 3, 4 and 16 are the KH type curves with resistivity combination $\rho1< \rho2> \rho3< \rho4$, while VES 1, 7, 8, 13 and 14 are the QH type with resistivity combination $\rho1> \rho2> \rho3< \rho4$ but VES 5, 6, 9, 10, 11, 15 are the H type curves with resistivity combination $\rho1 > \rho2 < \rho3$ (Table 4). VES 12 on its part indicates a QHA type curve with resistivity combination $\rho1 > \rho2 < \rho3 > \rho4 < \rho5$ as indicated in Table 4 (figures 3, 4 and 5). Hence the QHA typecurve consist of 5 layers, the H type curves has 3 layers and the QH type curves has 4 layers.

QUANTITATIVE INTERPRETATION

Geoelectric Section AA'

Data obtained from the computer iteration presents five different layers that were delineated. This section encompasses VES 1, 2, 3, 4, 5 on traverse AA' with the highest number of layers attributed to VES 4 which has 5 different geoelectric layers, although only 4 different lithologies were delineated and this include: topsoil, laterite, clay and sand (Figure 6). In effect therefore, the resistivity of this VES station ranges from 45.92Ωm-290.19 such that the highest resistivity is identified as possible sand (Table 2). For layer 1 in this section we have a thickness ranging from 0.14m-2.92m and corresponding resistivities ranging from 46.35Ωm-291.31Ωm. In the same vein, layer 2 has thicknesses ranging from 5.29m-14.67m and corresponding resistivities ranging from 29.44Ωm-222.21Ωm. Then for layer 3 the thickness ranges from 7.07m-58.06m, while the corresponding resistivities range from 12.29Ωm-496.58Ωm. For layer 4 therefore, the thickness is about 45m and the corresponding resistivities from 64.42Ωm-1107.18Ωm. Layer 5 then has a resistivity of about 290.19Ωm (Table 2).

Table 4: Qualitative Results of Resistivity Data

VES Stations	Curve type	Resistivity Combination
1	QH	$\rho1 > \rho2 > \rho3 < \rho4$
2	KH	$\rho1 < \rho2 > \rho3 < \rho4$
3	KH	$\rho1 < \rho2 > \rho3 < \rho4$
4	KH	$\rho1 < \rho2 > \rho3 < \rho4$
5	H	$\rho1 > \rho2 < \rho3$
6	H	$\rho1 > \rho2 < \rho3$
7	QH	$\rho1 > \rho2 > \rho3 < \rho4$
8	QH	$\rho1 > \rho2 > \rho3 < \rho4$
9	H	$\rho1 > \rho2 < \rho3$
10	H	$\rho1 > \rho2 < \rho3$
11	H	$\rho1 > \rho2 < \rho3$
12	QA	$\rho1 > \rho2 < \rho3 >$ $\rho4 < \rho5$
13	QH	$\rho1 > \rho2 > \rho3 < \rho4$
14	QH	$\rho1 > \rho2 > \rho3 < \rho4$
15	H	$\rho1 > \rho2 < \rho3$
16	KH	$\rho1 < \rho2 > \rho3 < \rho4$

