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INVESTIGATION OF THE VARIATION OF ELECTRICAL RESISTIVITY OF THE SUBTERRANEAN SECTION OF KARUGA AREA, CHIKUN LGA, KADUNA STATE USING VERTICAL ELECTRICAL SOUNDING

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Abstract

This work was carried out in Karuga - Karji Area of Kamazou, in Chikun Local Government Area, Kaduna State. The area is approximately located within longitudes 7° 490' 034"E and 7º491'428"E and Latitudes 10°487'579" N and 10º487'900"N and it is about 800m South West of Kaduna on Patrick Ibrahim Yakowa Road. The total area covered in this work measures about 8400m². The study is important because there was no any record to show that geophysical survey has been done in this area. Therefore, Geophysical survey in terms of Geoelectrical resistivity sounding using the Schlumberger array was adopted – sixteen vertical electrical soundings (VES's) were measured on the study area. The work was aimed on investigation of the aquifer variation of electrical resistivity of the subterranean section of the study area. Quantitative and qualitative Interpretations of data were carried out. Four profiles with four VES points on each profile of the geoelectric sections revealed that; profile 1 is about 0.105km long. The azimuth of the profile is west – east, with maximum of five geoelctric layers. The soundings were at the lowest and the highest resistivity of 95.59485 Ω-m and 85628.634 Ω-m. Profile 2 is about 0.105km long. The azimuth of the profile is west – east, with maximum of four geoelctric layers at lowest and highest resistivity of 138.57857 Ω-m and 404.61882 Ω-m. Profile 3 is about 0.105km long. The azimuth of the profile is west – east, with maximum of four geoelctric layers at lowest and highest resistivity of 83.82933 Ω-m and 269.84367 Ω-m. And Profile 4 is about 0.105km long. The azimuth of the profile is west – east, with maximum of five geoelctric layers at lowest and highest resistivity of 115.0464 Ω-m and 6869.11 Ω-m. The geologic sections correspondingly indicated the lithological variability compositions of the depths delineated. The characteristic resistivity formed for the various earth materials found alluded that the layers of the study area is composed of lateritic sands, weathered rocks, quartzite alluvium, clay, fractured and fresh basement rocks. The fouth VES point geoelectrical layer is considered the suitable aquifer for the area under investigation with moderate electrical resistivity value (115.0464 ohm.m), and could be recognized sometimes as the most extreme 18.6m depth of penetration. At the maximum depth of penetration of this area, the lower layer (fourth layer) was recognized with the highest electrical resistivity value (85628.634 ohm.m) The thickness of the over-burden is observed having no uniformity in the profiles. Profile 2 is the deepest zone within the study area with an average of 27.9m depth.
A maximum of five geoelectric layers were identified in the study area. The basement is resistive with variable resistivity values ranges from 38.1 Ω-m to 7029.4 Ω-m. The geologic sections of the rocks formed from the terrain is the weathered/fractured basement aquifer overburden the study area.

Keywords**:** Geoelectric Layers, Aquifer, Geomagnetic Variability and Electrical Resistivity, Potential.

1.0 Introduction

The importance of geophysical survey for groundwater determination cannot be overemphasized. Determination of subsurface structures requires information about subsurface rocks. This would help delineate nature of the materials present and strata boundaries. Exploration for groundwater is important since the area falls within some parts of central Nigeria where there is rainfall for six to seven months of the year, and surface sources of water are often inadequate [1]. This suggests that intensive exploitation for groundwater is indispensable to make living condition more meaningful for people in the area. Ground water is characterized by a certain number of parameters which geophysical methods are trying to determine from surface measurements, mostly indirectly, but sometimes directly. The most usual parameters are the porosity, the permeability, the transmissivity and the conductivity [2].

To identify the presence of ground water from resistivity measurements one can look to the absolute value of the ground resistivity, for a practical range of fresh water resistivity of 10 to 100 Ω-m, a usual target for aquifer resistivity can be between 50

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Ω-m and 2000 Ω-m. Most of the time it is the relative value of the ground resistivity which is considered for detecting ground water: In a hard rock (resistant) environment, a low resistivity anomaly will be the target, while in a clayey or salty (conductive) environment, it is a high resistivity anomaly which will most probably correspond to (fresh) water [3].

1.1 Location of the Study Area

The area under study is located at Karji Karuga Area of Kamazou, in Chikun Local Government Area, Kaduna state. The area is approximately located within longitudes 7°490'034"E and 7º491'428"E and Latitudes 10°487'579" N and 10º487'900"N and it is about 800m South West of Kaduna on Patrick Ibrahim Yakowa road. The total area covered in this work measures about $8400m^2$ (105m x 80m), it can be accessed through Motorable and minor footpath tracks from opposite Narayi junction via Kaduna state University or NNPC Junction. Thus accessibility within the study area is good, Figure 1 and 2.

