

**INTERNATIONAL JOURNAL OF SCIENCE FOR GLOBAL SUSTAINABILITY****Goelectrical Investigation of Groundwater Potential at Proposed Staff Quarters of FCE Technical, Gusau, Zamfara State, Nigeria**

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ABSTRACT

Goelectric investigation was carried out at proposed staff quarters of FCE, Technical Gusau, located along Gusau – Zaria highway, Zamfara State, Nigeria with the aim of delineating the groundwater potentials. The study area lies in the Basement Complex region of Northern Nigeria and it is situated on Latitude 12°8'19.64"N to 12°08'24.65"N and longitude 06°43'28.65"E to 06°43'37.25"E with an area coverage of 500 m by 500 m. Vertical Electrical Sounding (VES) technique was employed using Schlumberger array pattern. A total of thirty-six (36) VES points were sounded on Six (6) grided profiles (A-F) separated by 100 m apart with inter VES spacing of 100 m. The VES results depict two distinct curve types namely; H-type and A-type. The results also reveal three distinct geoelectric layers: the top layer, weathered/fractured layer and fresh basement. The top layer has resistivity, depth and thickness range of 10.4 – 158.8 Ωm , 0.4 – 3.6 m and 0.4 – 3.6 m respectively. The second layer has ranges of: resistivity, 6.3 – 525.3 Ωm ; depth, 1.4 – 20.8 m, and thickness, 1.0 – 20.4 m. The third layer has resistivity values range of 278.6 – 2726.5 Ωm , its depth and thickness are not defined (to infinity). Seven VES stations (A₃, A₄, B₄, C₃, E₂, F₂ and F₅) were delineated for groundwater potential having weathered/fractured resistivity varying between 37.4 and 121.1 Ωm . Depths range were found from 7.9 – 20.8 m and thickness varying between 6.6 and 20.4 m. The results of the study implies that the area has a good groundwater potentials.

Keywords: Goelectric, Resistivity, Depth, Thickness, Basement, Vertical Electrical Sounding.

1.0 INTRODUCTION

Water remains one of the greatest elements in life. It is very much vital for human existence. It is one of the natural resources that determine the survival of all forms of living things (plant and animal). The availability of water has played a key role in the development of all civilizations. Social welfare and economic development may also be hampered in the absence of reliable water supplies. The proper exploration of groundwater involves deep and comprehensive techniques to provide valuable information with respect to distribution, thickness, and depth of groundwater bearing formation (Sunday and Usman, 2021).

Groundwater is water that has percolated downward from the surface, filling voids or open spaces in the rock formation. It is located within the pores and fractured rock formation in the subsurface. Groundwater exploration involves the use of scientific methods to locate and extract. The primary target for the development of groundwater resources in crystalline rocks of basement complex are fractures which aid in enhancing their secondary porosities thus,

making them aquiferous (Ejepuet *al.*, 2014). A unit of rock or an unconsolidated deposit is referred to as an aquifer when it can yield a usable and exploitable quantity of water and this serve as a very important source of groundwater. Aquifers in crystalline rocks are housed by weathered layers or fractured bedrock. In some cases, combination of weathered layers and fractured bedrock are needed for optimum groundwater accumulation (Sunmonuet *al.*, 2012; Akinrinade and Adesina, 2016).

To tackle this problem, this research seeks to use vertical electrical sounding (VES) geophysical survey techniques to identify potential well site locations and to know the overall groundwater conditions of the study area. More specifically, the study was aimed to delineate the depth to the aquifers within the study area so as to identify the potential well sites that could balance the water demand and supply.

In recent times, many organizations worldwide depend on groundwater for use due to several factors. Some of these include increase in population, inability of government to provide

adequate water supply and high cost of providing this resource from surface water. The groundwater is significantly protected from surface pollutants as earth media (composed of different subsurface layers) acts as natural filter to infiltrated water. Water supply is a great challenge in the study area (FCE Technical Gusau) and has been grossly inadequate to meet-up with the mounting demand of the inhabitant of the area as the area falls on basement complex terrain where there are numerous unsuccessful drilled bore-holes.

The electrical resistivity method is one of the most adopted techniques in geophysical campaigns for groundwater exploration, though applications of 2D and 3D electrical resistivity surveys to groundwater exploration and other near surface features have been reported by some authors including (Loke *et al.*, 2013 and Adagunodo *et al.*, 2017). The proper exploration of groundwater involves deep and comprehensive techniques to provide valuable information with respect to distribution, thickness, and depth of groundwater bearing formation. Various surface geophysical techniques are used in groundwater exploration which includes the electrical resistivity method, seismic refractive method, magnetic method, radioactivity method, gravity method, and electromagnetic method. This current study is based on the application of electrical resistivity for groundwater exploration in the study area.

Fracturing and weathering activities of basement complex rocks may lead to appreciable secondary porosity and permeability of the rocks, thereby making them suitable aquifers (Akindeji O. F. 2020). The true riches of any country depend on its ability to provide for its dwellers. Potable water is one of the major resources that a citizen of any nation can benefit from, if well harnessed (Adesunloro Sunmonuet *al.*, 2022).

2.0 LOCATION AND GEOLOGY OF THE STUDY AREA

The study area located at Federal College of Education (Technical) campus, along Gusau-Zaria road, Gusau, Zamfara State (Figure 1). The area is situated on Latitude $12^{\circ}8'19.64''N$ to $12^{\circ}08'24.65''N$ and longitude $06^{\circ}43'28.65''E$ to $06^{\circ}43'37.25''E$. The area is gently undulating without outcrop. The elevation varies between 476 m to 486m. The area experiences two distinct seasons: the dry season (November – April) and rainy season (May – October).

Nevertheless, the surveyed area is entirely underlain by rocks of the Nigerian-basement complex. The main rock types of the area are the biotite and biotite-hornblende-granite (medium grained). Topography of the study area consists of low-lying terrains and was fairly flat. The vegetation consists of desert of bread leaved savannah with some scattered trees. Figure 1 is the Nigeria map showing the study area while Figure 2 is the Geological map of the study area using RGIS Google map.

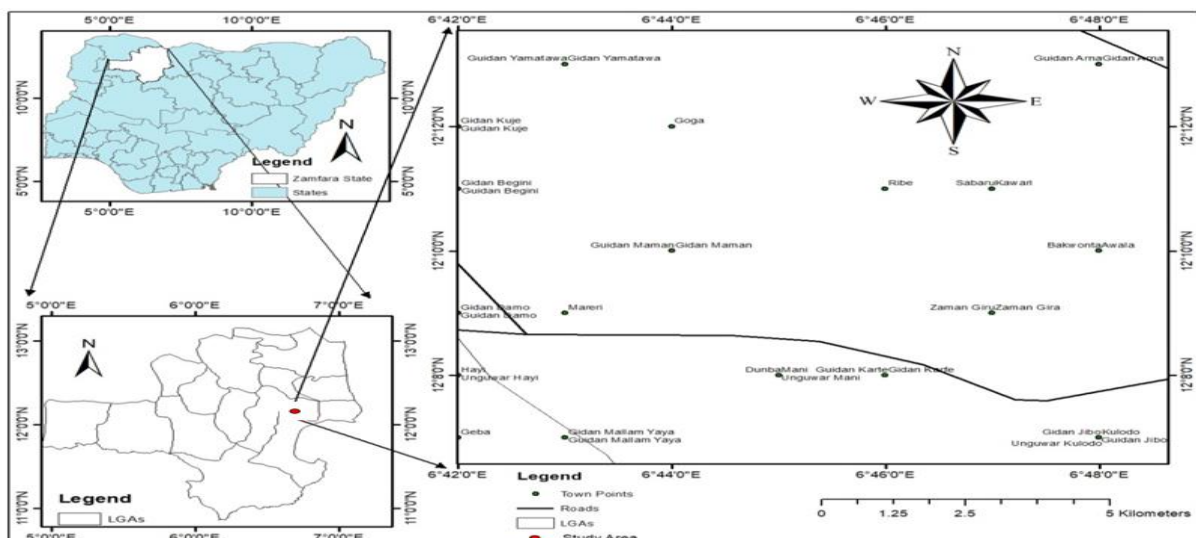


Figure 1: Map of Nigeria showing the study area (After Obaje, 2009).