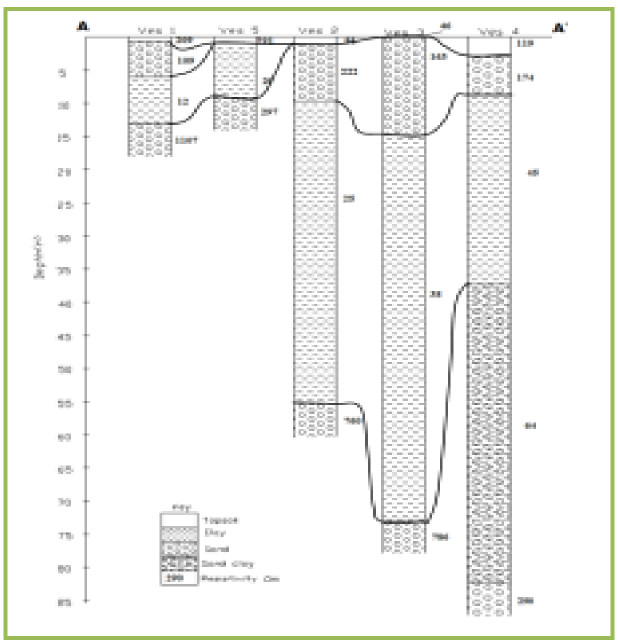


Figure 6: Geoelectric section along traverse AA'

Geoelectric Section BB'

Six (6) different VES stations make up this geoelectric section which includes: VES 6, 7, 8, 9, 10, 11 (Figure 7). The maximum number of geoelectric layers delineated at each VES station within this section is 4 layers and the lithologies delineated are sand, clayey sand, lateritic clay, topsoil in younging direction.

Layer 1 has thicknesses ranging from 0.44m-9.21m with corresponding resistivities between 239Ωm-619.45Ωm. Layer 2 has thicknesses ranging from 2.58m-35.36m and corresponding resistivities from 37.13Ωm-174.39Ωm. Layer 3 therefore has thicknesses ranging from 3.33m-40.89m and corresponding resistivities from 13.24Ωm-417.49Ωm. Layer 4 has resistivities ranging from 351.71Ωm-1980.52Ωm (Table 2).

Geoelectric Section CC'

Five (5) different VES stations make up this geoelectric section which includes: VES 12, 13, 14, 15 and 16 (Figure 8). The maximum number of geoelectric layers delineated at each VES station within this section is 5 layers and the lithologies delineated are sand, clay, laterite and topsoil in younging direction. Except for the lithology in VES station 16 which is a little bit of a deviant having sandy clay, clay, laterite and topsoil in younging direction.

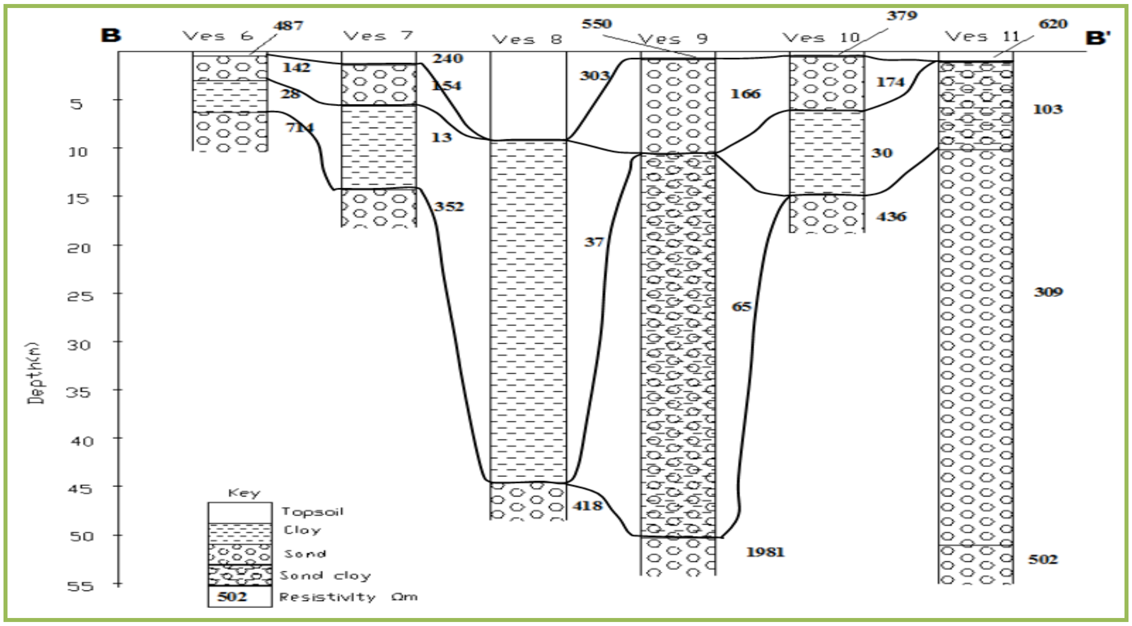


Figure 7: Geoelectric section along traverse BB'

