IOSR Journal of Applied Physics (IOSR-JAP)
e-ISSN: 2278-4861.Volume 14, Issue 2 Ser. I (Mar. – Apr. 2022), PP 06-15
www.iosrjournals.org

Evaluation of Groundwater Potential Using Electrical Sounding Technique at the General Hospital Wudil, Kano State, Nigeria

Abubakar Maitama Yusuf Hotoro[1]
Department Of Physics, Kano University Of Science And Technology Wudil

Auwal Alhassan[2]
Department Of Integrated Sciences, Jigawa State College Of Education Gumel, Jigawa State, Nigeria

Mudassir Umar Ali[3]
Department Of Physics, Kano University of Science And Technology Wudil

Abstract
The study was intended to identify an aquifer zones with a view to attending to the challenges of fresh water scarcity around the study area. Twenty (20) Vertical Electrical Sounding (VES) field data using Schlumberger array were obtained with maximum current electrode spread of 150m using ABEM Terameter SAS 1000 in order to evaluate the groundwater potential of Wudil General Hospital. The Data acquired were analyzed using IPI2win Computer Software. Several geo-electric curve types were identified with HK curve type being the most dominant, accounting for 65% of the total curve types of the study area. Four geo-electric layers were identified. The results of the interpretation has grouped the Aquifers of the study area, based on their thickness, into Good, Moderate and Bad Aquifer; The Good aquifer occurred at VES1, VES 10, VES 13, VES 15, VES 16, VES 17, and VES 18, while Moderate aquifers are at VES 3, VES 4, VES 5, & VES 8. The Bad aquifers occurred at VES 2, VES 6, VES 7, VES 9, VES 11, VES 12, VES 14, VES 19 and VES 20. The resistivity values for Good and moderate Aquifers range from 23.7Ωm at VES1 to 464Ωm at VES 13 and that of Bad aquifers zone's resistivities range from 4.98Ωm at VES11 to 118Ωm at VES7. The Transverse Resistance (T) values for the Good and Moderate aquifers zone in the study area were obtained to be in the range of 730.439Ω to 15843.15Ω. The Good and Moderate Aquifers has Longitudinal Conductance (LC) ranging from 0.07784 to 1.17020, while the Bad aquifers range from 0.166853Ω^{1} to 2.12649Ω^{1}. The study suggests that the Good aquifers regions of the study have sufficient groundwater for exploration. These are identified at VES 1, VES 10, VES 13, VES 15, VES 16, VES 17 and VES 18 for the drilling borehole in order to meet the increasing demand of water supply in the study area.

Key words: *Vertical Electrical Sounding, Aquifer, weathered, Fracture Schlumberger Array.*

Date of Submission: 01-03-2022 Date of Acceptance: 11-03-2022

I. Introduction

Water is one of the components of the environment. It is important for all forms of life. Developments of many societies are due to the availability and use of adequate water supply. This component of the environment is sometimes scarce and hence the need for an alternative source is eminent. Surface water resources are the main source for freshwater even though not they are not evenly distributed everywhere in the environment which therefore causes discrepancies in terms of supply for both domestic and industrial purposes. Therefore, we need to also search for additional groundwater resources which are hidden underneath the ground surface to classically supplement the surface sources in order fulfill the growing demands for water supply to the entire population across the globe.

Resistivity Method has been the most applied method to detect the groundwater potential (Molua *et al.*, 2005). This is because the operation of the field instrument is uncomplicated and the analysis of data is easy and economical. Others methods like seismic refraction, electromagnetic, gravity, magnetic and magneto telluric may be too complicated required an experience data interpreter. The choice of method used depends largely on the depth of investigation and sometimes cost (Issah, 2017). Schlumberger Array was used for the present study because of its advantages over other methods and arrays. The study was aimed to employment the Vertical Electrical Sounding (VES) method to evaluate the groundwater potential at the General Hospital Wudil, Local

Government of Kano State, thereby identifying the depth, thickness and resistivity of the Aquifers of the study area and determine areas that are suitable for borehole construction

1.2 The Study Area

The study area (Figure 1) is at Wudil Local Government Area which is situated in the Southern Senatorial District of Kano State, Nigeria with an estimated Land Area of 458km^2 and Population of about 190,189 (Census, 2006). It is located between Longitude of 8^{0}45'E and 8^{0}57'E and between Latitude of 11^{0}37'N and 11^{0}56'N. Figure 1 shows the Map of the study Area. It shares its western boundary with Warawa LGA to the northwest and Dawakin kudu LGA to the southwest. It is bounded to the South and South east by Garko LGA and on the East by Albasu LGA (southeast), Gaya (east) and Ajingi, northeast. The study was held at General Hospital Wudil, the people living in this area used the water for domestic purpose such as washing, drinking, bathing and other purpose.