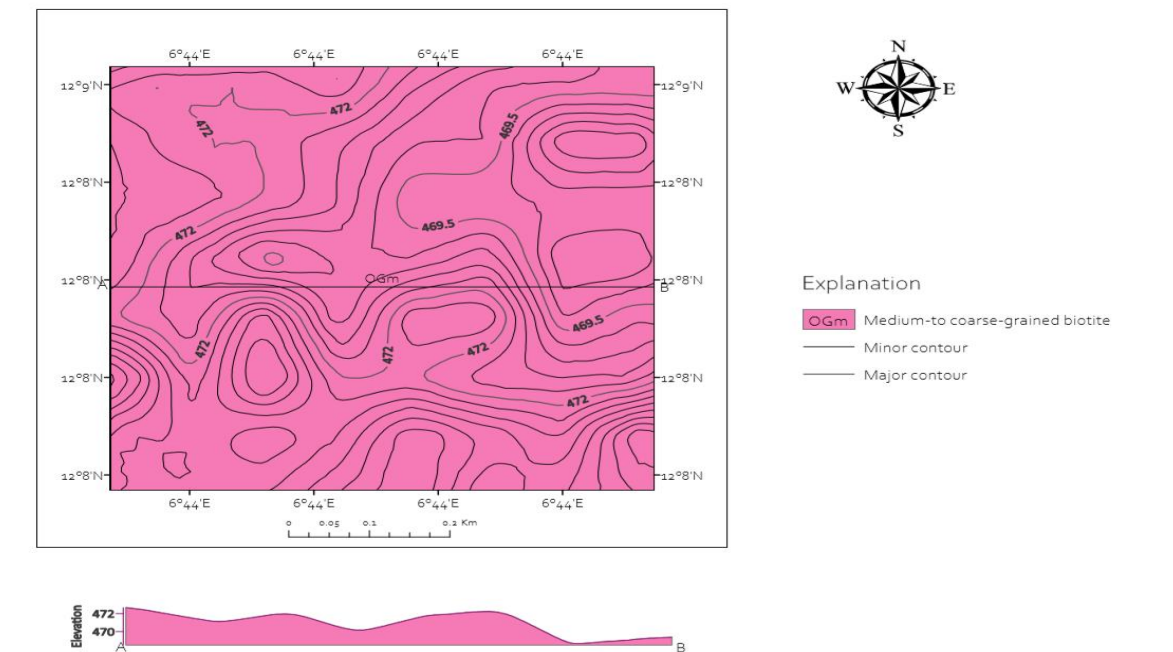


Figure 2: Geological map of the study area using RGIS Google map.

3.0 MATERIALS AND METHOD

The most important instrument used during this research work is the ABEM terrameter SAS 4000 for data collection on the field. The instrument is packaged in a portable box and contains the following components; Power source: The power is a d.c supply from the equipment battery, Current and voltage display screen: The Meter Model has digitized meters capable of displaying the values of current flow, the voltage for each measurement, The box handle: for lifting the instrument from one point to another. In addition to the Geosensorterrameter, the following tools were used; Four (4) steel electrodes of about 0.7m long each, two as potential electrode, two as current electrode, hammers with rubber handle, which are used to peg electrodes into the ground to ensure proper contact with the ground, four (4) reels of cables that connect the terrameter to the current and potential electrode, G.P.S. for taking the coordinate of the study area. Figure 3 is the Profile Layout of the study area.

The electrical resistivity method was adopted for the study due to its ease and flexibility in obtaining sound information of the proper points suitable for groundwater exploration. Vertical Electrical sounding (VES) technique was employed as it has been used extensively in groundwater investigation in the basement complex terrains. The field procedure began by inspecting the area as well as measuring the land

and establishing the required points on each profile at equal distance of 100m between two successive points. The measuring tape aided in measurement accuracy. The study area was gridded into six (6) profiles; (A – F). The length of each profile is 500 meters, the distance between one profile and the other is 100 meters. The field size is 500 m by 500 m at the interval spacing of hundred (100) meters, making the total sum of thirty-six (36) VES points on the study area. Vertical electrical sounding (VES) was established using the Schlumberger configuration. This is in order to achieve the aim of getting sound and detailed information of the groundwater potential points in the study area. The Vertical Electrical Sounding has the advantage of delineating the depth to bedrock and resistivity variation of the subsurface which makes it most suitable for the study.

Data Collection was done for thirty-six (36) Vertical Electrical Sounding (VES) points using Schlumberger array configuration. The Schlumberger electrode configuration was used, with maximum current and potential electrodes separation of AB=800meters and MN=40meters respectively. After acquiring the data, measured earth resistance (R) in Ohms was converted to apparent resistivity (ρ_a) in Ohm-meter by multiplying resistance (R) with the geometric factor (k). Figure 3 shows the layout of the study area.