Layer 1 has thicknesses ranging from 0.8m-2.42m with corresponding resistivities between 25.54Ωm-239Ωm. Layer 2 has thicknesses ranging from 5.88m-19m and corresponding resistivities from 20.94Ωm-706.82Ωm. Layer 3 therefore has thicknesses ranging from 5.83m-19.38m and corresponding resistivities from 35.3Ωm-598.93Ωm. Layer 4 has thickness of about 11.4m and corresponding resistivities ranging from 12.1Ωm-1821.03Ωm (Table 2). Layer 5 only has a resistivity of about 657Ωm.

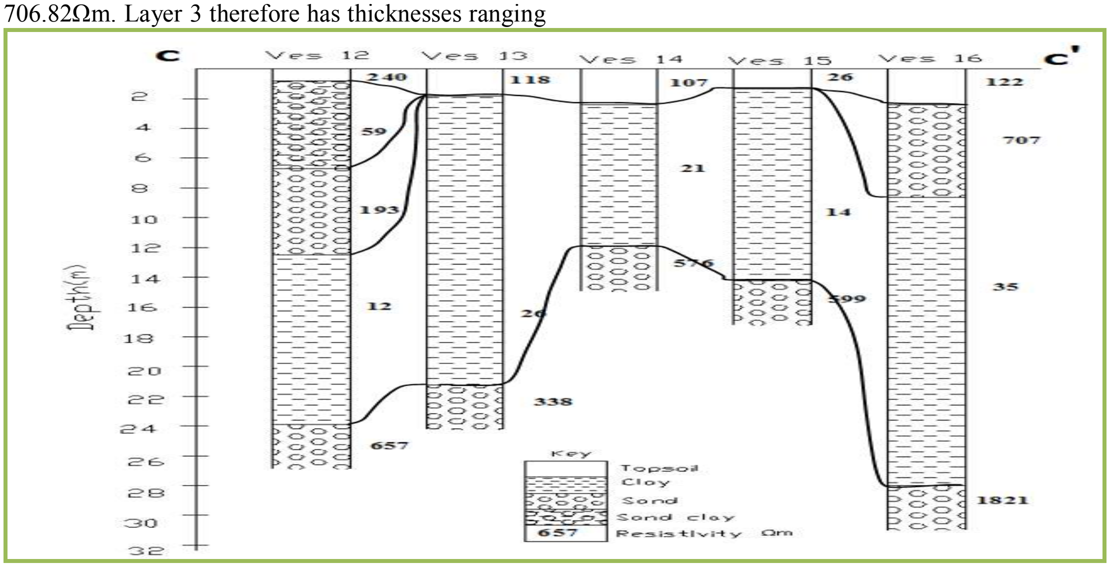
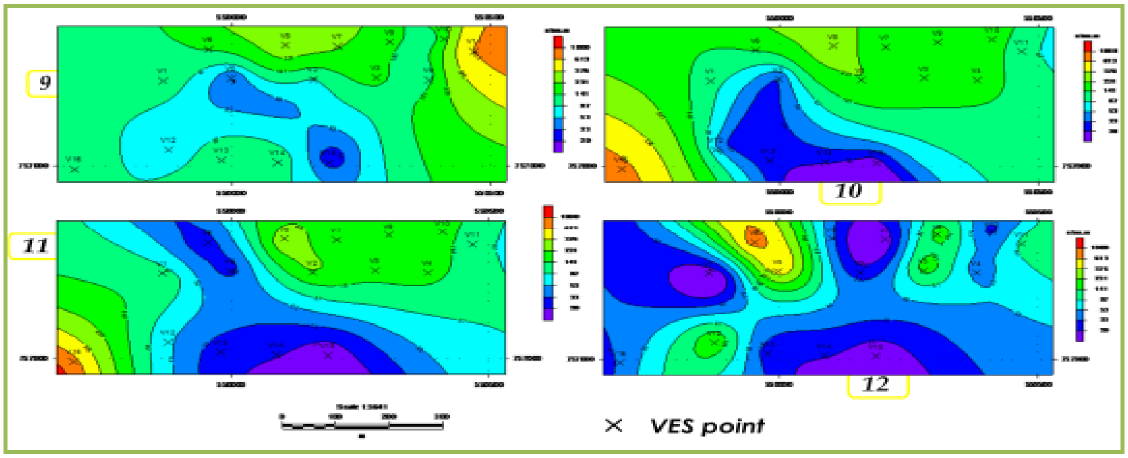


