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ORIGINAL RESEARCH ARTICLE

Application of Vertical Electrical Sounding for the Investigation of groundwater potentials at Umaru Musa Yar'adua University, Katsina.

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ABSTRACT

The population of Umaru Musa Yar'adua University, Katsina (the study area) is increasing every session and therefore, sources of safe water in the area is need to be improved; more importantly groundwater. Recently, water supply from Zobe Dam is connected to the study area but still it does not solve the water supply problem; hence other alternative is needed in order to supplement for existing. Various groundwater exploration programs that have been carried out in the study area have not yielded the required results. However, there was no academic research on groundwater in the study area. VES has been carried out in order to investigate groundwater potential, to determine the lithology, the resistivity value associated with the groundwater and prospect locations for groundwater exploration. The ABEM Terrameter SAS 4000 was used and a Schlumberger array was employed to accomplish this task by obtaining resistance of 7 VES points in the study area with a maximum current electrode spacing (AB) of 240 m. The VES data obtained were processed using IPI2Win software. The VES results in correlation with the and borehole log data have revealed that the near-surface materials with resistivity value between about 1 Ωm to 7,985 Ωm is representing 4 to 5 layers consisting of first layer mostly top soil and laterite, having resistivity values between 403 Ωm to 7,985 Ωm with thickness from 0.498 m to 1.21 m; second layer with resistivity values from 43.6 Ωm to 114.4 Ωm having thickness from 1.34 m to 4.71 m interpreted commonly as sandy clay and sandy soil; third layer showing resistivity values between about 1 Ωm to 38.4 Ωm is found to be a saturated layer with water; fourth layer generally indicating weathered basement with resistivity values from about 1 Ωm to 7.57 Ωm having thickness of 36.1 m and or infinite thickness, and fifth layer showing vary low resistivity value with infinite thickness. The result shows that the groundwater exploration should be conducted at VES 1, 2, 3, 4, and 5 at a depth from about 30 m to 50 m revealing low resistivity values ranging from 2 Ωm to 391 Ωm however, VES 6 and 7 indicates high resistivity value and therefore poor groundwater potentials.

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Vertical Electrical Sounding (VES), Resistivity, Groundwater

INTRODUCTION

One of the most basic components of human existence and socio-economic development is water. The earth's fresh water that is obtainable for man's use is about $4x10^6 km^3$ and is mainly available in the ground. Groundwater forms the most important source of water supply in the rural, pre-urban and urban areas of most sub-Sahara African (SSA) countries. The occurrence of groundwater in Precambrian basement terrain is stored within zones of fracturing and weathering which frequently are not continuous in lateral and vertical extent (Jeff, 2006). Most of the world surface water is found to be polluted either from nature such as salinity among others factors or anthropogenic activities by man. These factors have necessitated the purification of surface water before consumption or other uses incurring for cost for exploration. In the controlling of many diseases, safe drinking water is important. Unsafe water contributes a lot for water-related diseases such as diarrhoea, typhoid fever, cholera, infectious hepatitis and many more. Groundwater does not involve treatment

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cost and is generally free from odour, colour and contamination (Lawrence, et al., 2012). Groundwater met the requirement for drinking water; probably due to the natural filtration process the water has undergone (Danhalilu, *et al., 2018)*.

The survey area Umaru Musa Yar'adua University is located in Batagarawa Local Government area of Katsina State and it is situated 10 km from Katsina (Kofar Kwaya) and 1.9 km from Batagarawa Low-cost. The area falls between latitude 12° 53' 25"N to 12° 53' 42"N and longitude 7°34' 48"E to 7° 35' 26"E. The population of the study area is increasing every session and therefore, sources of safe water in the area is need to be improved; more importantly groundwater. Various groundwater exploration programs that have been carried out in the study area have not yielded the required results however; there was no academic research within the study area. Recently, water supply from Zobe Dam is connected to Umaru Musa Yar'adua University, Katsina the study area but still it does not solve the water supply problem. Due to this situation, water supplied to the area of research from above sources cannot be dependable throughout; hence other alternative is needed in order to supplement for existing sources of water and to reduce the use of Water Tankers in the supply of water to some structures within the study area.

Resistivity methods are the most important techniques as far as groundwater exploration is concerned. Evidence show that resistivity methods has been successfully employed for mapping/delineating of geo-materials in the subsurface that steer exploration of groundwater resources (Okhue and Olorunfemi, 1992; Anudu, *et al.,* 2008; Metwaly, *et al.,* 2012; Porsani, *et al.,* 2005).For obtaining the resistivity contrasts when the groundwater zone is reached the resistivity methods are generally preferable Vertical Electrical Sounding (VES) (Giao, et al, 2003).

Resistivity surveys determine the variation in the resistivity of the subsurface by applying electric current across arrays of surface electrodes (Loke, 1999). The survey data are processed to produce graphic depth sections of the thickness and resistivity of the subsurface electrical layers. The ground resistivity is related to various geological parameters such as the mineral and fluid content, porosity and degree of water saturation in the rock. Resistivity surveys have been used for many decades in hydrogeological, mining and geotechnical investigations.

Electrical resistivity (ϱ) is an inherent property of all earth materials and it is the reciprocal of electrical conductivity and thus is a measurement of a material resistance to the flow of an electrical current. In most porous rock systems, ionic conduction by interstitial fluids and surface conduction at the interface between the solid rock matrix and the electrolyte solution are responsible for the major part of electrical current flowing through a formation (Pfannkuch, 1969). Groundwater is capable of conducting current both electronically and through the electric double layer at the mineral-electrolyte interface, as a result of its high cation-exchange properties. The most important result is that low earth resistivity is recorded in areas with groundwater however, groundwater typically have lower resistivity than other silicate or carbonate minerals.

Vertical Electrical Soundings were carried out in some part of katsina by (Ahmed, *et al.* 2020; Akpaneno and Afuwai 2017; Kasidi and Victor 2019) to determine groundwater potentials.

MATERIALS AND METHODS

The study area

The survey area (Umaru Musa Yar'adua University, Katsina) is located in Batagarawa Local Government area of Katsina State and it is situated 10 km from Katsina (Kofar Kwaya) and 1.9 km from Batagarawa Low-cost. The area falls between latitude 12° 53' 25"N to 12° 53' 42"N and longitude 7° 34' 48"E to 7° 35' 26"E.

