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Aquifer Characteristics of Some Selected Villages around Kaduna Refining and Petrochemical Company (KRPC) in Chikun Local Government Area of Kaduna State, Nigeria

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Abstract

The Vertical Electrical Sounding (VES) technique was used to investigate the sub-surface layering in Unguwan-Barde, Rido village and kipi-nari kaukau, developing residential areas close to Kaduna Refining and Petrochemical Company (KRPC) in Chikun local government area of Kaduna State. 24 sounding stations were carried out aimed at evaluating the aquifer characteristics of the study area such as aquifer thickness. The result of the interpreted VES data suggests that the area is underlain by three to four layers and are inferred to be the topsoil, weathered basement, fractured basement and fresh basement. The resistivity values range from 80.7 Ωm. to 3063.5 Ωm. The resistivity values of the layers at the VES stations are characterized by H. K, Q, and HK resistivity curves with 14 of them having the HK, 6 with H curve type and 4 with Q curve type, The overburden thickness distribution map shows the southeastern region is 24.6 – 36.7 m (Rido village and Unguwan-barde) While the northwestern region is deeper 37.0 – 48.3 m (Kipi-nari kaukau).These suggest that the southeastern region have more potential for water than the northwestern region. The aquifer has an average resistivity of 346.2 Ωm, the weathered/fractured basement, which is the aquiferious formation has an average thickness of 25.1m. The thickness and resistivity of the aquiferious layers suggests that they are viable and they is good potential for water.

Keywords: Aquifer, Vertical Electrical Sounding (VES), Layers, Thickness, Petrochemical, Chikun.

Introduction

Groundwater is a vital resource, with a large fraction of the world population relying on the resource directly or indirectly for livelihoods (Sanjay, 2010). The world groundwater is estimated to be about 0.06% of the available water resources out of which 98% of groundwater is found to be freshwater (Bashir *et al.*, 2014).

An increase in population increases the demands for water which stimulates the development of underground water resources resulting in improved techniques for investigating the occurrence and movement of groundwater. The quantity of surface water available for domestic, agricultural, and industrial uses is often most times not sufficient to meet the current demand for water (Abdullahi & Iheakanwa, 2013). The scarcity of clean water supply has led to the prevalence of water-borne diseases like guinea-worm, cholera, and typhoid fever (Aboh, 2009). Water quality is influenced by many factors such as; atmospheric, chemicals, the underlying geology, anthropogenic activities, and climate changes (Tahir *et al.*, 2015). Groundwater is found within the pore spaces of soil or rock

called the aquifer. The nature of the aquifer is a function of subsurface geological composition that plays an important role in determining the circulation of water from the surface (infiltration) to subsurface water through recharge processes (Salako & Adepelumi, 2018).

An Aquifer is a body of saturated rock or geological formation through which water can easily move (permeable) into wells and streams (Salako & Adepelumi, 2018). Aquifers generally are known to serve as reservoirs and could dry up when people drain them faster than they are been refilled by nature. Aquifers must not only be permeable but must also be porous and are found to include rock types such as sandstones, conglomerates, fractured limestone, and unconsolidated sand, gravels, and fractured volcanic rocks (Salako & Adepelumi, 2018). While some aquifers have high porosity and low permeability others have high porosity and high permeability. Those with high porosity and low permeability are referred to as poor aquifers and include rocks or geological formation such as granites and schist while those with high porosity and high permeability are regarded as excellent aquifers and include rocks like fractured volcanic rocks (Salako & Adepelumi, 2018).

Aquifers within the Basement Complex of Nigeria are tapped within the weathered zones which are usually at shallow depths and contain a smaller quantity of groundwater. A proper understanding and description of the aquifer characteristics becomes very important to address the most geological and hydrogeological problems in the Basement Complex (Omeje *et al.,* 2015). It is on this basis that this study was undertaken to investigate the characteristics of the nature of aquifer in some selected villages behind the Kaduna Refining and Petrochemical Company in Chikun Local Government Area of Kaduna State, Nigeria.

Geology of the Study Area

Chikun Local Government Area and the entire adjoining landmass lies within the Precambrian Basement Complex in the northern part of Nigeria (Aboh, 2009). It is composed of hard crystal rocks of igneous and metamorphic origin.