Figure 8: Geoelectric section along traverse CC'

Isoresistivity Contoured Maps

Resistivity values earlier presented were used such that all the VES points are considered at similar depth first and later for different depth instances. Depth contouring was carried out so as to delineate the best probable water bearing zones and these are presented in contoured maps as shown in Figure 9 and Figure 10 which denotes the correlation of resistivity information at depths of 1m and 3m respectively. It is revealed in these maps that portions bearing colours yellow to red have high resistivity but those bearing colors purple to green have low resistivity values. Other contoured maps for depths of 5m, 10m, 20m, 30m, 40m, 50m, 60m, 70m, 80m and 100m are respectively presented in Figures 11-20 to further validate depth resistivity correlation by viewing the subsurface to a maximum depth of 100m over an area marked by sixteen different VES stations

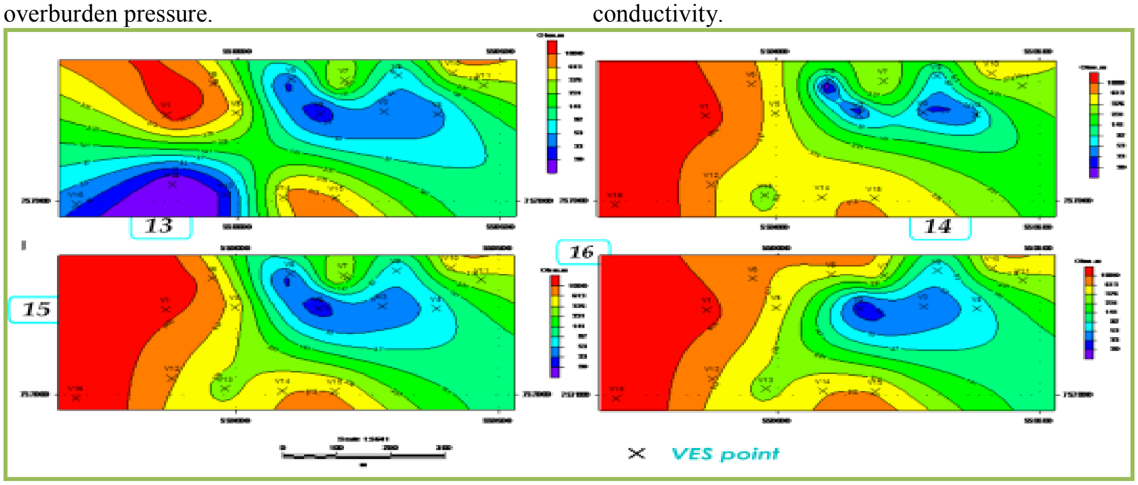


Figures 9-12: Isoresistivity Contoured Map for 1m depth (9), 3m depth (10), 5m depth (11) and 10m depth (12).