Figure1: Google earth map of study area (Courtesy Google earth).

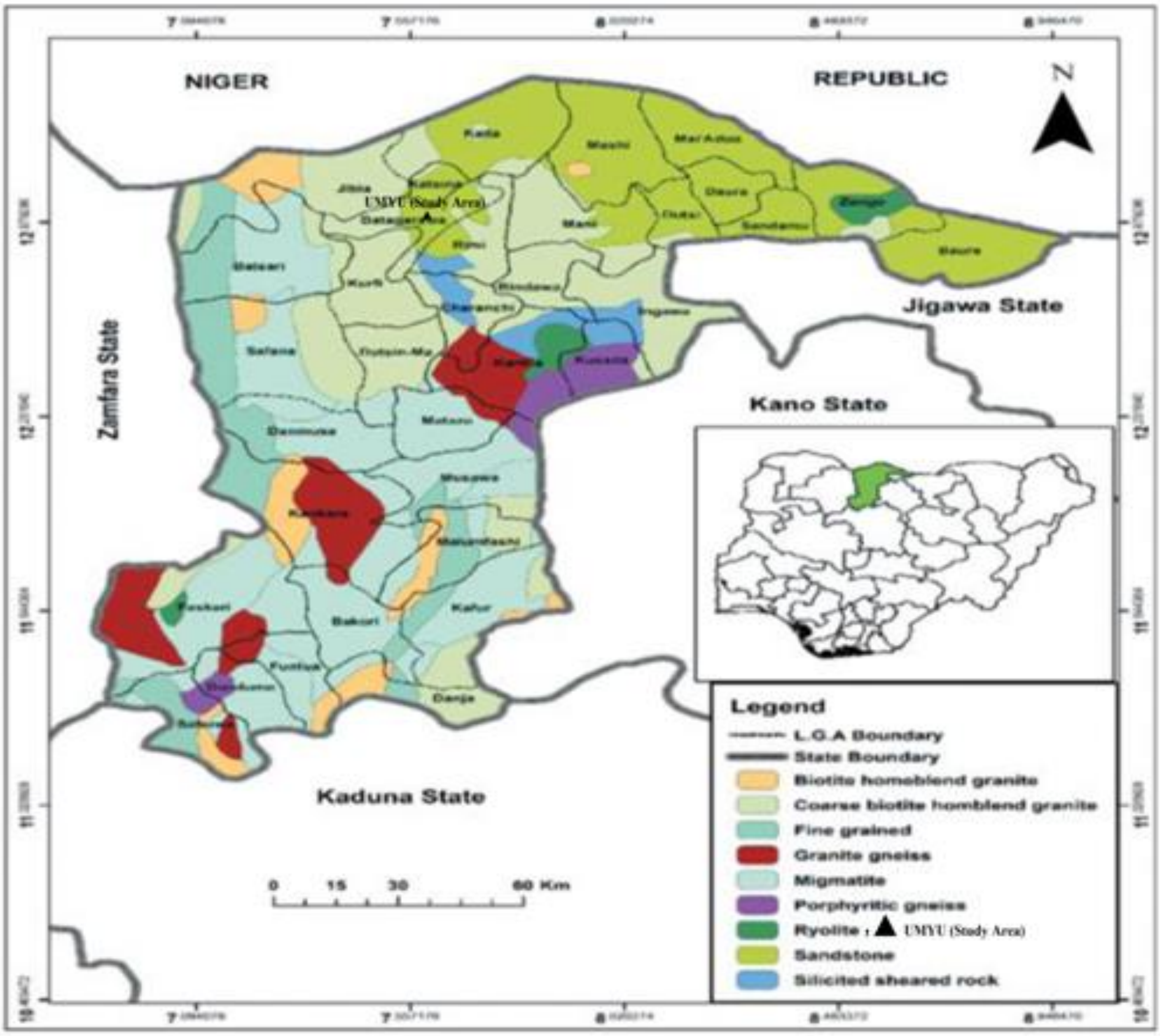

Figure 2: Geological map showing the survey area (Mukhtar et al., 2021).

Geology of the study area

Katsina State is underlain by three major formations, namely; Chad formation, the Illo Gundumi Formation of the Sokoto Basin and the Basement Complex area of Nigeria. Chad formation and Illo Gundumi formations make up 20% of the total area of Katsina State while 80% of the geology is underlined by the Basement Complex which is characterized by nine geological formations consisting of biotite homeblend granite, coarse biotite homeblend granite, fine grained, granite gneiss, migmatite, porphyritic gneiss, ryolite, sandstone and Solicited sheared rock. The area considered in this research, Umaru Musa Yar'adua University which is located in Batagarawa Local Government area is underlain by coarse biotite homeblend granite and sandstone (Mukhtar *et al*., 2021).

List of instruments for the survey

i. ABEM Terrameter SAS 4000
ii. Four steel electrodes
iii. Field hammers
iv. Measuring tape and
v. Reels of wire

Method

Vertical Electrical Sounding was carried out using Schlumberger array with a maximum current electrode spacing (AB) of 240 m and potential electrode spacing (MN) of 20 m during this survey. The instruments used to measure and record the resistance of the subsurface for the survey are: ABEM Terrameter SAS 4000 switched to SAS 1000, four steel electrodes, field hammers, measuring tape and reels of wire, and global positioning system (GPS). Current was injected into the earth through a pair of current electrodes and the potential difference was measured between a pair of potential electrodes. The current and potential electrodes are normally arranged in a linear array. However, electrode spacing varies for each measurement and the center of the electrode array where the electrical potential is measured remains constant. The electrodes are distributed along a line, placed at a midpoint of each profile which was taken as the center of the sounding. Furthermore, the two current electrodes and the two potential electrodes are placed in line with one another. The current electrodes were at the same distances from the center of the sounding (AB/2 = 2 m). The potential electrodes were also at the same distances from the center of the sounding; however, this distance (MN/2 = 0.5 m) is much less than the distance AB/2. Most of the available interpretation software assumes that the spacing of the potential electrode is negligible compared to the current electrode spacing. When the distance between the current electrodes is larger, then the distance between the potential electrodes was increased to have a measurable potential difference and electrode configuration are arranged in the number of ways of setting up of current and potential electrodes. The AB/2 was increased in steps up to a maximum value of 120 m and MN/2 to 10 m. The instrument was then transferred to the next VES point and the entire process was repeated. During this resistivity sounding surveys, 7 vertical electrical soundings were acquired across the study area.