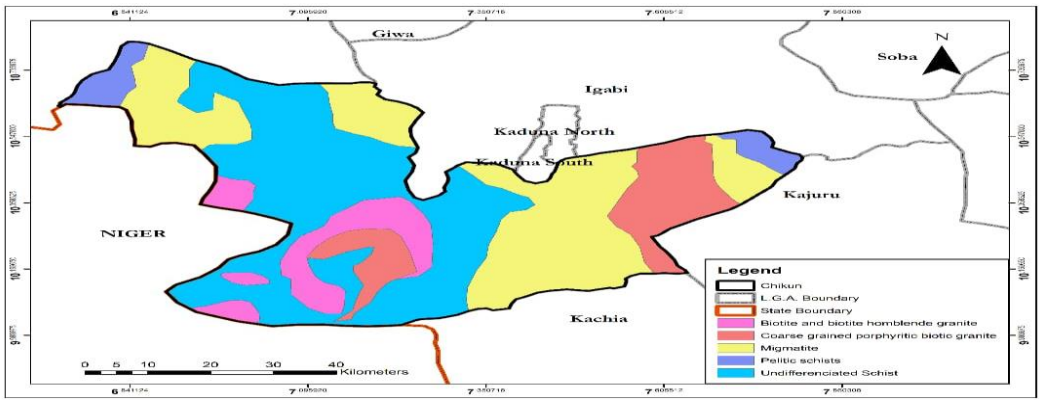


Figure 1: Geology map of Chikun Local Government Area (Olaniyan and Tsuzom, 2014)

Statement of the Research Problem

The increase in demand for quality water in the study area has stimulated the development of groundwater, leading to the expansion of means of groundwater abstraction. This scarcity of clean water supply has led to the prevalence of water-borne diseases (Aboh, 2009).

This research is meant to evaluate the resistivity of the study area, the aquiferious levels or zone of the study area and the aquifer thickness of the study area.

Aim and Objectives of the Study

This study aims at evaluating the aquifer characteristics of the study area.

The objectives include the following:

i. To determine the resistivity of the study area.
ii. To determine the aquiferious levels or zone of the study area.
iii. To determine the aquifer thickness of the study area.

Materials and Methods

Geophysical investigation using Vertical Electrical Sounding (VES) was carried out to evaluate the aquifer characteristics of Kipi-Nari Kaukau, Rido, and Ungwan-Barde village all along the KRPC pipeline, data were collected and interpreted using winRESIST software, oasis montaj software, Grapher software and surfer software in order to determine the geoelectric layers, the resistivity values and the aquifer thickness.

Theory and Working Principles of Ohmega Resistivity Meter

Ohmega resistivity meter is a high-quality portable earth resistance meter capable of accurate measurement over a wide range of conditions. In the electrical resistivity method, the Ohmega Resistivity Meter is used, electric currents are generated artificially and introduced into the ground and the resulting potential differences are measured at the surface. Deviations from the pattern of potential differences expected from homogeneous ground provide information on the form and electrical properties of the subsurface inhomogeneities.

The resistivity of a material is defined as the resistance in ohms between the opposite faces of a unit cube of the material. For a conducting cylinder of resistance δR, length δL and cross-sectional area δA, the resistivity ρ is given by

$$\rho = \frac{\delta R \delta A}{\delta L} \text{ ----------1}$$

In an element of homogeneous material, current I is passed through the cylinder causing a potential drop ($-\delta V$) between the ends of the element. Ohm's law relates the current, potential difference and resistance such that $-\delta V = \delta R I$, And $\delta R = \frac{\delta V}{I}$

Substituting δR into eqn. 1, it becomes

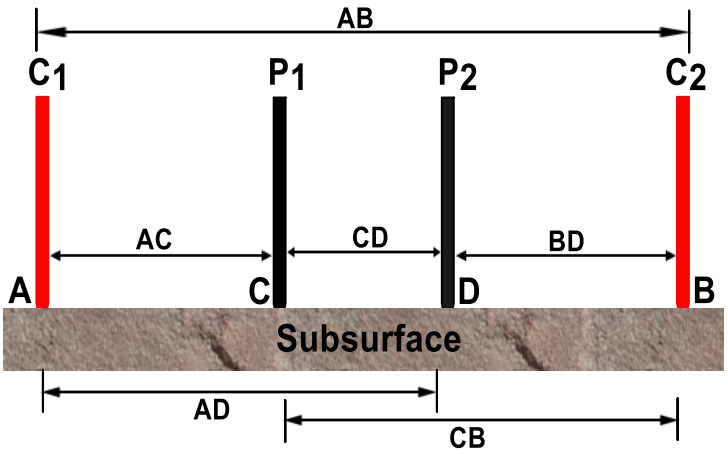
$$\frac{\delta V}{\delta L} = -\frac{\rho I}{\delta A} \text{ ----------2}$$