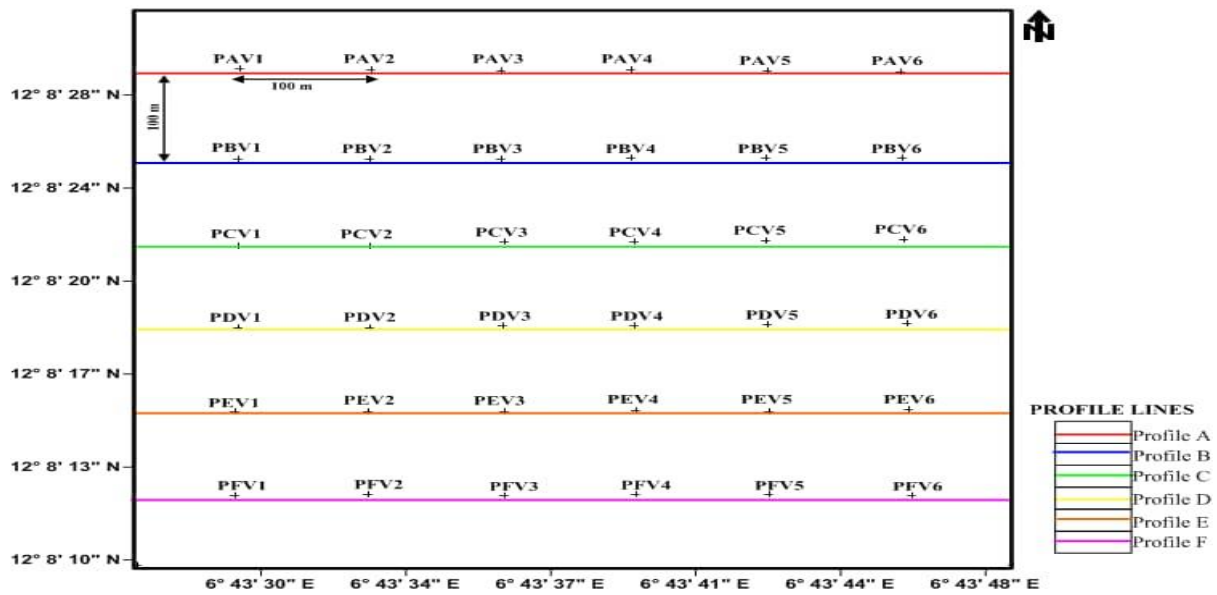


Figure 3: Profile Layout

Table 1: Ranges of resistivity of various rocks component in basement complex (Esimai, 2017).

Rock Type	Range of Resistivity (Ω m)
Clay	1-100
Famada loam	30-90
Weathered basement	20-500
Alluvium and sand	10-800
Weathered laterite	150-900
Fresh laterite	900-3500
Granite	300-105
Sand	500-5000
Quartzite (various)	10 – 2 x 108
Gravel	100-5000
Fractured basement	500-1000
Fresh basement	> 1000

4.0 RESULTS AND DISCUSSION

The Vertical Electrical Sounding (VES) data were modelled using WinResist software which plots Geoelectric sections(VES curves) with their corresponding resistivity, depth and thickness as shown in figure 4a and 4b. Two distinct curves types were observed throughout the study area which are H- type and A-type.

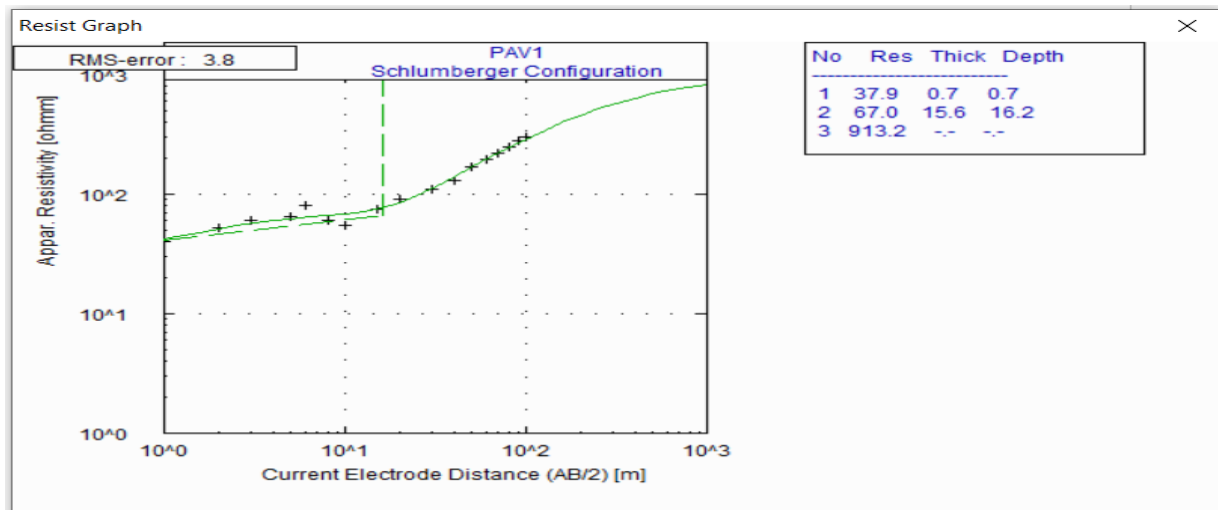


Figure 4a: Geoelectric section of VES point A₁

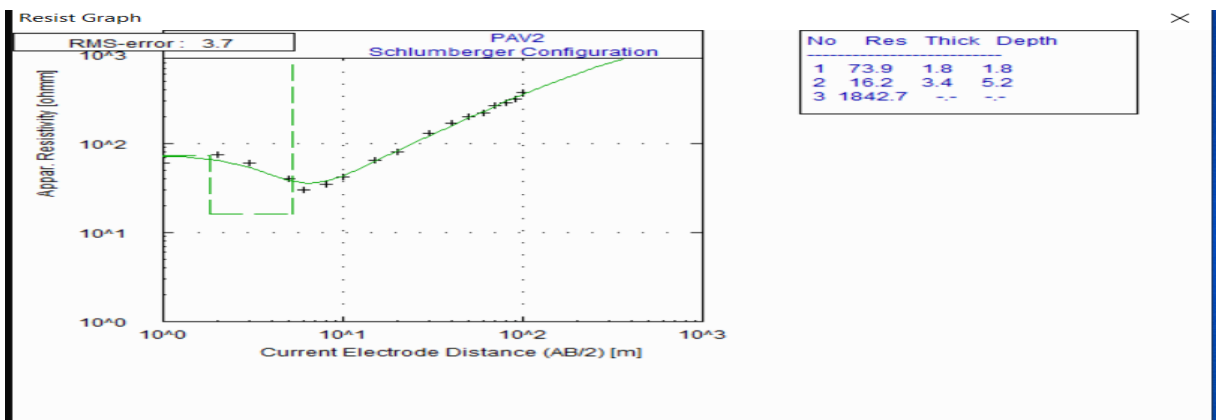


Figure 4b: Geoelectric section of VES point A₂

H-type: This group consists of curves with 3 layer ($\rho_1 > \rho_2 < \rho_3$) this curve type were observed in VES A₂, A₆, B₂, B₃, B₅, B₆, C₁, C₂, C₃, C₄, C₅, C₆, D₂, D₃, D₆, E₅, F₂, F₃, F₄, F₅, and F₆.

A-type: This group consist of curves with 3 layer ($\rho_1 < \rho_2 < \rho_3$), which were observed in VES A₁, A₃, A₄, A₅, B₁, B₄, D₁, D₄, D₅, E₁, E₂, E₃, E₄, E₆, and F₁.

Table 2 shows the summary of results obtained from each geoelectric section across profile A to F which reveals that the study area is underlain by three (3) geoelectric subsurface layers. The first layer which is the top layer has resistivity value ranging from 10.4 – 158.8Ωm, its depth and thickness varies between 0.4 and 3.6 m, 0.4 and 3.6 m respectively which corresponds to the resistivity of clay and fadama loam (Esimai, 2017). The second layer has resistivity value ranging from 6.3 - 525.3Ωm, depth of 1.4 – 20.8 m and thickness of 1.0 - 20.4 m; this layer refers to the weathered/fractured basement. The

resistivity of the third layer ranged from 278.6 - 2726.5Ωm, its depth and thickness are undefined.