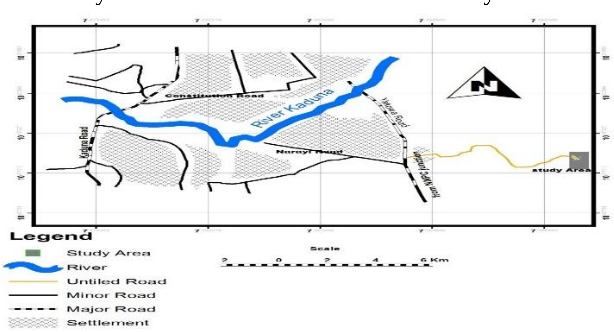

Figure 1: Motorable tracks and minor footpaths to Karuga

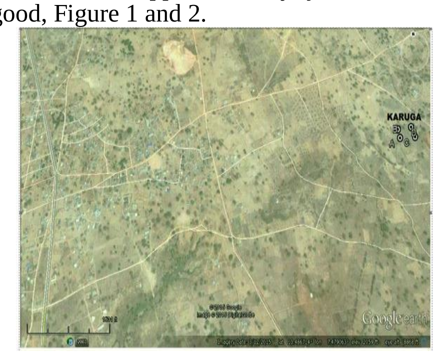

Figure 2: Satellite Image of Karuga New Extension Showing the Study Area

1.2 Climate, Topography and Drainage

Karji Karuga is situated on generally undulating land mass. It lies within the savannah belt of West Africa, but it is essentially more of residual forest than the typical savannah grassland. This residual forest is semi-deciduous in nature. They are usually located at areas bordering streams and rivers and on quartzite ridges which form the core of the hills around the area [4].

It has two climatic seasons, the wet and dry seasons. The wet season begins at about April and runs through to late November. It is characterized by thunder storms of the south –westerly wind originating from the equatorial rain belt and blowing from the higher pressure zones which occurs over the Atlantic. The dry season begins around November and extends up to about March. This season is also called "Hamattan" is of the North-eastern trade wind [5]. It is characterized by dryness of the atmospheric air, with sometimes thick dust laden wind blowing.

The nature of rainfall in the study area is averagely 1.0 m per annum. The dry season with temperature reaching up to 38º c, bring drought condition. This is further aggregated by the fact that many rivers and streams in the area dry up. The humidity ranges from about 30% during the dry season and 100% during the year [6].

Karagu is surrounded by a number villages, these are: Babban Saura (1.5 Km),Kamazou (3.0 Km), Rimi (3.5 Km), Ungwan Rimi (4.0 Km), Mashi (4.5 Km), Kabala (4.9 Km), Tudun Wada (5.1 Km), Kaduna (5.5 Km), Barnawa (5.6 Km), Ungwan Bado (6.1 Km), Bardon Yana (6.3 Km), Nassarawa (6.5 Km) Kura (6.7 Km), Parma (6.9 Km), Ungwan Kanawa (7.5 Km), Kaduna South (7.5 Km), Tudun Wada (7.9 Km), Ungwar Shanu (8.1 Km), Ungwan Galadima (8.3 Km) [7].

The types of lithologies developed in the rocks of an area will affect the occurrence of groundwater. Some rocks contain water in their pore spaces while others do not. Others do not even have pore spaces. Igneous rocks, for example, ordinarily do not have pores. They only have pore spaces when the rocks are jointed or fractured or fissured or even faulted [8]. Some crystalline rocks may be naturally highly permeable while others may not be at all. The permeability of non-crystalline rocks is determined by the type of cementing materials and the inter connectivity of the pores. The features which make a formation a good aquifer include high effective porosity and permeability. These, in turn depend on the degree of weathering and fracturing of the rock [8].

From the geological information available for the study area compared with the characteristics of the sample rocks from the area, the hydro geological elements likely to exist in the area for storage of groundwater include:Weathered basement and fractured basement.

According to [9], weathered and fractured basement are the most important aquifers within the basement complex of Nigeria. Weathered basement aquifer(s) are sometimes covered by lateritic loam and where they are exposed to erosion, they exhibit evidence of mobilization, where weathering of the rock has been in-situ, the weathering product is usually capped by laterite and fresh basement which is porphyritic granite [9].

Karuga new extension area is a settlement that has social amenities such as electricity and pipe borne water as there is a big World Bank completed water project facility in the area. The aim of this research study is to determine the hydraulic conductivities of the subterranean section of the area under study using VES and VLF Geophysical methods of investigation.

Water resources management is defined as the continuous use of limited available water resources, surface or underground, conjunctively or separately, for supply of water for domestic, industrial, agricultural, power and navigation requirements. The limitation in the availability arises from the fact that the usefulness of these storages depends on the readiness of extraction or recharge, which is controlled by hydraulic conductivity and other components of hydraulic cycle.

Since rainwater finally ends up in the sea either directly through runoff or indirectly by infiltration and subsurface flow, hence water resources management is aimed at prolonging the movement to the sea as much as possible by means of dams, and boreholes in surface and underground water resources management respectively. The result of hydraulic conductivity measurements are also used to know the quantity of water, both surface and underground; to design drainage system and other agricultural management schemes; to estimate seepage from open channels or reservoirs and to predict groundwater contamination waste disposal sites. Therefore the use of hydraulic conductivity in control of water hazards and effective utilization of the available water cannot be overemphasized.

Water moves towards the sea as overland flow along the soil surface or as ground water flows through the groundwater overflow eventually set in, after the onset of rainfall, when the surface and subsurface storage requirements are met by the falling rain, the surface storages being depression and detention storages. The volume of the surface runoff and the rate of replenishing these storages is a function of the hydraulic conductivity of the soil over which the flow is taking place. Thus the volume of runoff flowing past a soil is of high hydraulic conductivity and the value is smaller compared to the same volume of runoff flowing resistivity of the impermeable soil materials. The decrease in volume is due to seepage losses due to infiltration into the groundwater reservoirs. The variation in the value of the hydraulic conductivity of the various stratified layers of the aquifer materials is responsible for the slow response of the groundwater flow to the infiltrating water from the surface [10]. Although groundwater flows is slow and its contribution to most flood is slow. It is the only source of stream flow during protection dry spells.

Exploration of the soil for any purpose like agricultural production and to maximize the yield requires proper soil-water management. The hydraulic conductivity is thus a measure of the amount of water lost to seapage through the embankment or into the groundwater.