$\frac{\delta V}{\delta L}$ Represents the potential gradient through the element in volt$m^{-1}$and J the current density in Am^{-2}. The current density in any direction within a material is given by the negative partial derivative of the potential in that direction divided by the resistivity (Adeoti *et al.*, 2012)

Schlumberger Configuration

In carrying out resistivity sounding surveys, electrodes are distributed along a line, centered about a midpoint that is considered the location of the sounding. The Schlumberger electrode array (Figure 2) was used in data acquisition. The Schlumberger survey involves the use of two current electrodes labelled A and B, and two potential electrodes M and N placed in line with one another and centered on same location. It is worthy to state that the potential and current electrodes are not placed equidistant from one another.

Figure 2. Schematic diagram of the Schlumberger array



To acquire the resistivity data in the field, current is introduced into the ground through the current electrodes and the potential electrodes are then used to quantitatively measure the voltage pattern (Anomohanran, 2011).

$V_C = \mathrm{V_A} + \mathrm{V_B}$ ----------3

The potential gradient associated with this current density is

$\frac{\partial V}{\partial r} = -\frac{\rho I}{2\pi r^2} = -\rho I$----------4

The potential (V_r) at distance r is then obtained by integration

$V_r = \int \partial V = -\int \frac{\rho I \partial r}{2\pi r^2} = \frac{\rho I}{2\pi r}$ ----------5

Eqn. 5 can be written as

$V_C = \frac{\rho I}{2\pi}\left[\frac{1}{AC} - \frac{1}{CB}\right]$ ----------6

The potential difference is then given by;

$\Delta V = \mathrm{V_C} - \mathrm{V_D} = \frac{\rho I}{2\pi}\left[\left(\frac{1}{AC} - \frac{1}{CB}\right) - \left(\frac{1}{AD} - \frac{1}{BD}\right)\right]$----------7

$$\rho_a = \frac{2\pi\Delta V}{I}\left[\left(\frac{1}{AC}-\frac{1}{CB}\right)-\left(\frac{1}{AD}-\frac{1}{BD}\right)\right]^{-1} \text{ ----------8}$$

Hence, $\rho_a = RK$ ----------9

where

$$K = \frac{2\pi}{\left(\frac{1}{AC}-\frac{1}{CB}\right)-\left(\frac{1}{AD}-\frac{1}{BD}\right)} \text{ ----------10}$$

where R is resistivity ($i.e\ R = \Delta V/I$), and K is called geometrical factor which depends on the arrangement of the four electrodes. While (AC), (BC), (AD), and (BD) are the distances in meters between the respective electrodes, when $(AC) = (BD)$ and $(BC) = (AD)$; K can be defined from

$$K = \pi\frac{[AC][AD]}{[CD]} \text{ ----------11}$$

VES Data Collections and Interpretation

Schlumberger array was used to acquire data from 24 VES stations. The Schlumberger array provides for high signal to noise ratio, requires fewer electrodes to be moved for each sounding, has excellent vertical resolution and good depth sensitivity. Raw field resistance data (in ohms) for all the Vertical Electrical Sounding (VES) point locations were converted to apparent resistivity (in ohm-meter) by multiplying it with the appropriate geometric factor. The apparent resistivity data were plotted against current electrode spacing and interpreted using winRESIST. The results, which gave root mean square (RMS) error of <5%, revealed three to four geoelectric layers/units with their corresponding thicknesses and apparent resistivities at variable depths across the study area. The geology (lithology) of the geoelectric layers was interpreted and inferred from the apparent resistivity distribution pattern and general geology of the study area. The lithologies are topsoil, weathered, fractured, and fresh basement. The Vertical Electrical Sounding curve types obtainable in the VES points in the study area, their frequencies and percentage were determined. The map of resistivity variation at the topsoil, weathered basement, fractured basement, overburden thickness and Aquifer thickness in the study area is drawn. A total of 24 Vertical Electrical Sounding (VES) stations were occupied for the resistivity measurement.