4.1 Curve Types Distribution

The curve distribution (Figure 5) indicates two curve types. The H-type is the dominant curve with 58% of the area. The weathered/fractured layer in the H-curve type is usually characterized with low resistivity value made up of clayey or sandy clay, and it is usually water saturated and highly porous (Olorunfemiet *al.* 1999). The A-curve type constitutes 42% of the total area.

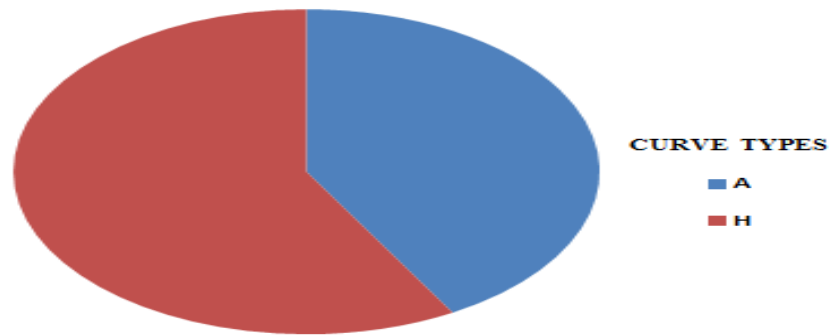


Figure 5: Curve type distribution

The aquifer thickness contour map in figure 6 was produced from thickness of the second layers of the VES points. It is contoured at the interval of 1 m. The thickness of the weathered basement layer ranges from 1 – 20.8 m with an average thickness of 12 m. The highest aquifer thickness of 15 m, 16 m, and 17 m, 18 m, 19 m and 20 m were found at A₅, A₆, C₄, C₆, D₅ and D₆ and this serves as points of good potentials for

groundwater and this accounts for 16.68% of the entire points in the study area. Aquifer thickness of 8 m - 14 m was observed at A₃, A₄, B₄, C₅, D₄, E₅ and E₆, this account for 19.46% of the entire points of the study area at the weathered zone. Other remaining points possess least aquifer thickness of 7 m and below which is not relatively poor and this accounts for 63.94% of the entire study area at the weathered zone.

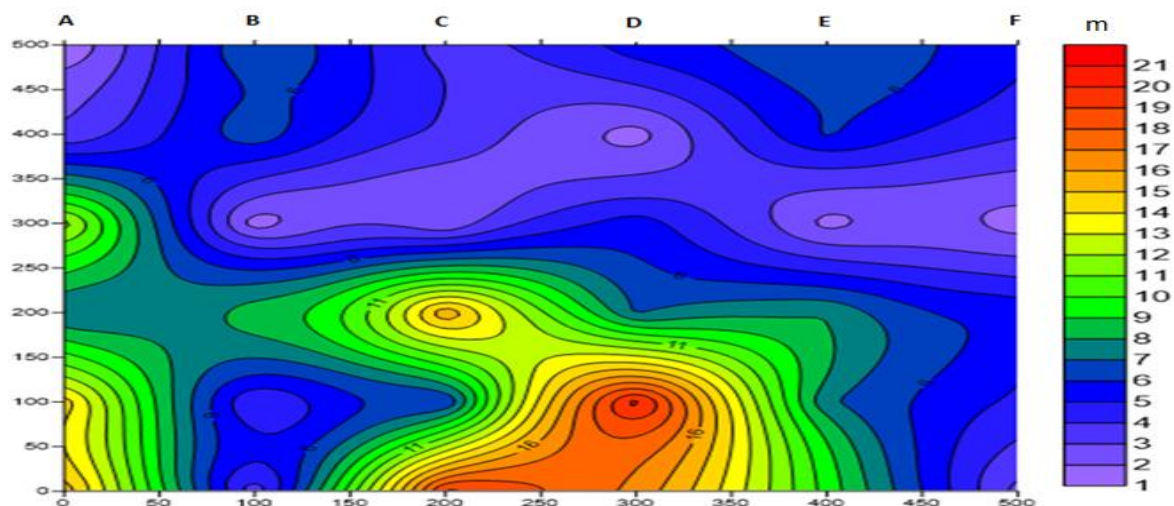


Figure 6: Aquifer thickness contour map

4.3 Aquifer Resistivity and its Iso-map

An interval of 200 Ωm was used to generate the iso-resistivity contour map of the third layer (Aquifer zone) in Figure 7. This layer has resistivity values range from 53.3 to 2,726.5 Ωm. The northwestern, eastern, southeast and

southwestern parts of the study area has higher resistivity value while the region of lower resistivity value trends from the southern through the central to the western and northeastern parts of the study area.

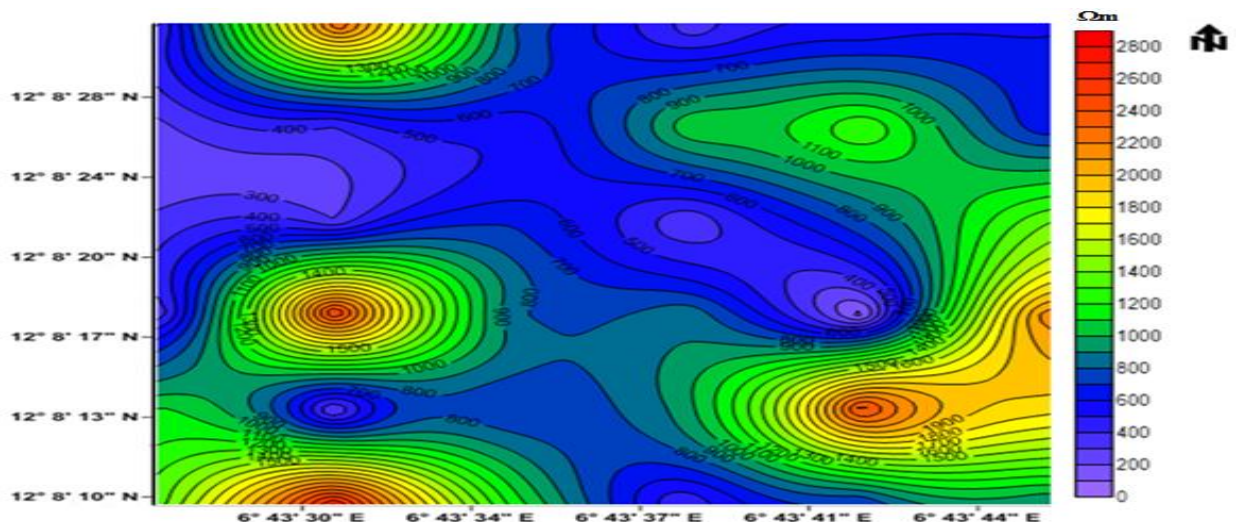


Figure 7: Aquifer Resistivity Iso-map

4.4 Aquifer Depth and its Iso-map

The Aquifer depth Iso- map was generated at an interval of 1 m, the values range from 1.4 to 20.8 m as shown in figure 8. The contour reveals that the study area has higher overburden thickness at its southern part and lower overburden thickness around northern and eastern region.