The value of hydraulic conductivity at waste disposal sites also helps in determining the degree of groundwater pollution [11-13]. In urban cities, human waste disposal is by burying in pit or septic tank and domestic wastes disposal is by incineration. Surface runoff over these sites washes the surface water and transports them along and infiltrates into and pollutes the groundwater resources at a rate depending on the permeability of the soil over which it flows. When the groundwater flow is in the direction of a pit latrine is septic tank, the degree of pollution is directed by the hydraulic conductivity of the walls of the tank or latrine. If the wall has high coefficient of permeability, the rate of osmotic movement of the dissolved wastes into the groundwater flow is high and vice versa. The ranking of aquifers into confined, unconfined and semi confined is a function of the value of the hydraulic conductivity of aquifer layers.

2.0 TOOLS/EQUIPMENT

In this work, the instruments for data acquisition are ABEM S.A.S. 300B Terrameter and GPS were used. The GPS is used for situating and collecting the coordinates. The other accessory tools used for collecting the resistivity data, were hammer, cables, tapes and electrodes. The terrameter consists of two units, the outer box containing both the terrameter unit and the receiver, and the lower chamber consists of the rechargeable battery. These are assembled in rugged Aluminium boxes capable of withstanding rough transport and field conditions. Thus, the boxes give excellent protection to the electronic circuitry and other sensitive component parts of the instrument. The instrument is completely waterproof and the casing sealed against dust and dampness. It has a dial which is used to balance the resistivity of the ground set up due to the passage of current into the ground.

2.1 Theory of Direct Current Resistivity Method

The physical principle underlying the method of direct current conduction as deduced from Ohm's law [14]. For a single point source of current within the subsurface, which assumes homogeneous and isotropic conditions, the potential can be derived from these two basic equations.

$$\vec{E} = \rho J \tag{1}$$

Where

$\vec{E}$= Electric field intensity

J = Current density

ρ = The resistivity of the medium

The Divergence condition

$$\nabla . J = 0 \tag{2}$$

The implication of equation (2) is that in the absence of current sink or source, all current passed into a piece of material will leave at the other side (opposite).

The divergence of a vector $\underset{J}{\rightarrow}$must be zero everywhere except at the current source.

Combining equation (1) and (2) the Laplace's equation is obtained.

$$\nabla . J = \frac{1}{\rho} \nabla . \vec{E} \ = 0 \tag{3}$$

$$\text{But } \vec{E} = -\nabla V \tag{4}$$

$$\text{J} = -\frac{1}{\rho} \nabla . V \tag{5}$$

Putting equation (5) into (3), get:

$$\nabla . J = \frac{1}{\rho} \nabla^2 V \tag{6}$$

Where, E = Electric field

J = current density

ρ= Resistivity

V = Scalar potential

The Laplacian equation in spherical polar coordinates becomes

$$\nabla^2 V \ = \frac{1}{r2} \frac{\partial}{\partial r} (r^2 \frac{\partial V}{\partial r}) + \frac{1}{r2 \sin \theta} \frac{\partial}{\partial \theta} (\ \sin \theta \ \frac{\partial V}{\partial \theta}) + \frac{1}{r2 Sin^2 \theta} \frac{\partial^2 V}{\partial \Phi^2} = 0 \tag{7}$$

The spherical coordinates r, θ and Φ are related with Cartesian coordinates thus

X = r cosΦsinθ

Y=rsinΦsinθ

Z = rcosΦ

There is complete symmetry of current flowing through θ and Φ directions if a single source of current I is introduced into an infinite homogeneous medium, the potential at a distance r, there will only be a function of r, then equation (7) becomes

$$\frac{d^2V}{dr^2} + \frac{2}{r}\frac{dv}{dr} = 0 \qquad (8)$$

(Since $r \neq 0$)

Or

$\frac{1}{r2}\frac{\partial}{\partial r}\left(r^2\frac{\partial V}{\partial r}\right) = 0$ *then* $r^2\frac{dv}{dr} = a$ and $v = -\frac{a}{r} + b$

Where *a* and *b* are constants and r is the distance from the current electrodes.

Since v = 0 when I→ ∞ , then b = 0

Therefore $v = -\frac{a}{r}$ (9a)

The current flows radially through a hemispherical surface in the lower medium

$I = 2\pi r^2 J$, but $J = -\frac{1}{\rho}\nabla.V = -\frac{1}{\rho}\frac{dv}{dr}$

Hence $I = -2\pi r^2.\frac{1}{\rho}\frac{dv}{dr} = -2\frac{\pi}{\rho} r^2\frac{dv}{dr} = -2\frac{\pi}{\rho}a$

this shows that $a = -I\frac{\rho}{2\pi}$ (9b)

$$v = \frac{I\rho}{2\pi r} \qquad (10)$$

Where we have a heterogeneous medium (several sources of current), the potential can be calculated by algebraic summation of each source independently.