Result

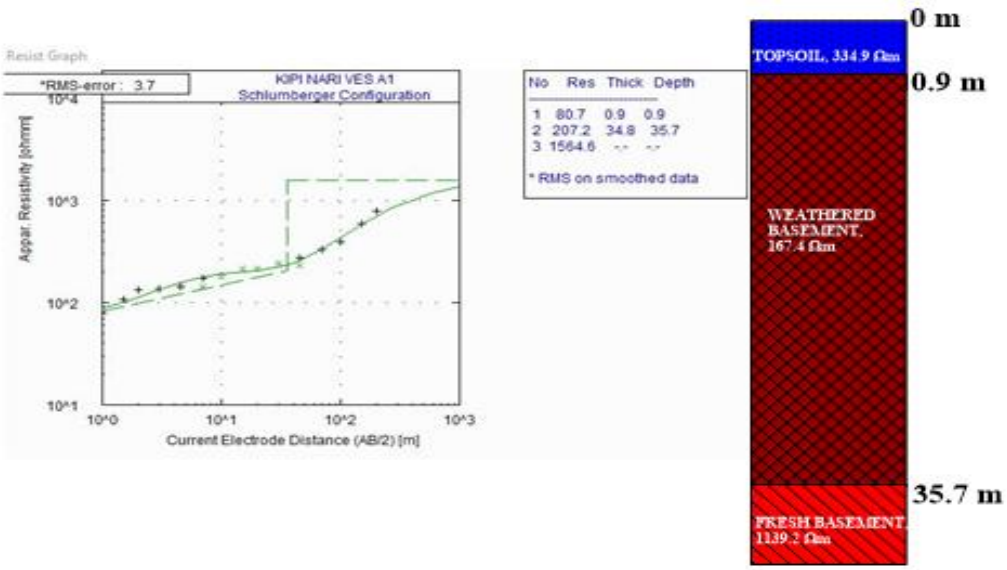


Figure 2: The curve of VES point 1 along profile 1

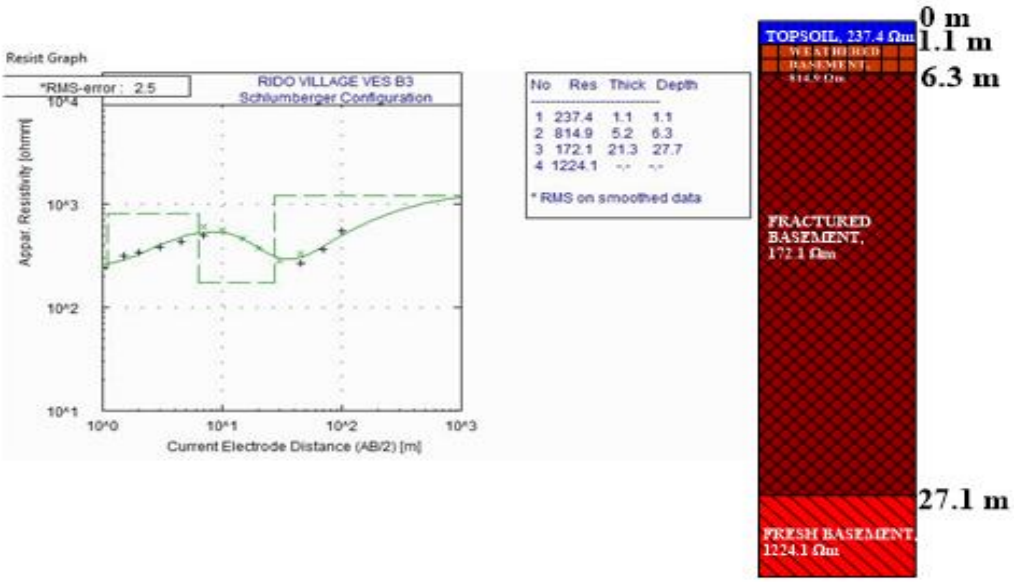


Figure 3: The curve of VES point 3 along profile 2

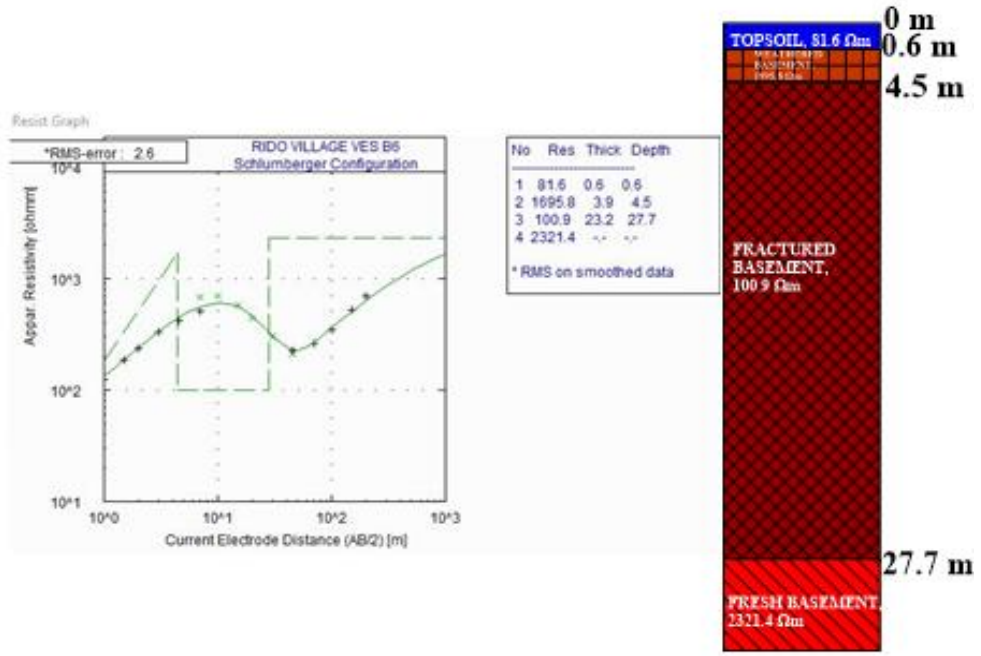


Figure 4: The curve of VES point 6 along profile 2