The coordinates of the center of VES points were also noted to facilitate identification (Table 1).

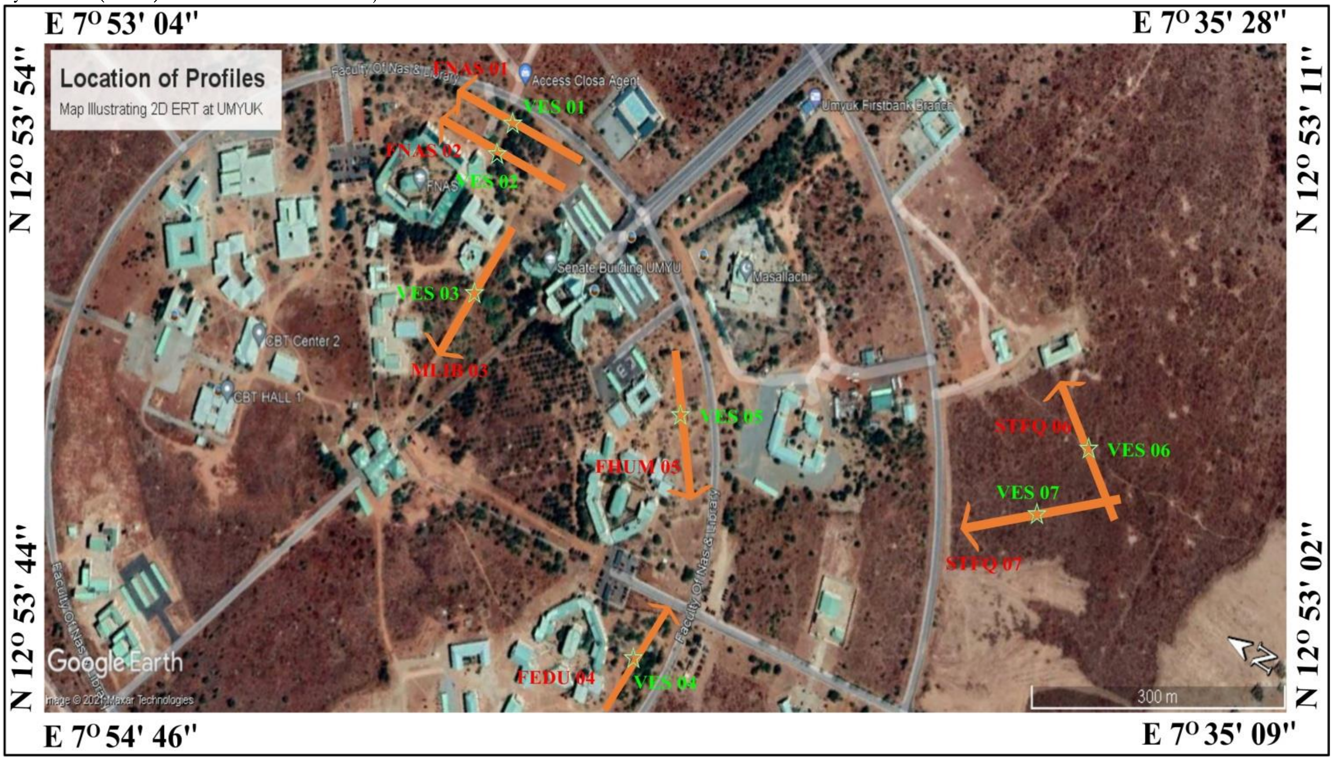

Figure 3: A map illustrating the 7 VES points

Table 1: Coordinates points of VES.

VES	Center	
	Latitude	**Longitude**
1	N12⁰53'38.6"	E07⁰35'11.4"
2	N12⁰53'38.0"	E07⁰35'10.0"
3	N12⁰53'35.9"	E07⁰35'4.4"
4	N12⁰53'25.0"	E07⁰34'55.7"
5	N12⁰53'26.4"	E07⁰35'6.1"
6	N12⁰53'11.6"	E07⁰35'12.0"
7	N12⁰53'12.5"	E07⁰35'8.7"

RESULT

The computer inversion program IPI2WIN was used in conversion VES data in this study while computing the geo-electrical parameters of the study area. The interpretation results of the survey were correlated with a Borehole Log in Batagarawa town close to the survey area obtained from Rural Water Supply and Sanitation Agency (RUWASSA), Katsina State, Nigeria

Table 2: VES 1 Interpretation.

Layer number	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	1,510	1.12	1.12	Top soil + laterite
2	108	3.33	4.45	Sandy clay
3	19.3	9.39	13.8	Saturated sandy clay
4	1.12	36.1	49.9	Aquiferous layer
5	0.146			Weathered basement