For *n* current source, equation (10) becomes

$$V_n = \frac{\rho}{2\pi}\left(\frac{I_1}{r_1} + \frac{I_2}{r_2} + \frac{I_3}{r_3} + \ldots\ldots\ldots. + \frac{I_n}{r_n}\right) \qquad (11)$$

If a solid with constant resistivity on assumption, that current *I*, is introduced into the solid material through electrodes A and B respectively, on its surface and the potential is measured across the electrodes at M and N. The distance r_1 from electrode M at A and distance r_2 from electrode N at B as shown respectively written thus:

$$V_m = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} + \frac{1}{r_2}\right) \qquad (12)$$

$$V_n = \frac{I\rho}{2\pi}\left(\frac{1}{R_1} + \frac{1}{R_2}\right) \qquad (13)$$

The potential difference (P. d) ΔV from equation (12) and (13) is shown below:

$$\Delta V = \text{Vm} - \text{Vn} = \frac{I\rho}{2\pi}\left\{\left(\frac{1}{r_1} + \frac{1}{r_2}\right) - \left(\frac{1}{R_1} + \frac{1}{R_2}\right)\right\} \qquad (14)$$

The apparent resistivity can be found as

$$\rho = \frac{2\pi\Delta V}{I}\left(\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} - \frac{1}{R_2}}\right) \qquad (15)$$

If K, is the geometric factor which represents $\left(\frac{1}{\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{R_1} - \frac{1}{R_2}}\right)$, equation (15)becomes

$$\rho = \frac{2\pi\Delta V}{I}k \qquad (16)$$

K depends on the electrode configuration used during the field measurement.

The distance AB (2L) between the current electrodes is large compared with distance MN (2L) between the potential electrodes as shown below in Figure 3.0.

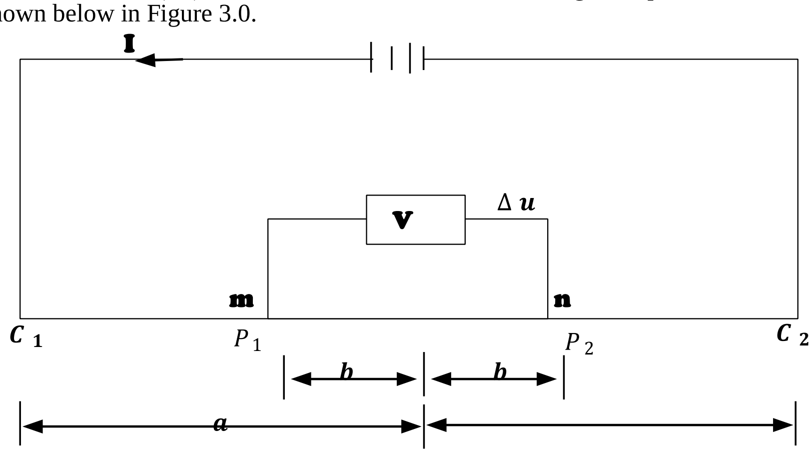

Figure 3. General four (4) Electrode Configuration for Resistivity Measurement.

Equation (15) can be used to deduce the apparent resistivity thus:

$$\rho a = \frac{\pi}{2I}\{L^2 - l^2\}\frac{\Delta V}{I} \quad (17)$$

For L>>l

$$\rho a = \frac{\pi}{2I} L^2 \frac{\Delta V}{I} \quad (18)$$

Thus equation (18) gives the relationship between apparent resistivity and the approximate value normally given by the ABEM Terrameter during the field measurement. The geometrical factor characterized the spacing used in the field measurement.

The resistivity value of a homogeneous medium is independent of the electrode position and is not altered even when the current and the potential electrodes are alternated. On the contrary, the effective resistivity in equation (15) is called apparent resistivity because it is not the resistivity of the surface earth which also varies with the position of the electrodes. Its values changes with the electrode spacing to indicate the variation of the resistivity with the depth or the thickness [15].

Apparent resistivity is defined as the resistivity which the ground would have if it were homogeneous [16]. This shows that, it does not represent the average resistivity and can be higher than the bigger value or lower than the smaller value within the subsurface [17].

2.2 Choice of Electrical Configuration

Electrical resistivity perspectives have a number of electrode configurations which include the three point partition arrays, the Dipole-Dipole arrays, the Schlumberger and the Wenner array. The choice of the electrode configuration depends on the following factors: the terrain of the area of the investigation; the type of investigation needed and the suspected geological positional structure.

The Schlumberger was chosen for this field work. This is because it is cost effective; less sensitive to undetected lateral variation of resistivity and this array eliminates electrode effect on the resistivity curves due to perturbation passage of electrodes potential over superficial heterogeneous current electrodes [18].

2.3 Data Collection

2.3.1 The Vertical Electrical Sounding Survey

The VES or electric drilling technique is based on the principle that the fraction of the electric current put into the ground which penetrates below any particular depth, increases with an increase in the separation of the current electrodes. The depth of investigation of sounding, therefore, increases generally with increase in the electrodes spacing. This way, the various subsurface layers/ structures under laying the point being sounded are reached [4].

A total of 16 soundings were carried out within the study area. The Schlumberger electrode array was chosen for the work (Figure 5).

Soundings that were carried out at specific locations which had features that could assist in the general interpretation of the data collected. The VES stations were located using two lowest readings and two highest readings each from the four profiles readings so obtained; thus VES1, profile 1 was sounded at lowest and highest readings, 95.59485Ω-m and 85628.634 Ω- m (table 1). VES2, profile 2 sounded at the lowest and highest readings 138.57857 Ω- m and 404.61882 Ω- m (table 2). VES3, profile 3 sounded at lowest and highest readings 83.82933 Ω- m and 269.84367 (table 3), and VES4, profile 4 sounded at the lowest and highest readings 115.0464 Ω- m and 6869.11 Ω- m (table 4).

2.3.2 Field Procedure

This method involves the supply of direct current or low-frequency alternating current into the ground through a pair of current electrodes and the measurement of the resulting potential through another pair of electrode called potential electrodes. Since the current is known and the potential can be measured, an apparent resistivity can be calculated. For Schlumberger soundings, the apparent resistivity values (ρ_a) were plotted against half current electrode separation (AB/2) on a log-log graph and a smooth curve was drawn for each of the soundings. Then, the sounding curves were interpreted to determine the true resistivities and thicknesses of the subsurface layers. The resistivity of the subsurface material observed is a function of the magnitude of the current, the recorded potential difference and the geometry of the electrode array used. The depth of penetration is proportional to the Schlumberger array which uses closely spaced potential electrodes and widely spaced current electrodes. In general, the depth of infiltration is small in this method and only shallow subsurface layers have been surveyed [19].