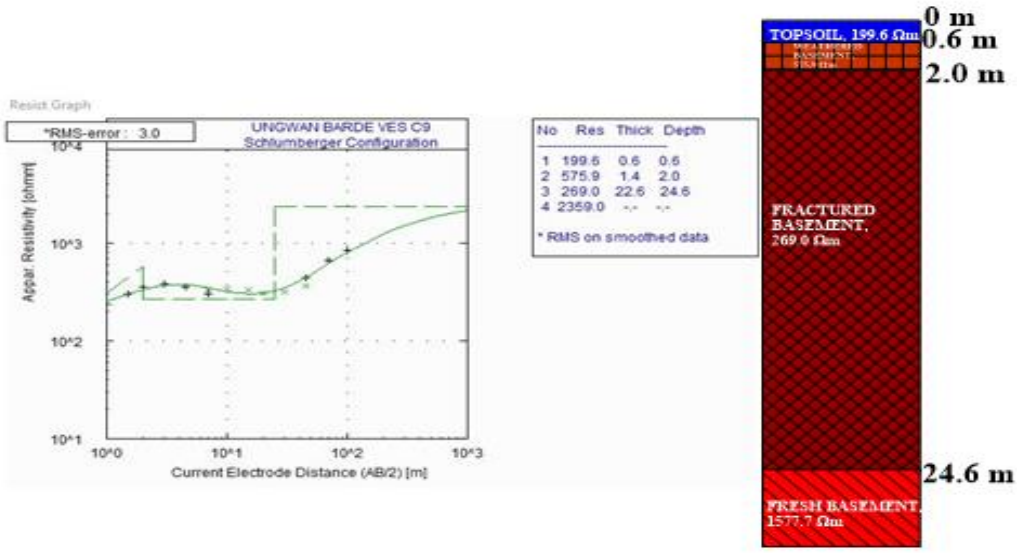


Figure 5: The curve of VES point 9 along profile 3

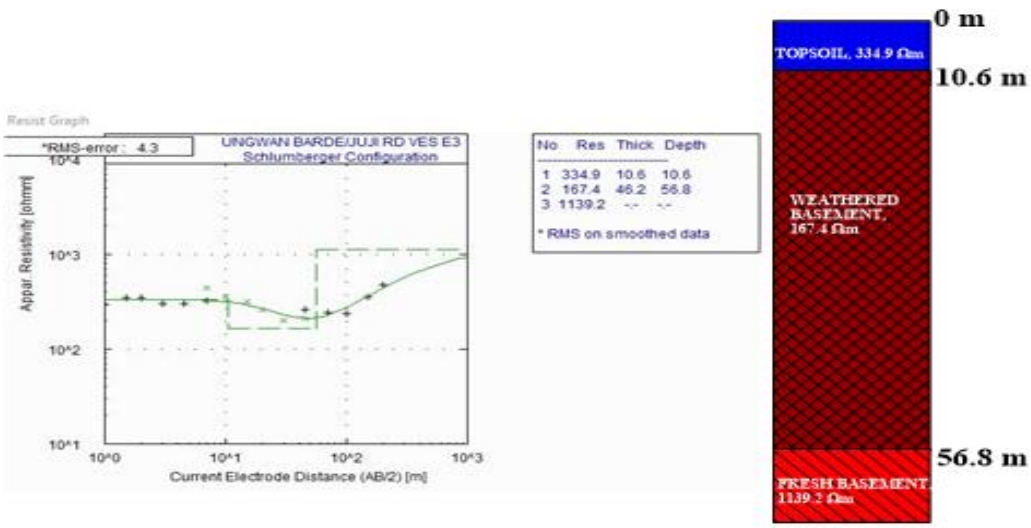


Figure 6: The curve of VES point 3 along profile 5

Table 1: Classification of the Vertical Electrical Sounding curve types