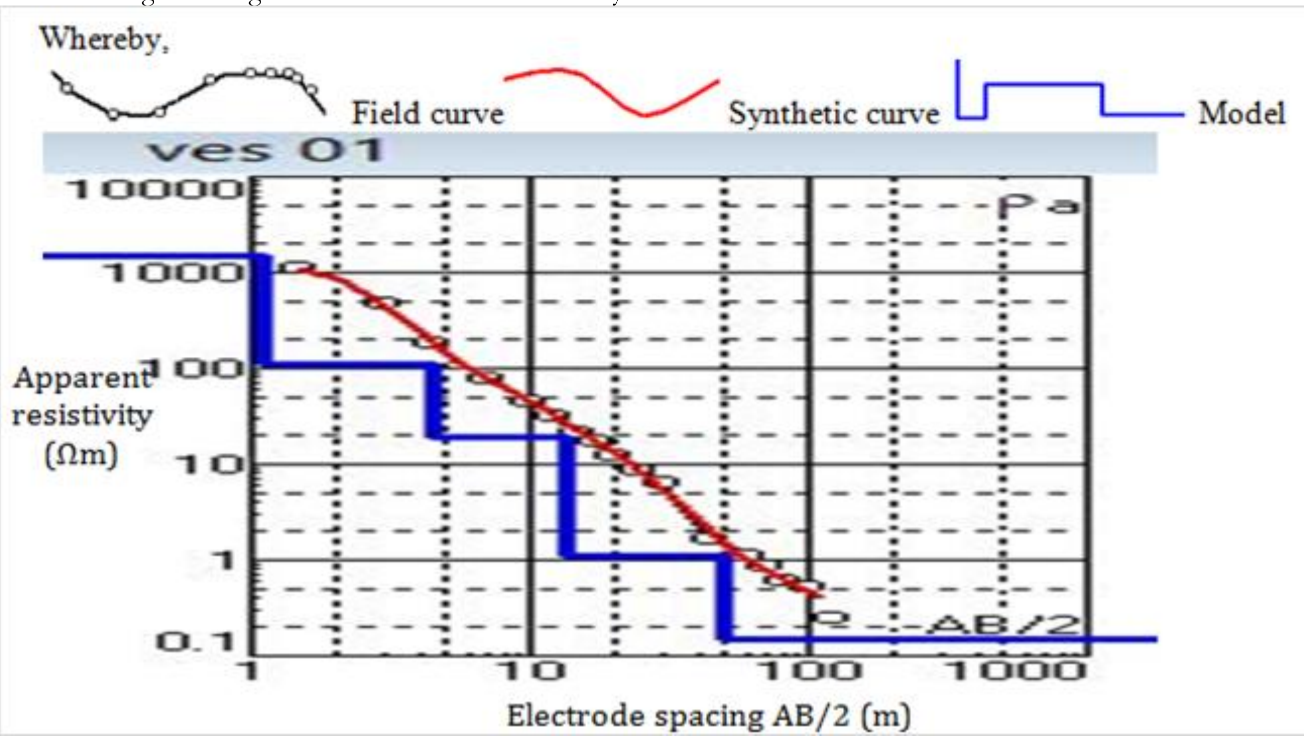

Figure 4: Computer iterated curve of VES 1

Figure 4 shows VES 1 curve, characterized by $\varrho_1>\varrho_2>\varrho_3>\varrho_4>\varrho_5$; Table 2 shown VES 1 interpretation with the top soil and laterite having 1,510 Ωm as the resistivity value and thickness of 1.12 m; the second layer has a resistivity value of 108 Ωm with a thickness of 3.33 m and a depth of 4.45 m, with sand clay as a possible material. The third layer has a resistivity value of 19.3 Ωm with a thickness of 9.39 m at the depth of 13.8 m, which is saturated sandy clay. The fourth layer has a resistivity value of 1.12 Ωm which may be referred to as the aquiferous layer with thickness of 36.1 m at the depth of 49.9 m and is good for groundwater development and the bottom layer represent the weathered basement with resistivity value of 0.146 Ωm having infinite thickness.

Table 3: VES 2 Interpretation

Layer number	Thickness (m)	Depth (m)	Lithology	
1	403	1.21	1.21	Top soil + lateritic soil
2	46.5	4.71	5.92	Sandy clay
3	0.946	3.88	9.8	Sand stone
4	5.89	12.6	22.6	Decomp osed basement
5	0.0087			Weathere d basement

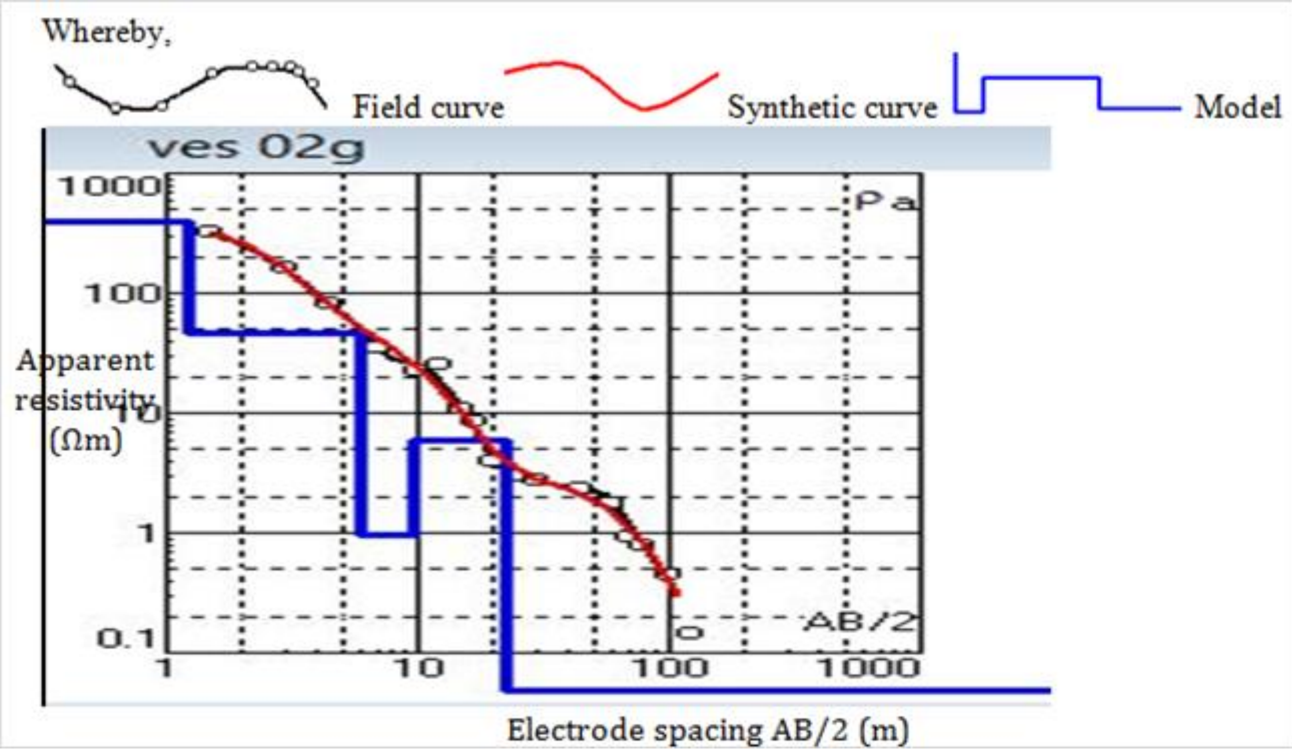

Figure 5: Computer iterated curve of VES 2

VES 2 is curve type as shown in Figure 5, characterized by $\varrho_1 > \varrho_2 > \varrho_3 < \varrho_4 > \varrho_5$; where Table 3 represent VES 2 interpretation. The first layer is the top soil and lateritic soil with a resistivity value of 403 Ωm and a thickness of 1.21 m; the second layer has a resistivity value of 46.5 Ωm interpreted as sandy clay with a thickness of 4.71 m, the third layer is the sand stone, with a resistivity value of 0.946 Ωm and a thickness of 3.88 m at a depth of 9.8 m; the fourth layer is the decomposed basement with an increase in resistivity value of 5.89 Ωm with a thickness of 22.6 m and the fifth layer showing decrease in resistivity value indicating weathered basement.