The current and potential electrodes were maintained along a straight line at same relative spacing around a fixed central point; it is termed as vertical electrical sounding (electrical drilling). The current penetrates continuously deeper with increasing separation of the current electrodes. The purpose of electrical sounding is to deduce the variation of resistivity with depth below a given point on the ground for near-horizontal layers of formation below. The method is useful for determining loose horizontal overburden thickness over hard rocks in river valley projects and groundwater [20]. Constant separation traversing was obtained by progressively moving an electrode spread with fixed electrode separation along a traverse line, the configuration of the electrodes being aligned either in the direction of the traverse longitudinal [20].

At each of the points sounded, the potential electrodes were fixed symmetrically about the point while the current electrode spacing was expanded symmetrically about the centre of the spread, from AB/2 = 1.0 m to 105m. At stages where the potential difference (P. d) between the potential electrodes become too small to the accurate measurement, the potential electrodes spacing was increased accordingly and measurements continued according to AB/2 versus MN intervals employed. Such change-over points were observed at MN =7.50m, 10.0m and 37.5m respectively. Thus, the potentials electrode spacing or separation (MN) was varied from 1.0m to 10.0m during the investigation. Four soundings on each profile on a total of four profiles, seventeen (17) samples readings were taken from each profile, thus covered a distance of 0.105km long, with a vertical spacing of 20m between each profile Figure 4 and figure 5 respectively.

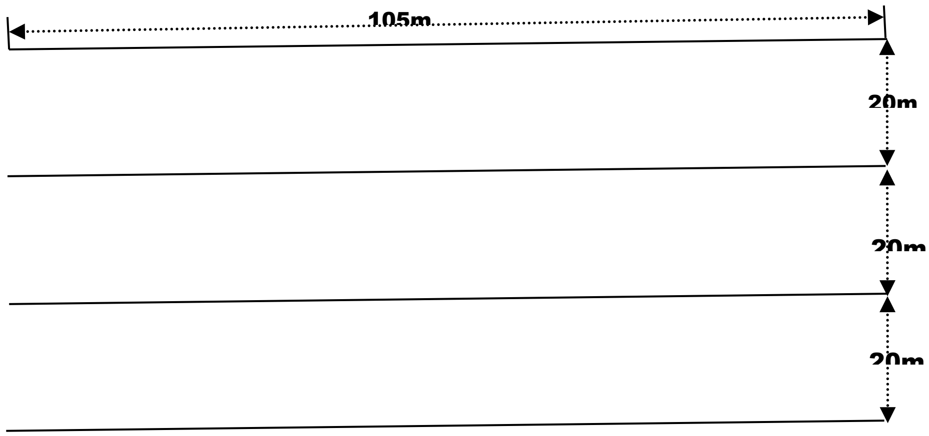

Figure 4: Profiles and the spacing

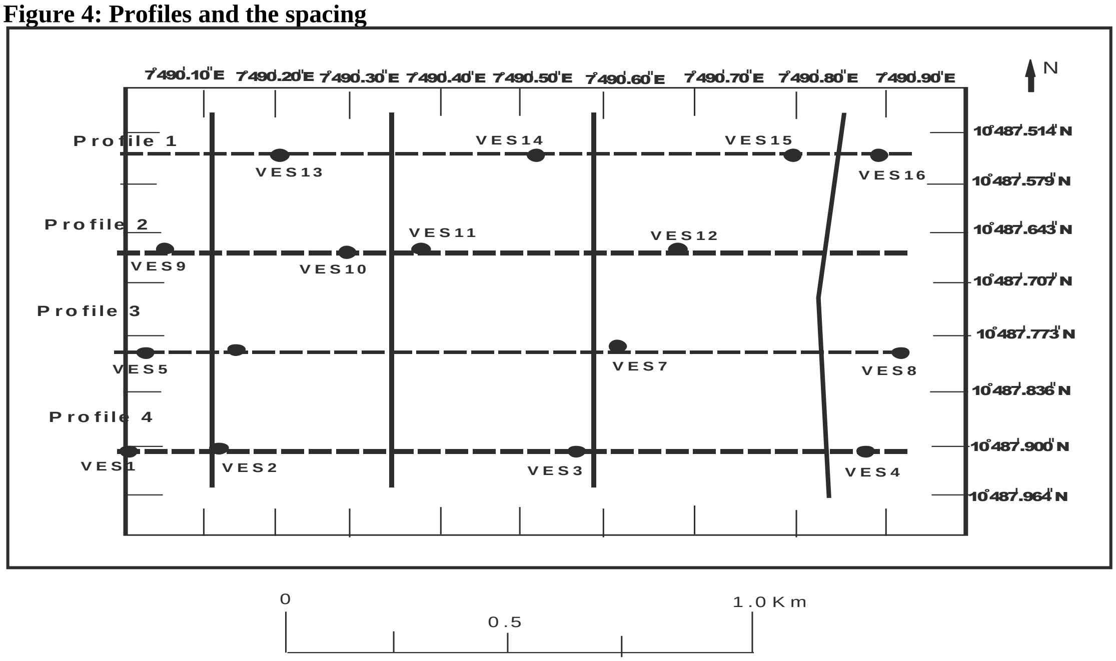

Figure 5: Showing VES Points on profiles

3. 0 Interpretation of Data

3.1 The VES Data Processing

The data obtained at each VES point were recorded and tabulated. This was done by recording the corresponding resistivity values against each AB/2 and its corresponding MN profile by profile. At the changeover points, which occurred at distance when the potentials measured across the potential electrodes became too small, the length (MN) was increased approximately. The value of the resistivity was hence, taken for such AB/2. The values taken for the AB/2 was then computed and used.