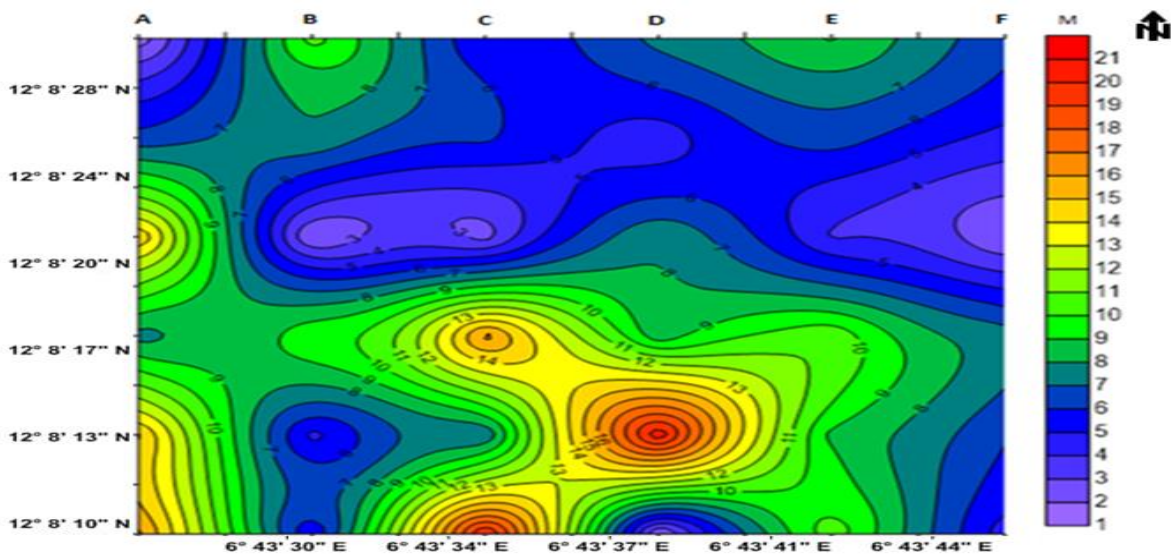


Figure 8: Aquifer Depth Iso-map

4.5 Iso-Resistivity Contour Maps

4.5.1 Iso-Resistivity Contour Map of the First Layer

The iso-resistivity contour map of the first layer was produced with an interval of $10\Omega\text{m}$ as shown in figure 9. The resistivity values range from 10 to $270\Omega\text{m}$ which corresponds to the resistivity of

clay and fadama loam (Esimai, 2017). The study area has its lowest resistivity values at the Northeastern, Eastern, Southeastern, Northwestern, Western and Southwestern parts while the Northern, Southern and extreme Western parts has the moderate resistivity values with high resistivity concentrated at the central part of the study area.

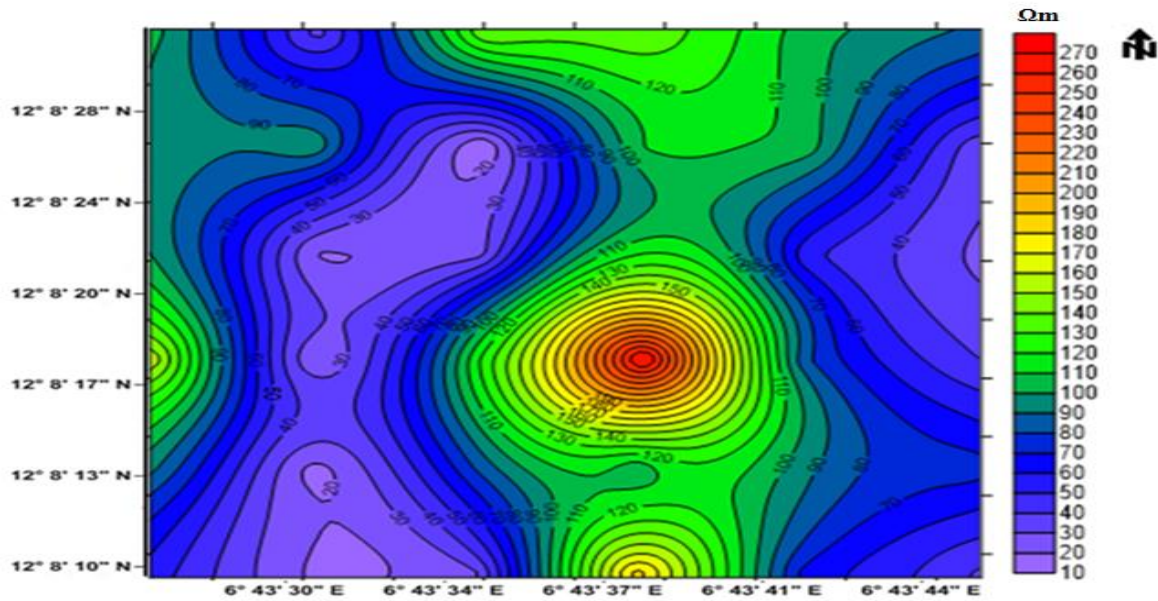


Figure 9: Iso-resistivity contour map of the first layer

4.5.2 Iso-Resistivity Contour Map of the Second Layer

Figure 10, is the iso-resistivity contour map of the second layer, it was generated at an interval of 20 Ωm. This layer referred to as the weathered/fractured zone, its resistivity value

range from 6.3 to 525.3 Ωm. Apart from the Southwestern part of the study area which has higher resistivity value, other parts has low resistivity value depicting that the zone is highly weathered or fractured

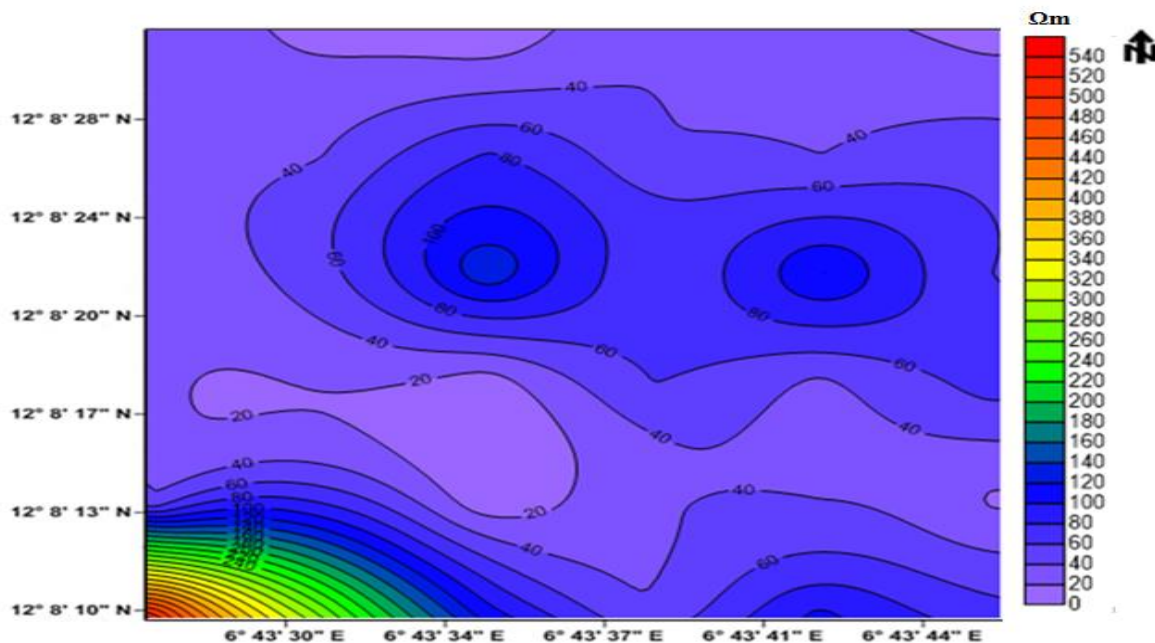


Figure 10: Iso-resistivity contour map of the second layer

4.6 Geologic Section of Profile A

The geologic section through profile A in Figure 11 reveals that the profile is characterised by three layers. The first layer is the top soil which spreads through the entire profile; its resistivity, depth and thickness range from 28.1 – 87.0Ωm, 0.5 – 1.8 m and 0.5 – 1.8 m respectively. The