Table 4: VES 3 Interpretation

Layer number	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	6,685	1.003	1.003	Top gavels + laterite
2	114.4	2.964	3.967	Dry sandy soil + gravel (dry)
3	25.2	8.891	12.86	Weathered basement
4	2.54	31.37	44.23	Aquifer
5	0.00313			Fresh basement

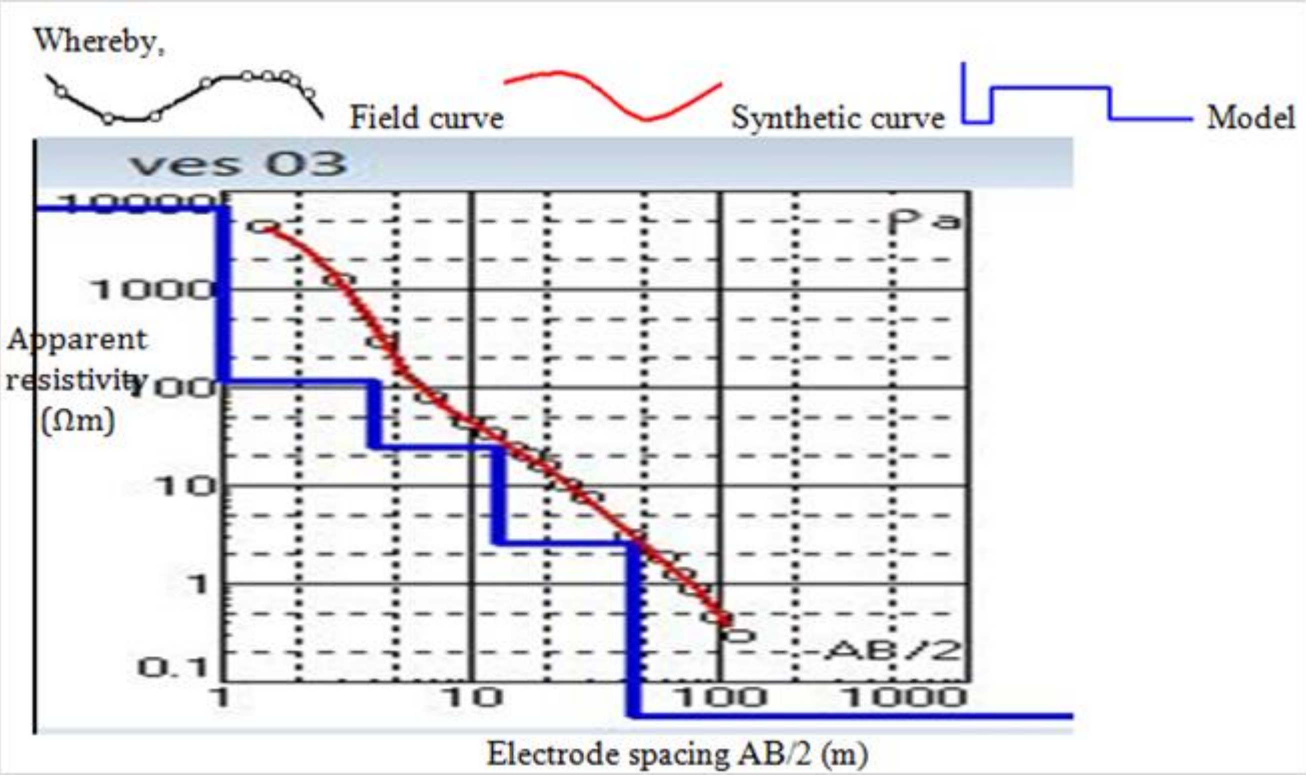

Figure 6: Computer iterated curve of VES 3

VES 3 is a curve type as shown in Figure 6, characterized by $\varrho_1>\varrho_2>\varrho_3>\varrho_4>\varrho_5$; Table 4 shown VES 3 interpretation with the top gavels and laterite having 6,685 Ωm as the resistivity value and thickness of 1.003 m; the second layer has a resistivity value of 114.4 Ωm with a thickness of 2.964 m, with sandy clay and gravel as the possible materials. The third layer has a resistivity value of 25.2 Ωm with a thickness of 8.891 m at the depth of 12.86 m, which is weathered basement. The fourth layer has a resistivity value of 2.54 Ωm which may be referred to as the aquifer layer with thickness of 31.37 m and is good for groundwater development while the fifth layer is representing a fresh basement with an infinite thickness.

Table 5: VES 4 Interpretation

Layer number	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	1,606	1.01	1.01	Top soil + gravel (dry)
2	55	3.77	3.77	Sandy clay
3	5.68	16.5	16.5	Weathered sandstone
4	0.233			Weathered basement