VES curve types	VES curve characteristics	Frequency	Percentage
Q	ρ1>ρ2>ρ3	4	16.67
HK	ρ1>ρ2<ρ3>ρ4	14	58.33
H	ρ1>ρ2<ρ3	6	25
Total		24	100

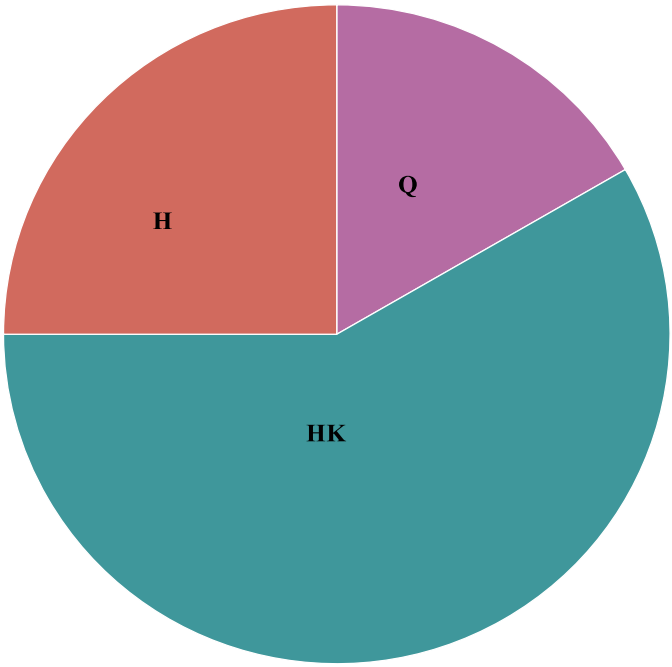
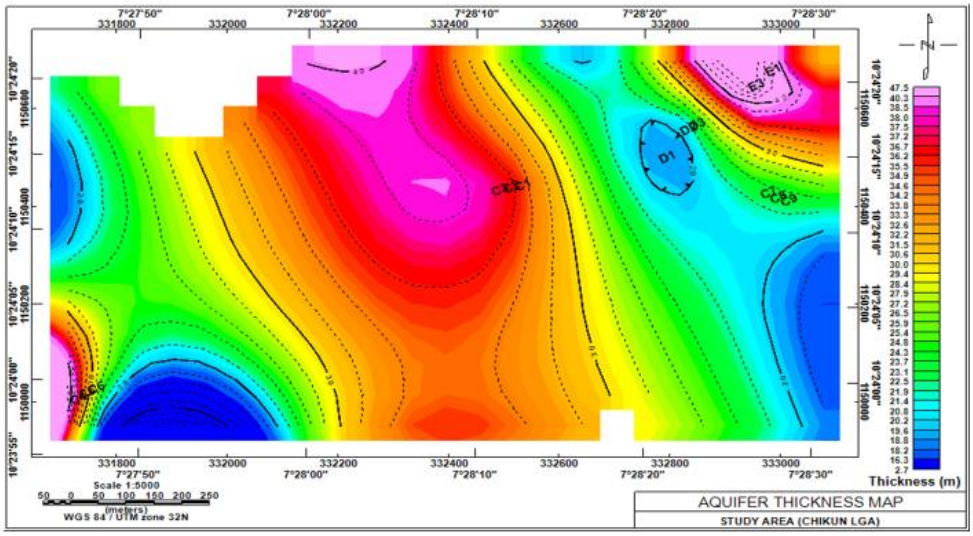


Figure 7: Pie chart classification of the Vertical Electrical Sounding of the study area.