second layer is a weathered/fractured layer, its resistivity, depth and thickness varies between 15.5 and 67.9Ωm; 1.7 and 20.3 m and 2.7 and 19.3 m respectively; it spreads across the entire profile. VES point A₃ and A₄ are fractured and observed to be the Aquifer. The third layer which is the fresh basement underlies the second layer;

it has a resistivity range from 623.7 – 2166.9 Ωm and undefined depth and thickness.

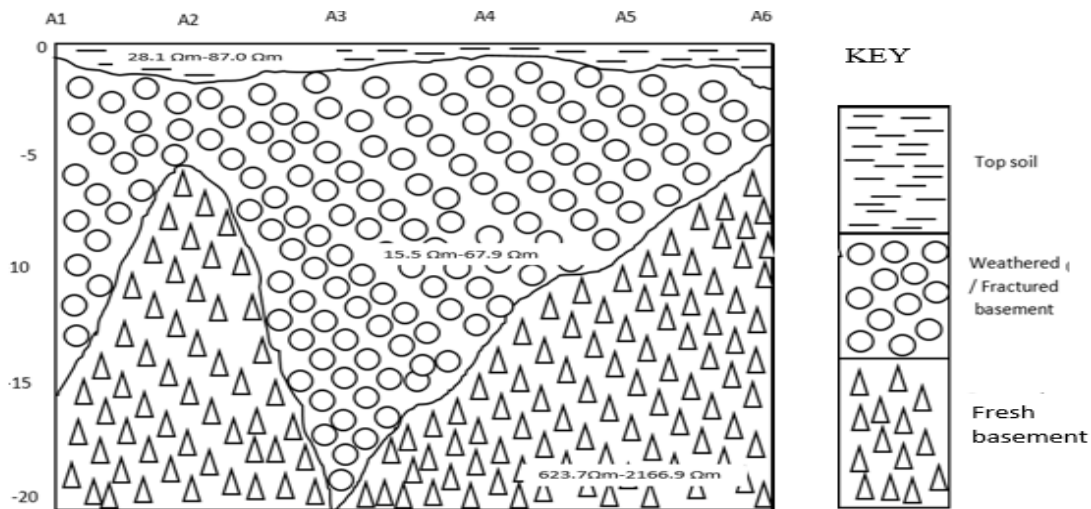


Figure 11: Vertical geologic section through profile A

4.8 Geologic Section of Profile B

Figure 12 represents the geologic section through profile B, it reveals that the profile is characterised by three geoelectric layers. The first layer which is the top soil spreads through the entire profile; its resistivity, depth and thickness ranges from 51.8 – 105.0 Ωm ; 0.4 – 1.6 m and 0.4 – 1.6 m respectively. The second layer refers to the weathered/fractured layer, its resistivity, depth and thickness varies between 26.3 & 121.0

Ωm ; 4.7 & 20.8 m and 4.0 & 20.4 m respectively; it spreads across the entire profile. VES point B4 is fractured which was observed to pass through from profile A. This fractured point is suggested to be aquifer point. The third layer which is the fresh basement underlies the second layer; it has a resistivity range of 523.3 – 2459.5 Ωm and undefined depth and thickness.

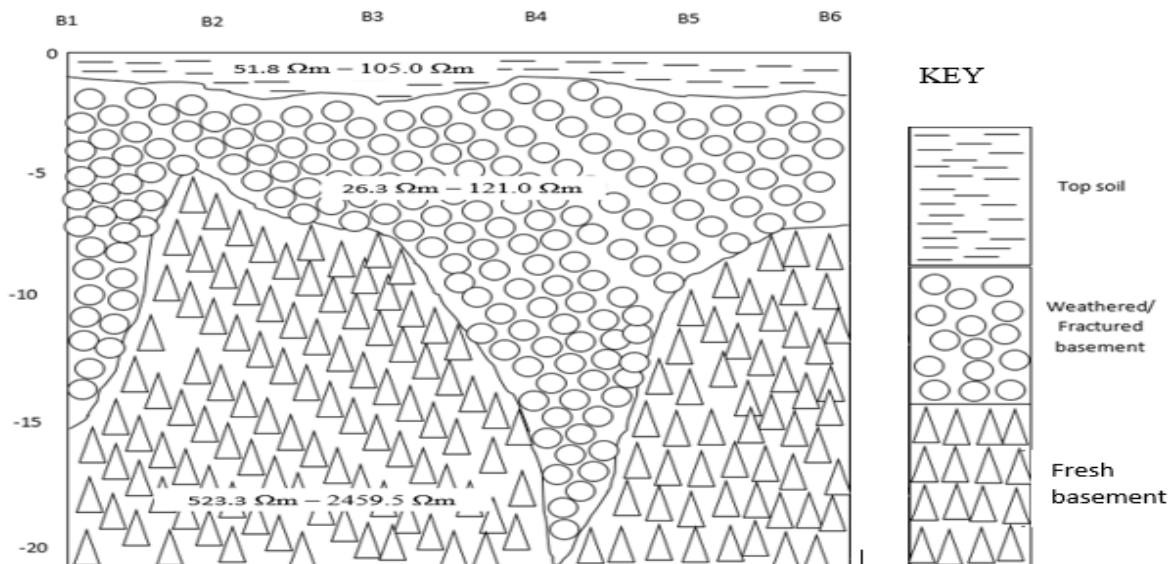


Figure 12: Vertical geologic section through profile B

4.9 Geologic Section of Profile C

The geologic section through profile C in Figure 13 reveals that three distinct layers exist therein. The first layer is the top soil spreading through the entire profile; its resistivity, depth and

thickness range from 1102.1 – 276.0 Ωm ; 0.5 – 3.0 m and 0.5 – 3.0 m respectively. The second layer is a weathered/fractured layer which also spreads across the entire profile, its resistivity, depth and thickness varies between 38.8 & 64.4

Ωm ; 7.5 & 16.4 m and 5.7 & 15.8 m respectively. VES point C₃ is observed as good point for groundwater reservoir. The third layer which is

the fresh basement underlies the second layer; it has a resistivity range of 307 – 1092.2 Ωm and undefined depth and thickness.