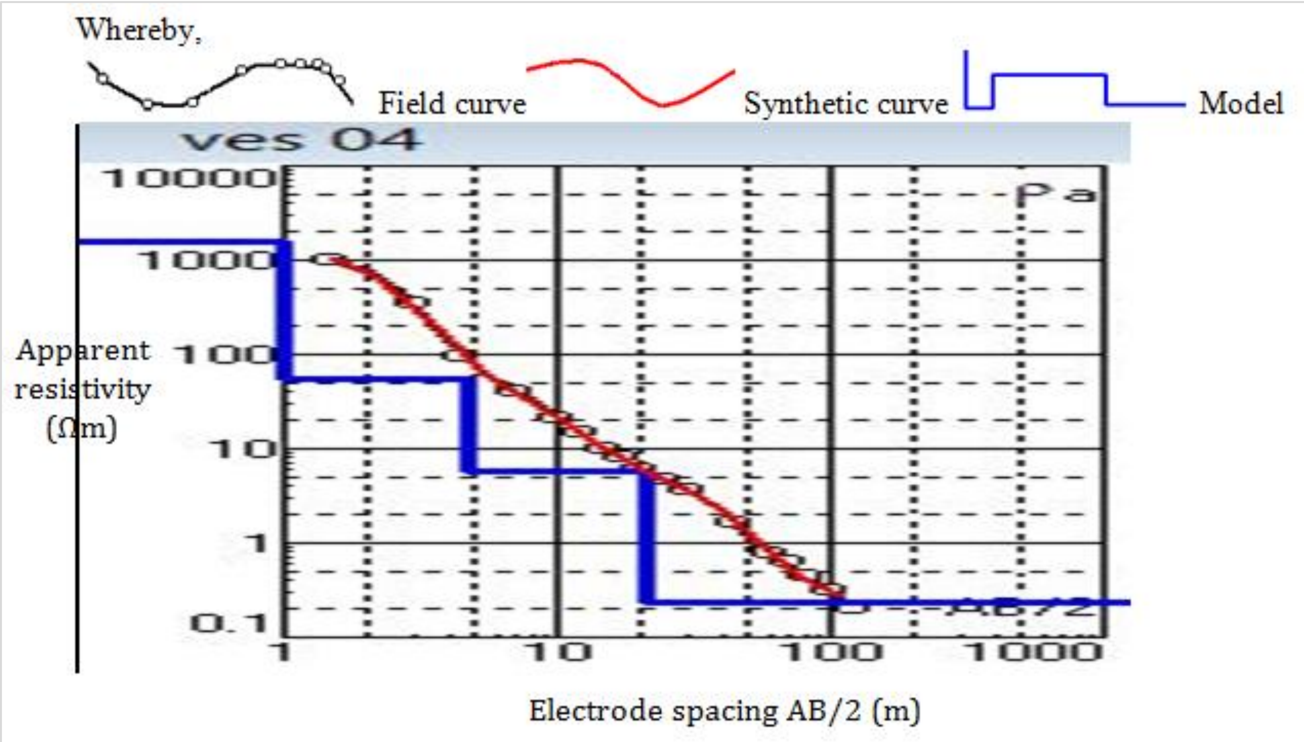

Figure 7: Computer iterated curve of VES 4

VES 4 is a curve type as shown in Figure 7, characterized by $\varrho_1 > \varrho_2 > \varrho_3 > \varrho_4$, where Table 5 shown VES 4 interpretation showing four regolith layers with the first layer being the top soil and gravel (dry) with a resistivity value of 1.606 Ωm and relative thickness of 1.01 m, the second layer with resistivity value of 55 Ωm has 3.77 m as its thickness which is the sandy clay and the third layer with resistivity value of 5.68 Ωm, which is the Weathered sandstone of thickness 16.5 m. The bottom layer represents also the weathered basement with resistivity value of 0.233 Ωm having infinite thickness.

Table 6: VES 5 Interpretation

Layer number	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	7,985	0.498	0.498	Top laterite
2	505	1.34	1.83	Dry sandy soil + lateritic soil
3	38.4	3.6	5.44	Saturated laterite
4	7.57	18.2	23.7	Aquifer
5	0.474			Weathered basement

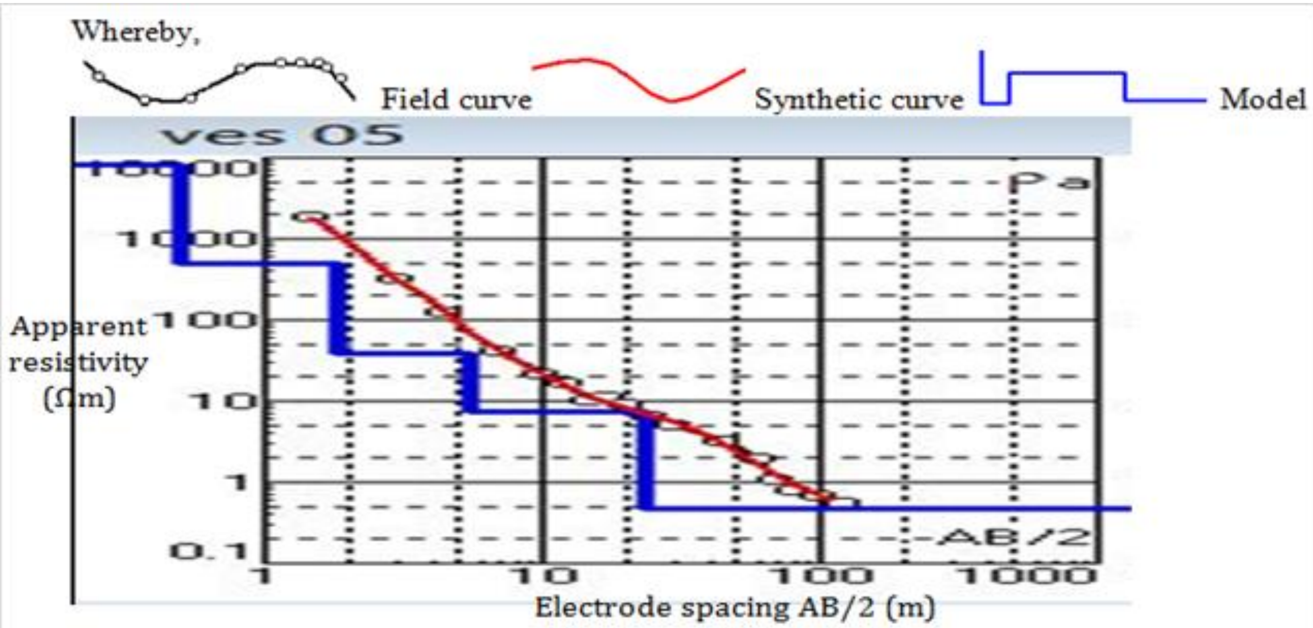

Figure 8: Computer iterated curve of VES 5

VES 5 is a curve type as shown in Figure 8, characterized by $\varrho_1 > \varrho_2 > \varrho_3 > \varrho_4 > \varrho_5$; where Table 6 represents VES 5 interpretation. The first layer is the top laterite with resistivity value of 7,985 Ωm and thickness of 0.498 m; the second layer with resistivity value of 505 Ωm which shown dry sandy soil and lateritic soil materials with a thickness of 1.34 m at the depth of 1.83 m. The third layer has a resistivity value of 38.4 Ωm showing a saturated laterite with a thickness of 3.6 m at a depth of5.44 m. The fourth layer has low resistivity value of 7.57 Ωm at the depth 18.2 m with thickness of 23.7 m, which could be referred to as aquifer layer and is good for underground water development and the last layer is representing fresh basement having infinite thickness.