Map of aquifer thickness of the study area.

Figure 8: Map of aquifer thickness of the study area.

Table 2: Village identification by alphabets

S/N	Villages	Alphabetical Representation
1	Kipi-Nari Kaukau	A1, A2 and A3
2	Rido 1	B1, B2, B3, B4, B5 and B6
3	Rido 2	C1, C2 and C3
4	Juji	D1, D2 and D3
5	Unguwan-Barde	E1, E2 and E3, C4 To C9

Aquifer Thickness of the Study Area

The aquifer thickness distribution map of the study area shows that C1,C3 and E1 to E3 (which is unguwan-barde and Rido village 2) is 33.3 – 47.5 m While A1,A2,A3, B1 to B4 and D1 to D3 (kipi-nari kaukau, and rido 1) is 2.7 – 28.4 m.These suggest that unguwan-barde and Rido village 2 have thicker aquifer and more potential for water than kipi-nari kaukau, and rido 1.

Discussion

The interpretation of the Vertical Electrical Sounding using the winRESIST yields the resistivity and depth of each layer. The VES points are characterized by about four layers and are inferred to be; the first layer is the topsoil, the second layer is weathered basement, the third layer is the fractured basement, and the last with an infinite depth is the fresh basement. It is found that some VES points are of three layers these are VES points 1 – 3 along profile 1, VES points 1, 3, 7, and 8 along profile 3, and VES points 1 – 3 along profile 5. The resistivity value ranges from 80.7 to 3063.5 Ωm, and the nature of resistivity variation

of each layer was used in the classification of the VES curve (Table 1). VES points with a weathered basement of low resistivity value are associated with H/HK-type curve, and the weathered /fractured basement is suggestive of the aquifer (Aboh, 2009; Dogara *et al.*, 2016). Hence about 60 % of the study area shows good potential for underground water.

The topsoil which is about 2 m thick has a resistivity range from 175.5 to 1280.1 Ωm, it is observed that the eastern edge and central part of the study area are of low resistivity which is an indication of the presence of some conductive materials at that level.

The weathered basement layer has a resistivity range from 327.6 to 1297.7 Ωm. The low resistivity at the eastern margin of the study area at the topsoil layer is believed to have emanated from a deeper source as it is noticed at the weathered basement layer. The fractured basement which is believed to be the aquifer formation with the weathered basement layer has the lowest range of resistivity; 19.8 – 346.2 Ωm. The northern region of the layer is characterized by a very low resistivity, an indication of the presence of a conductive material that is believed to be water.

The overburden thickness is thin at the southeastern region of the study area, around the refinery inclusive, which could be an indication of intrusion and it thickens at the northwestern region. Although there is are indications of low resistivity at the western and northeastern edge of the layer.

The weathered basement of the study area is characterized by a thickness that ranges from 18.3 to 48.9 m. The thickness and resistivity of the aquifer usually determine its potential (Aweto, 2012). Therefore, VES points 1 – 6 along profile 2, VES points 2 – 6, and 9 along profile 3, and VES points 1 – 3 along profile 4 shows signs of a viable aquifer with average thickness of 25.1m.

Conclusion

The study area is recording an increase in settlement and it is essential to provide water for drinking, cooking, and other domestic purposes.

The Vertical Electrical Sounding was carried out at 24 stations within the study area to identify the nature of the aquifer.

The result shows that the study area is characterized by a maximum of four geoelectric layers that are inferred to be topsoil, weathered, fractured basement and fresh basement. The resistivity of the study area ranges from 80.7 to 3063.5 Ωm, while the aquifer which is the weathered/fractured basement has a thickness that ranges from 2.7 to 47.5 m and the lowest resistivity value is an average of 346.2 Ωm. The most of the VES curve is of HK and H types, which indicates the presence of water as a result of the low resistivity value of the weathered/fractured basement layer. A low resistivity value and thickness of 2.7 to 47.5 m recorded at 14 VES stations points to a potentially sustainable source of water for residents of the study area.

Recommendation

This study succeeded in identifying the nature of the aquifer as possessing the potential for water, but cannot tell the quality of the water in the study area due to limitation of the methodology and resources. Hence further geochemical and geophysical investigation of the study area to ascertain the water quality is recommended.

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