In all cases, the obtained values of the reading from the Terrameter instrument was each multiplied by the corresponding geometric factors to obtain the apparent resistivity values. At the end of evaluating all the required readings, a table of the apparent resistivity values with electrode separation was produced for every profile (table 1 – 4).

SCHLUMBERGER PROFILE 1
TABLE 1: PROFILE 1
N-S
Battery 11.86v

Series No	AB/2(m)	MN(m)	K-Factor	Meter Reading R (Ω)	Computed Apparent Resist ρa (Ωm)
1.	1.0	0.5	2.357	185.5	437.2235
2.	1.5	0.5	6.286	75	471.45
3.	2.5	0.5	18.857	20.8	392.2256
4.	3.75	0.5	43.41	7.5	325.575
5.	5	0.5	77.793	3.62	281.61066
6.	7.5	0.5	176.07	1.442	253.89294
7.	10	0.5	313.502	0.728	228.229456
8.	7.5	1.5	56.571	4.62	261.35802
9.	10	1.5	102.407	2.24	229.39168
10.	15	1.5	233.357	0.747	174.317679
11.	25	1.5	652.451	0.261	170.289711
12.	37.5	1.5	1470.69	0.065	95.59485
13.	50	5.0	2614.69	0.164	428.80916
14.	37.5	5.0	434.096	0.226	98.105696
15.	50	5.0	777.935	0.308	239.60398
16.	75	5.0	1759.72	15.58	27416.4376
17.	100	5.0	3136.58	27.3	85628.634

Note: Date 1/5/2015Location Karji Karuga Electrode configuration-Schlumberger Instrument, _ Abem Terrameter.

SCHLUMBERGER PROFILE 2
TABLE 2: PROFILE 2
N – S
BATTERY = 11.88V

Series No	AB/2(m)	MN(m)	K-Factor	Meter Reading R (Ω)	Computerd Apparent Resist ρa (Ωm)
1.	1.0	0.5	2.357	135.7	319.8449
2.	1.5	0.5	6.286	49.3	309.8998
3.	2.5	0.5	18.857	16.88	318.30616
4.	3.75	0.5	43.41	6.64	288.2424
5.	5	0.5	77.793	3.7	287.8341
6.	7.5	0.5	176.07	1.706	300.37542
7.	10	0.5	313.502	0.923	289.362346
8.	7.5	1.5	56.571	5.73	324.15183
9.	10	1.5	102.407	3.04	311.31728
10.	15	1.5	233.357	1.18	275.36126
11.	25	1.5	652.451	0.282	183.991182
12.	37.5	1.5	1470.69	0.096	141.18624
13.	50	5.0	2614.69	0.053	138.57857
14.	37.5	5.0	434.096	0.32	138.91072
15.	50	5.0	777.935	0.18	140.0283
16.	75	5.0	1759.72	0.111	195.32892
17.	100	5.0	3136.58	0.129	404.61882

Note: Date 1/5/2015Location Karji Karuga Electrode configuration-Schlumberger Instrument, _ Abem Terrameter.

SCHLUMBERGER PROFILE 3
TABLE 3: PROFILE 3

N – S

BATTERY = 11.90V

Series No	AB/2(m)	MN(m)	K-Factor	Meter Reading R (Ω)	Computed Apparent Resist ρa (Ωm)
1.	1.0	0.5	2.357	125	294.625
2.	1.5	0.5	6.286	36.7	230.6962
3.	2.5	0.5	18.857	10.98	207.04986
4.	3.75	0.5	43.41	5.41	234.8481
5.	5	0.5	77.793	3.25	252.82725
6.	7.5	0.5	176.07	1.521	267.80247
7.	10	0.5	313.502	0.815	255.50413
8.	7.5	1.5	56.571	4.77	269.84367
9.	10	1.5	102.407	2.53	259.08971
10.	15	1.5	233.357	0.894	208.621158
11.	25	1.5	652.451	0.147	95.910297
12.	37.5	1.5	1470.69	0.057	83.82933
13.	50	5.0	2614.69	0.044	115.04636
14.	37.5	5.0	434.096	0.213	92.462448
15.	50	5.0	777.935	0.121	94.130135
16.	75	5.0	1759.72	0.102	179.49144
17.	100	5.0	3136.58	0.087	272.88246

Note: Date 1/5/2015Location Karji Karuga Electrode configuration-Schlumberger Instrument, _ Abem Terrameter.

SCHLUMBERGER PROFILE 4
TABLE 4: PROFILE 4

N – S

BATTERY = 11.48V

Series No	AB/2(m)	MN(m)	K-Factor	Meter Reading R (Ω)	Computed Apparent Resist ρa (Ωm)
1.	1.0	0.5	2.357	211	497.327
2.	1.5	0.5	6.286	32.4	203.6664
3.	2.5	0.5	18.857	23.5	443.1395
4.	3.75	0.5	43.41	11.88	515.7108
5.	5	0.5	77.793	4.56	354.7361
6.	7.5	0.5	176.07	2.7	475.389
7.	10	0.5	313.502	1.401	439.2163
8.	7.5	1.5	56.571	7.71	436.1624
9.	10	1.5	102.407	4.04	413.7243
10.	15	1.5	233.357	1.532	357.5029
11.	25	1.5	652.451	0.304	198.3451
12.	37.5	1.5	1470.69	0.083	122.0673
13.	50	5.0	2614.69	0.044	115.0464
14.	37.5	5.0	434.096	1.35	586.0296
15.	50	5.0	777.935	0.17	132.249
16.	75	5.0	1759.72	15.81	27821.17
17.	100	5.0	3136.58	2.19	6869.11

Note: Date 1/5/2015Location Karji Karuga Electrode configuration-Schlumberger Instrument, _ Abem Terrameter.