DISCUSSION

In effect some second layers are 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 ground water. This accommodates a fresh water aquifer from which portable water in commercial quantity can be derived. Since this will likely give a very productive aquifer the clay overburden serves as a protective cover (aquiclude) to conserve these ground water resources. Based on these values, it is confirmed that layer 1 is composed of decomposed organic matter or superficial deposits and layer 2 is mostly made up of lateritic clay having undergone compaction due to overburden pressure.

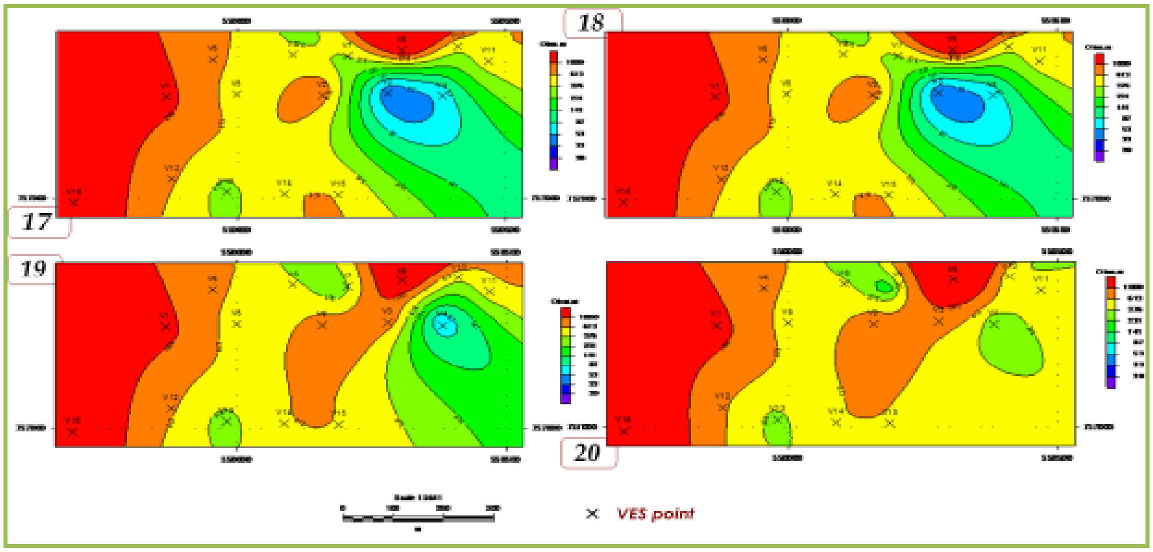
It was deduced that layer 1 is fairly conductive typical of loose soil type with organic matter content, this being the top soil whose thickness falls between 2m and 6m. On the other hand, layer 2 is more conductive than the overlying unit, it is then inferred that this layer is made up of wet clay (lateritic clay). The thickness of this layer ranges from 3m to 8m. Furthermore, layer 3 can be said to be associated with an average mixture of sand, silt, gravel and alluvium, hence, it is a combination of sand and compacted clay, although it is more sandy than clayey. The third layer being predominantly sand has good capillary effect, hence, a good source of ground water. Density is observed to increase in depth with increase in conductivity.



Figures 13-16: Isoresistivity Contoured Map for 20m depth (13), 30m depth (14), 40m depth (15) and 50m depth (16)

CONCLUSION

Electrical resistivity method has been utilized to profile for ground water occurrence and possible exploration. However, this method is not infallible as other geophysical methods such as seismic refraction method can be used for further investigation. Although this method could fail if situations such as nearly equal velocity contrast is encountered. In the same vein the electrical resistivity method could not equally separate sand from clay in the uppermost layer due to the absence of good resistivity contrast. Future work may be targeted at unraveling the fourth layer using a hybrid array method or other geophysical methods with lower frequency and higher penetrating power like refraction seismic engaging competent energy source.



Figures 17-20: Isoresistivity Contoured Map for 60m depth (17), 70m depth (18), 80m depth (19) and 100m depth (20)

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