Table 7: VES 6 Interpretation

Layer number	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	4,247	0.773	0.773	Top gravels + laterite
2	156	3.72	4.5	Dry sandy soil
3	4.41	24.1	28.6	Saturated sandy clay
4	0.364			Weathered sandstone

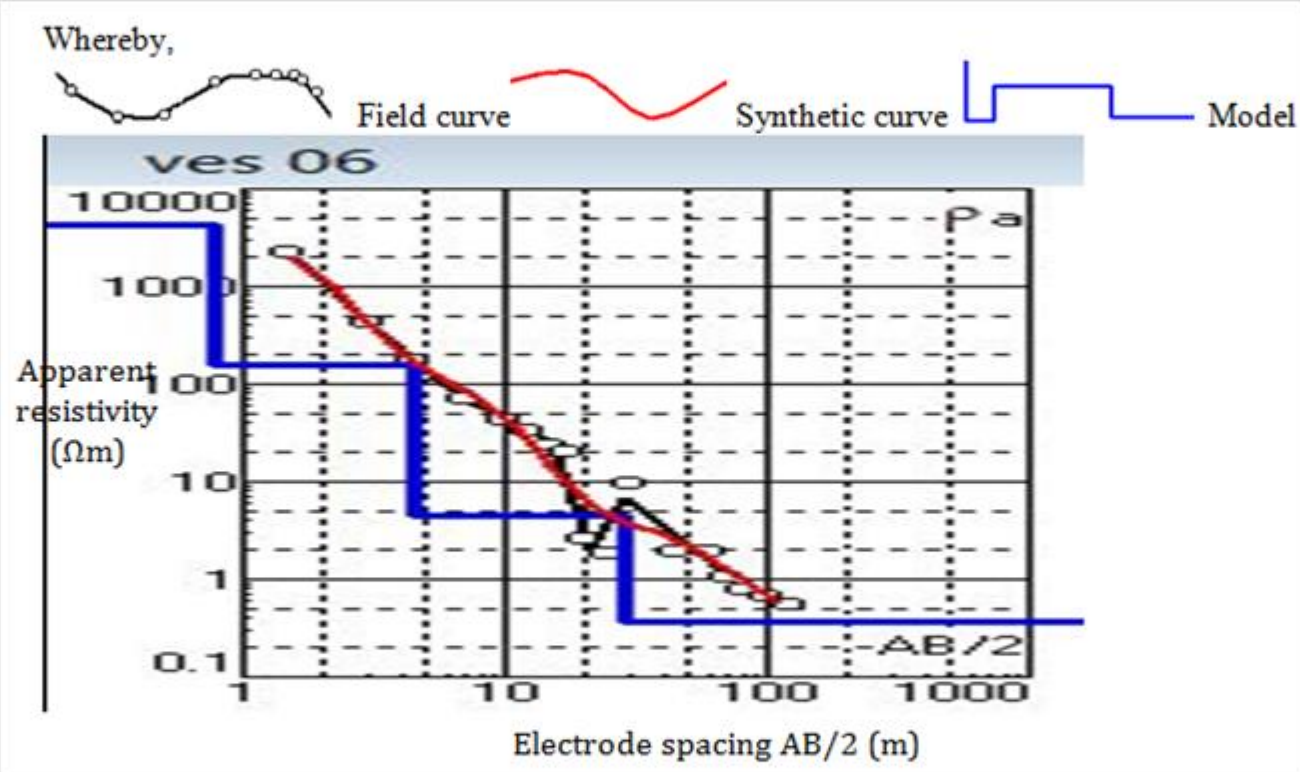

Figure 9: Computer iterated curve of VES 6

VES 6 is a curve type as shown in Figure 9, characterized by $\varrho_1 > \varrho_2 > \varrho_3 > \varrho_4$; Table 7 shown VES 6 interpretation. The first layer having a resistivity value of 4,247 Ωm and a thickness of 0.773 m shows the top gravels with laterite; the second layer has a resistivity value of 156 Ωm with a thickness of 3.72 m at a depth of 4.5 m and is considered as dry sandy soil. The third layer is saturated sandy clay having a resistivity value of 4.41 Ωm. The fourth layer represents the weathered sandstone with resistivity value of 0.364 Ωm having infinite thickness.

Table 8: VES 7 Interpretation

Layer number	Resistivity (Ωm)	Thickness (m)	Depth (m)	Lithology
1	3,133	0.803	0.803	Top lateritic soil
2	43.6	2.87	3.67	Sandy clay + laterite
3	3.93	25.4	29.1	Saturated sandy clay
4	0.103			Weathered basement