3.2 Interpretation of VES Data

The VES data collected were processed using equation18. The "geometric factor" value for each spacing was multiplied by the corresponding instrument reading to obtain the apparent resistivity value (in Ohm Meter). These computed apparent resistivity (ρa) values obtained for the various spacing at a given station (location) were then plotted against their corresponding AB/2. The values of AB/2 were plotted on the x-axis (abscissa) while the apparent resistivity values (ρa) were plotted on the y-axis (ordinate). A typical resulting resistivity curve is shown for VES which also indicate the geo-electrical layers thicknesses and depths are presented (Figure 6, figure7, figure 8 and figure 9) respectively.

Preliminary interpretation of the field curve, is H-type [21], using four layer standard curves and auxiliary curves designed by Mooney [5]. This preliminary interpretation provided the parameters for the initial model (number of layers, apparent resistivity values, thickness as well as the depth to each layer).

The interpretation was carried out using the computer facility of the National geological survey Agency, Kaduna. The computer based Programme software used for the interpretation is the win resist. The programmed has been used in interpreting geophysical survey for all their D.C resistivity exploration works which were found to be satisfactory.
The sixteen (16) VES sounded, from which four of the resulting number of layers and the corresponding resistivity layer as well as the thickness and depth in the Schlumberger configuration of the layers were shown.

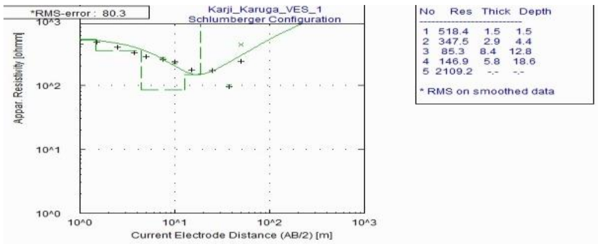

Figure 6: Geoelectric layers Graph of VES 1
Note that figure 6 indicated that $\rho_1 > \rho_2 > \rho_3$

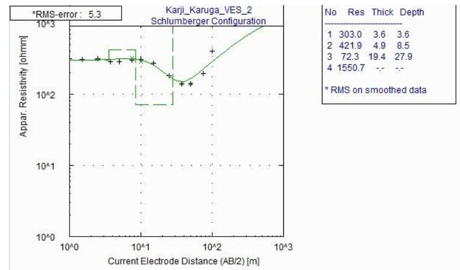

Figure 7: Geoelectric layers Graph of VES 2
Note that figure 7 indicated that $\rho_1 > \rho_2 < \rho_3$

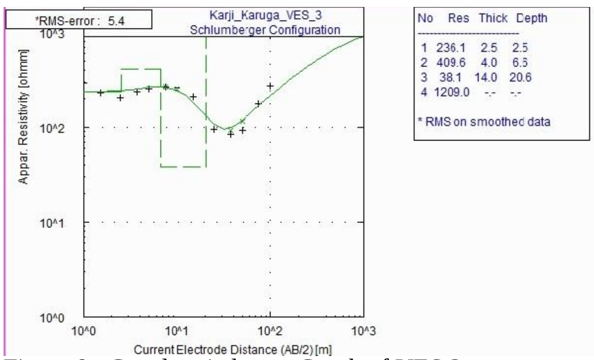

Figure 8: Geoelectric layers Graph of VES 3
Note that figure 8 indicated that $\rho_1 > \rho_2 < \rho_3$

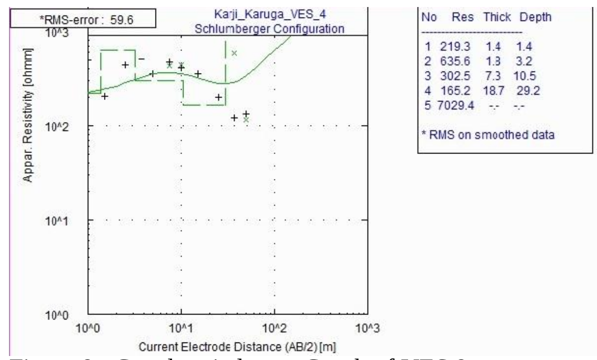

Figure 9: Geoelectric layers Graph of VES 9
Note that figure 9 indicated that $\rho_1 < \rho_2 < \rho_3$

Table 5: Resistivity values Adopted for this Research Work [4]

S/N	ROCK TYPE	RESISTIVITY RANGE (Ω-m)
1.	Alluvium and Sands	10 – 800
2.	Clay	1 – 100
3.	Sands and Gravel	100 – 180
4.	Lateritic Sand	200 – 500
5.	Quartzites (Various)	10 – 2000
6.	Weathered Laterite	500 – 1000
7.	Weathered Basement	20 – 400
8.	Fractured Basement	400 – 900
9.	Fresh Basement	1000

4.0 Results and Interpretations

4.1 Results from the VES Survey

The VES survey analysis using Schlumberger configuration for each of the four profiles was drawn. The profile and azimuth are about 0.105Km long and West - East respectively for each profiles. The interpretation of the rock type was adopted from the standard convention for basement complex region of Nigeria (Table 5).