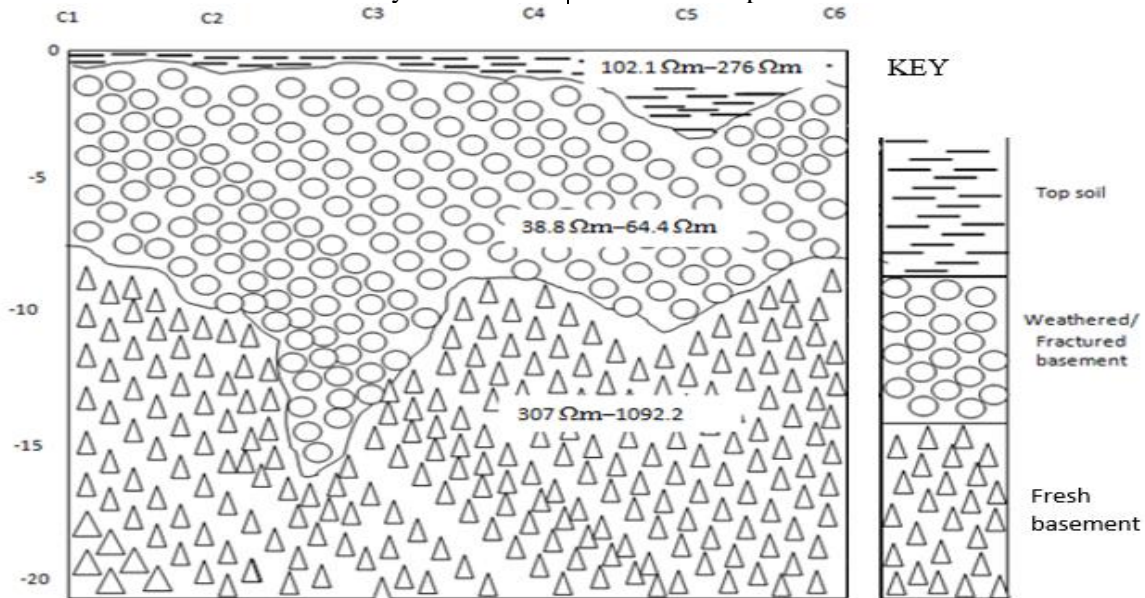


Figure 13: Vertical geologic section through profile C

4.10 Geologic Section of Profile D

Three geoelectric layers exist within profile D as clearly revealed by its geologic section in Figure 14. The first layer which is the topsoil spreads through the entire profile; its resistivity, depth and thickness range from 102.1 – 276 Ωm ; 0.4 – 2.5 m and 0.4 – 2.5 m respectively. The second layer which is the weathered/fractured

layer has resistivity, depth and thickness of 10.4 – 139.3 Ωm ; 1.9 – 14.9 m and 1.5 – 12.4 m respectively; it spreads across the entire profile. The fresh basement which is the third layer underlies the second layer; its resistivity range from 522.3 – 1185.2 Ωm with depth and thickness undefined.

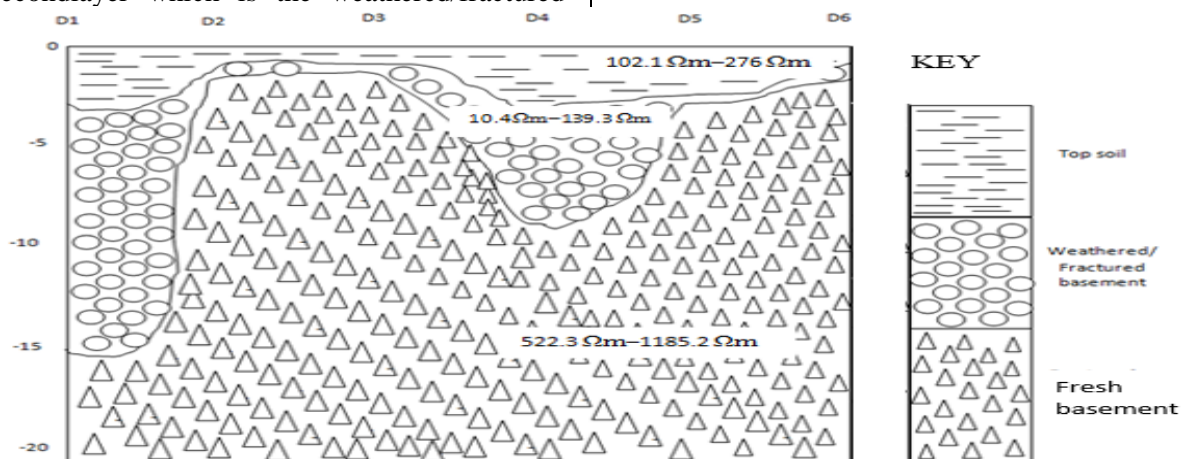


Figure 14: Vertical geologic section through profile D

4.11 Geologic Section of Profile E

Figure 15 shows the geologic section through profile E, it reveals that three distinct layers exist therein. The first layer is the top soil which spreads through the entire profile; its resistivity, depth and thickness range from 16.0 – 98.4 Ωm ; 0.4 – 3.3 m and 0.4 – 3.3 m respectively. The second layer is a weathered/fractured layer which

also spreads across the entire profile, its resistivity, depth and thickness varies between 15.2 & 288.2 Ωm ; 4.4 & 7.9 m and 1.6 & 6.6 m respectively. The observed aquifer point of this profile is at VES E₂. The third layer which is the fresh basement has a resistivity range from 278.6 – 2726.5 Ωm with an undefined depth and thickness.

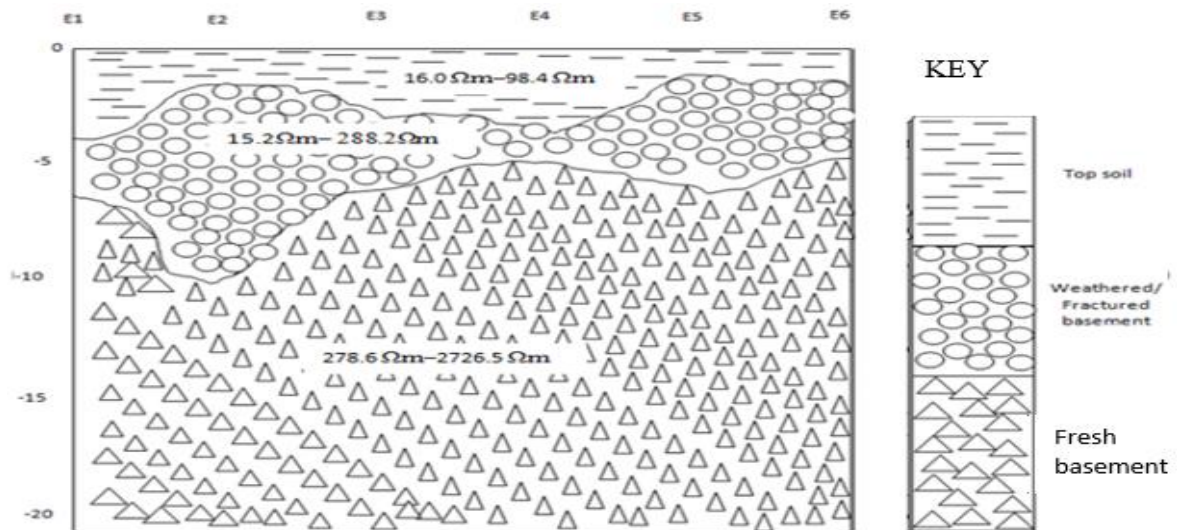


Figure 15: Vertical geologic section through profile E

4.12 Geologic Section of Profile F

The geologic section through profile F in Figure 16 reveals that the subsurface is made up of three geoelectric layers. The first layer is the top soil which spreads through the entire profile; its resistivity, depth and thickness range from 55.5 – 155.8Ωm; 0.4 – 3.4 m and 0.4 – 3.4 m respectively. The second layer is the weathered/fractured layer which also spreads

across the entire profile, its resistivity, depth and thickness varies between 26.0 & 525.3 Ωm; 1.4 & 10.4 m, and 1.1 &7.0 m respectively. VES points F₂ and F₅ are the aquifer point observed in this profile. The third layer which is the fresh basement has a resistivity range from 281.0 – 1347.1Ωm with an undefined depth and thickness.