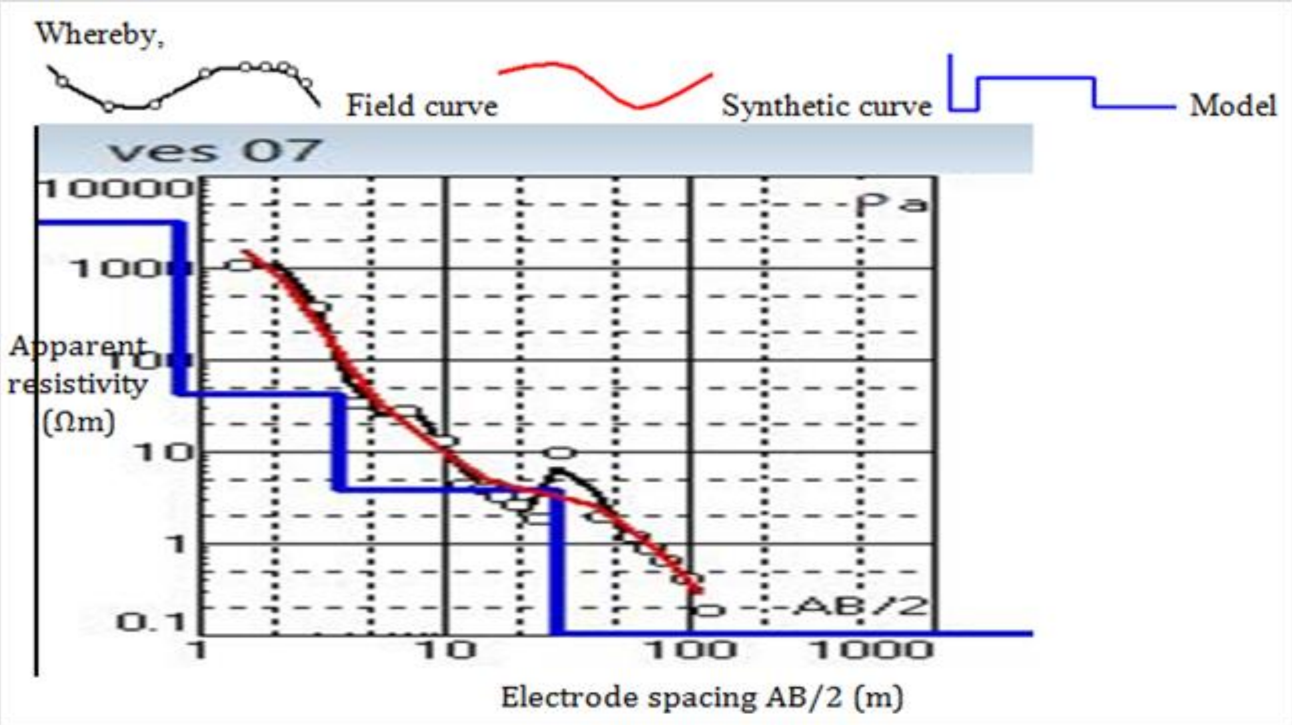

Figure 10: Computer iterated curve of VES 7

VES 7 is a curve type as shown in Figure 10, characterized by $\varrho_1>\varrho_2>\varrho_3>\varrho_4$; the first layer is the top lateritic soil with a resistivity value of 3,133 Ωm and a thickness of 0.803 m; the second layer has a resistivity value of 43.6 Ωm with a thickness of 2.87 m at a depth of 3.67 m represents sandy clay and laterite; the third layer is the saturated sandy clay, with a resistivity value of 3.93 Ωm and a thickness of 25.4 m at the depth of 29.1 m and the forth layer indicating the weathered basement.

DISCUSSION

The result of the geophysical investigation of the study area (Umaru Musa Yar'adua University, Katsina) indicated that the resistivity value ranging from about 1 **Ω**m to 7,985 **Ω**m is representing 4 to 5 layers as follows:

The first layer

This layer shows a resistivity value ranging from 403 Ωm to 7,985 Ωm having maximum thickness of 1.21 m is representing top soil of VES 1, VES 2 and VES 4; laterite of VES 1, VES 3, VES 5 and VES 6; lateritic soil of VES 2, and VES 7; gravel (dry) of VES 4 and top gavels of VES 3 and VES 6. Based on the interpreted result it indicated that the first layer of the study area is composed of top soil, laterite mix with gravel.

The second layer

The second layer has a resistivity value starting from 43.6 Ωm to maximum value of 114.4 Ωm is a layer consisting of sandy clay of VES 1, VES 2, VES 3, VES 4 and VES 7; dry sandy soil of VES 5 and VES 6 and lateritic soil of VES 5.This layer is found to be dominated with sandy clay mix with laterite at VES 5 and VES 7 and with gravels at VES 3, having a variable thickness ranging from 1.34 m to 4.71 m with a maximum depth of 5.92 m.

The third layer

This layer is interpreted as saturated layer with sandy clay of VES 1, VES 6 and VES 7, laterite of VES 5; weathered basement of VES 3; sand stone of VES 2 and weathered sand stone of VES 4, having resistivity value from 0.946 Ωm to 38.4 Ωm with a maximum thickness of 25.4 m at depth of 29.1 m. There is a decrease in resistivity on this layer due to the saturation of water within the layer.

The fourth layer

The fourth layer indicating a low resistivity value of 0.233 Ωm to a maximum of 7.57 Ωm value is layer representing aquiferous layer VES 1, VES 3 and VES 5; weathered basement of VES 4 and VES 7 and weathered sandstone of VES 6 while VES 2 indicating decomposed basement due to increase in resistivity value. The layer revealed infinite thickness of VES 4 and VES 6 at a maximum depth of 28.6 m. These layers of VES 1, VES 2, VES 3, VES 4 and VES 5 are good for groundwater development at depth from about 30 m.

The fifth layer

The bottom layer of VES 1 and VES 2 indicating weathered basement while VES 3 and VES 5 representing fresh basement from a maximum depth of about 50 m with a finite thickness.

Based on the decreasing in resistivity of VES 1, VES 2, VES 3, VES 4 and VES 5, the types of lithology and the arrangement of the layers interpreted, revealed that the pints are expected to have groundwater potentials and good for groundwater development while VES 6 and VES 7 are not.

CONCLUSION

The result of the geophysical investigation of the study area (Umaru Musa Yar'adua University, Katsina) showed that the resistivity value ranging from about 1 Ωm to 7,985 Ωm is representing 4 to 5 layers consisting of first layer (top soil, laterite, lateritic soil, top gravel and dry gravel); second layer (sandy clay, sandy soil, laterite, dry sandy soil lateritic soil and gravels); third layer (saturated sandy clay, saturated laterite, weathered sandstone and weathered basement); fourth layer (weathered basement, weathered sandstone, aquifer and at VES 2 decomposed basement) and the fifth layer (weathered basement and fresh basement) with infinite thickness.

It has been shown that, the low resistivity values of VES 1, 2, 3, 4, and 5 ranging from 2 Ωm to 391 Ωm indicates good prospect for groundwater nevertheless, VES 6 and 7 indicates high resistivity value and therefore poor groundwater potentials. The groundwater exploration should be conducted at VES 1, 2, 3, 4, and 5 at a depth from about 30 m to 50 m.

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