Profile 1, VES 1, Figure 1, table 1, revealed that there are five geoelectric layers which has the geologic section lithological composition of layer 1 having a fractured basement zone, layer 2, is lateritic sand zone, layer 3 sand and gravel zone, layer 4 sand and gravel and layer 5 is weathered basement zone.
The profile has an average thickness of 1.5m; the resistivity value of the first layer is 518.4 Ω-m with a depth of 1.5m underlying this layer is the second layer which is relatively thicker than the first, its thickness is 2.9m; its resistivity is 347.5 Ω-m with depth of 4.4m. The third layer has thickness 8.4m, with resistivity of 85.3 Ω-m and its depth 12.8m, the fourth layer has thickness 5.8m, resistivity 146.9 Ω-m with depth 18.5m and the fifth layer is an infinite thickness and infinite depth with resistivity 2109.2 Ω-m. with depth 18.6m.

Profile 2, VES 2, Figure 2, table 2, shows that a maximum of four geoelectric layers underlie the profile. The first layer is thin, with an average thickness of 3.5m; the resistivity value of the first layer is 303.0 Ω-m with a depth of 3.6m, which is lateritic sand, underlying this layer is the second layer which is relatively thicker than the first, its thickness is 4.9m; its resistivity is 421.9 Ω-m with lateritic sand depth of 8.5m, which is lateritic sand. The third basement layer has thickness 19.4m, with resistivity of 72.3 Ω-m and its depth 27.9m and the fourth layer is an infinite thickness and infinite depth with resistivity of 1550.7Ω-m, with quartzites zone.

Profile 3, VES 3, Figure 3, table 3, shows that a maximum of four geoelectric layers underlie the profile. The first layer is thin, with an average thickness of 2.5m; the resistivity value of the first layer is 236.1 Ω-m with a depth of 2.5 m, that is lateritic sand, underlying this layer is the second layer which is relatively thicker than the first, its thickness is 4.0m; its resistivity is 409.6 Ω-m with depth of 6.6m.This is lateritic sand The third basement layer has thickness 14.0m, with resistivity of 38.1 Ω-m and its depth 20.6m, which is clayish zone and the fourth layer is an infinite thickness and infinite depth with resistivity of 1209.0 Ω-m. This layer is weathered.

Profile 4, VES 4, Figure 4, table 4, shows that a maximum of five geoelectric layers underlie the profile. The first layer is thin, with an average thickness of 1.4m; the resistivity value of the first layer is 219.3 Ω-m with a depth of 1.4 m, which is lateritic sand, underlying this layer is the second layer which is relatively thicker than the first, its thickness is 1.3m; its resistivity is 635.6 Ω-m with depth of 3.2m, this layer is weathered zone. The third basement layer has thickness 7.3m, with resistivity of 302.5 Ω-m and its depth 10.5m with lateritic sand, the fourth basement layer has thickness 18.7m, resistivity 165.2 Ω-m with depth 29.2m, that is sand and gravel. And the fifth layer is an infinite thickness and infinite depth with resistivity of 7029.4 Ω-m.

Table 6: Summary of Results of Aquifer Parameters Computed from the VES Measurements

VES	Aquifer thickness (m)	Aquifer Depth (m)	Resistivity (Ω-m)
VES 1 Location 10° 487' 579" 7° 490' 034”			
	1.5	1.5	518.4
	2.9	4.4	347.5
	8.4	12.8	85.3
	5.8	18.6	146.9
			2109.2
VES 2 Location 10° 487' 796" 7° 491' 428”			
	3.6	3.6	303.0
	4.9	8.5	421.9
	19.4	27.9	72.3
			1550.7
VES 3 Location 10° 487' 596" 7° 491' 228”			
	2.5	2.5	236.1
	4.0	6.6	409.6
	14.0	20.6	38.1
			1209.0
VES 4 Location 10° 487' 900" 7° 490' 438”			
	1.4	1.4	219.3
	1.3	3.2	635.6
	7.3	10.5	302.5
	18.7	29.2	165.2
			7029.4

5. Conclusion

In the two geoelectrical methods adopted for this work, the analysis of the acquired field data showed that the study area is made up of earth layers with variation in values of resistivity, thickness and the conductivity and transmissivity aquifer zones which delineate highly weathered basement and the fractured basement complex, important as water bearing units. The four VES points performed at each of the profile on the four profiles aided in revealing the geoelectric and geologic sections of the study area. These VES revealed that there are two to five maximum geoelectric layers (VES 1 and 4) and two to four maximum geoelectric layers (VES 2 and 3) found beneath the various VES points. The first layer is the top soil, the second layer is the weathered/fractured basement and the third layer is the fresh/consolidated basement. The VES also show that the resistivity vary from 38.1 Ω-m to 7029.4 Ω-m. The geologic sections correspondingly indicated the various lithological compositions of various layers delineated. The characteristic resistivities formed for the various earth materials found alluded that the layers is composed of lateritic sands, weathered rocks, quartzite alluvium, clay, fractured and fresh basement rocks.

The basement geometry of the study area is averagely 10.9m deep in the study. The thickness of the over-burden is observed having no uniformity in the profiles. Profile 2 is the deepest zone within the study area with an average of 13.9m depth.

Sixteen Vertical Electrical Sounding were carried out on four profiles with azimuths along west –east and north- south direction. A maximum of five geoelectric layers were identified in the study area. The basement is resistive with variable resistivity values ranges from 38.1 Ω-m to 7029.4 Ω-m. The geologic sections of the rocks formed from the terrain is the weathered/fractured basement aquifer overburden most favourable point to construct any pump, since it is the best water bearing basement complex with an average thickness of 27.9m.

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