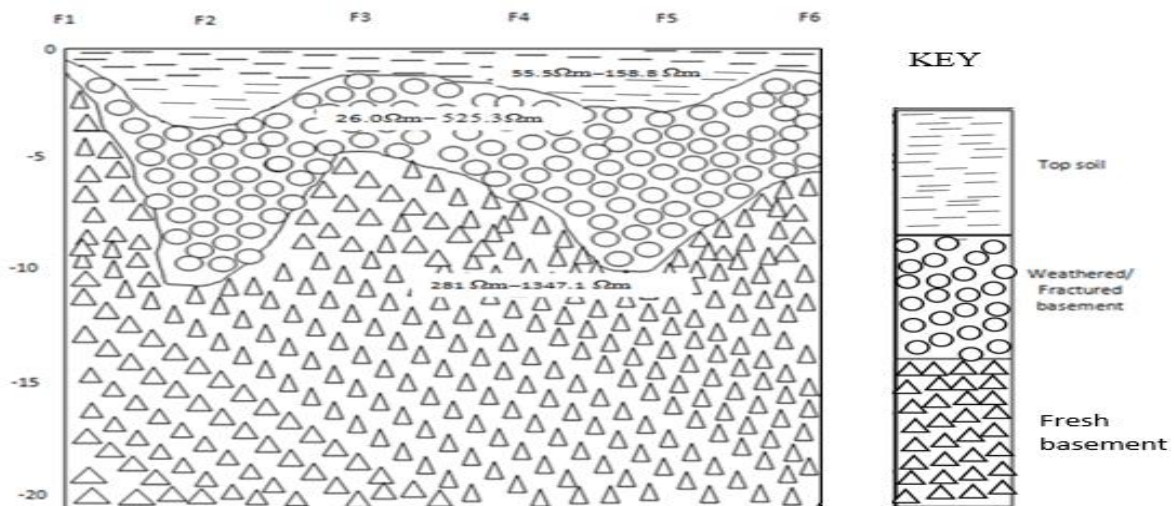


Figure 16: Vertical geologic section through profile F

Table 2: Delineated Aquifer Potentials of the Study Area

Table 2 contains the VES points delineated as aquifer potential of the study area, the resistivity, depth and thickness of these VES point.

VES Station	Latitude (°)	Longitude (°)	No. of Layers	Layer Resistivity ρ (Ω m)			Layer Depth (m)			Layer Thickness (m)			Curve Type
				ρ_1	ρ_2	ρ_3	d_1	d_2	d_3	h_1	h_2	h_3	
A ₃	12.14122762	6.726644284	3	40.5	67.9	2166.9	1.0	20.3	∞	1.0	19.3	∞	A
A ₄	12.14123285	6.727539861	3	28.1	58.6	1399.2	0.5	17.1	∞	0.5	16.6	∞	A
B ₄	12.14029014	6.727539861	3	51.8	121.1	785.4	0.4	20.8	∞	0.4	20.4	∞	A
C ₃	12.13937885	6.726661567	3	276.0	60.1	876.3	0.5	16.4	∞	0.5	15.8	∞	H
E ₂	12.1375567	6.725717282	3	16.0	81.4	278.6	1.3	7.9	∞	1.3	6.6	∞	A
F ₂	12.13666488	6.725717282	3	91.7	44.3	1121.4	3.4	10.4	∞	3.4	7.0	∞	H
F ₅	12.13666488	6.728487812	3	97.6	37.4	281.0	2.1	9.1	∞	2.1	7.0	∞	H

5.0 CONCLUSION

The VES results depict two distinct curve types namely; H-type and A-type. The results also reveal three distinct geoelectric layers: the top layer, weathered/fractured layer and fresh basement. The top layer has resistivity, depth and thickness range of 10.4 – 158.8 Ω m, 0.4 – 3.6 m and 0.4 – 3.6 m respectively. The second layer has ranges of: resistivity, 6.3 – 525.3 Ω m; depth, 1.4 – 20.8 m, and thickness, 1.0 – 20.4 m. The third layer has resistivity values range of 278.6 – 2726.5 Ω m, its depth and thickness are not defined (to infinity). Seven VES stations (A₃, A₄, B₄, C₃, E₂, F₂ and F₅) were delineated for groundwater potential having weathered/fractured resistivity varying between 37.4 and 121.1 Ω m. Depths range were found from 7.9 – 20.8 m and thickness varying between 6.6 and 20.4 m. The results of the study implies that the area has a good groundwater potentials.

REFERENCES

- Akinrinade, O. J., and Adesina, R. B. (2016). Hydrogeophysical investigation of groundwater potential and aquifer vulnerability prediction in Basement complex terrain – a case study from Akure, southwestern Nigeria. *RMZ-M G* 63, 55–66. doi: 10.1515/rmzmag-2016-0005.
- Adagunodo, T. A., Adeniji, A. A., Erinle, A. V., Akinwumi, S. A., Adewoyin, O. O., Joel, E. S., (2017). Geophysical investigation into the integrity of a reclaimed open dumsite for civil engineering purpose. *Interciencia Journal* 42,24–339.

- Adesunloro, Gbenga Michael, Olumodeji Ibukun I. and Itakorode O. Daniel (2022) Geoelectrical investigation of ground water potential using vertical electrical sounding. *World Journal of Advanced Research and Reviews*, 2022, 15(02), 322–329.

- Akindeji Opeyemi Fajana (2020). Groundwater aquifer potential using electrical resistivity method and porosity calculation: a case study AyedunEkiti, Southwestern .

- Ejepu, S.J., Adebowale, T.A, Abdullahi, D.S., Yusuf, A. &Ochimana K. (2014). Subsurface Structural Mapping for Groundwater Resource Development of a Part of Tudun-Fulani North-Central Nigeria Using Radial Vertical Electrical Sounding Techniques. *International journal of engineering sciences &*

- Loke, M.H., 2011. *Electrical resistivity surveys and data interpretation*. in Gupta, H (ed.), *Solid Earth Geophysics Encyclopaedia* (2nd Edition) “Electrical and Electromagnetic” Springer-Verlag, 276-283.

- Sunday, A. and Usman, A. (2021). Investigation of groundwater potential zones using electrical resistivity method in mubi south local government area of adamawa state, north eastern Nigeria. *International Journal of Physical Sciences Research* Vol.5, No.1, pp.10-20, 2021.