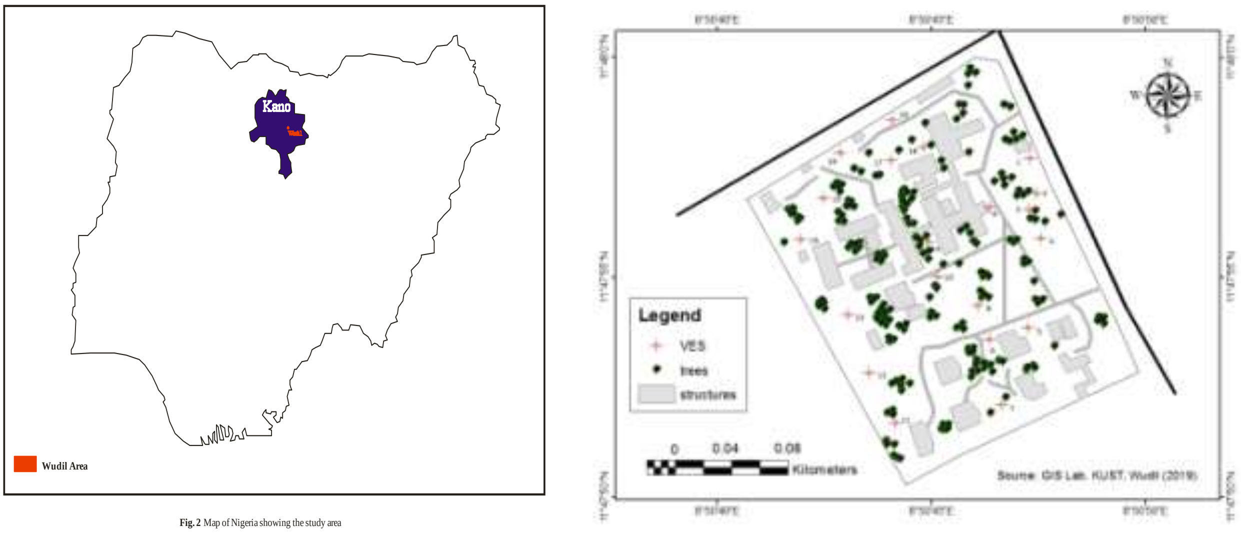


Fig. 2 Map of Nigeria showing the study area

Figure 1: Maps Showing the Study Area (Source: GIS Lab. KUST, Wudil, 2021)

1.3 **Geology and Hydrogeology of the Study Area**

Hazell *et al*., (1988) report the existence of rocks of younger granites series in the study area. Kano Agricultural and Rural Development Authority KNARDA (1989) identifies the individual members of the older granite suite, but rocks of the younger metasediments and those of the migmatite – gneiss complex were simply grouped as the migmatite gneiss complex in many places. Three most dominant Groups of rocks namely, Migmatites, gneisses derived from Birrimain Sedimentary rocks through high grade metamorphism and granitization exist in northern part of Nigerian basements (Yusuf *et al*., 2012). Hotoro, (2016) Reports that there are two main distinct hydrogeologic aquifer units in Kano; the crystalline basement unit and unconsolidated sediments of Chad formation. Groundwater in the basement rocks is found where the rocks have been significantly weathered or in underlying fracture zones. On the other hand, groundwater in the Chad formation is found within sands and gravels. However, the availability of groundwater in the study area depends largely on the geology, even though recharge to aquifers is very important in determining sustainable groundwater exploration. Generally groundwater in Kano occurs in top few meters of weathered and fractured basement and the aquifer system is characterized by thickness ranging from 10m to 45m.

II. Materials and Methods

Groundwater evaluation was carried out at General Hospital Wudil from November, 2021 to December, 2021 at the beginning of the Winter Period in Kano. The Schlumberger array was applied using the ABEM Terameter SAS1000, Coiled wire, Tape, Hammer, GPS meter, Current and potential electrodes, and Car Battery to acquire the field data. Finally, the acquired results were interpreted using computer software named IPI2win.

2.1 Application of Electrical Resistivity for Groundwater

Geophysical methods were employed to assess and monitor geophysical properties that were extremely useful, as they are non-invasive, easier and cheaper to perform than drilling many sampling wells and are faster in operation. One of the commonly used geophysical methods in geophysics investigations is the Electrical

Resistivity method (Telford *et al.*, 1990; Reynolds, 1997). The main application or essence of applying geo-electric survey is to quantify the resistivity values of the rook based on the measurement at the surface and the actual resistivity value can be obtained from the measured value. Temenu *et al.*,(2019) used Wenner - Schlumberger VES to determine the average resistivity and thickness of the first layer, second, third and fifth and suggest that the potential groundwater would likely be located in the fourth layer, thus determining effective places to drill observation wells. VES is also very useful in determining risk assessment of aquifers

2.2 Schlumberger Array

The Schlumberger array (Figure 2) is one of type of configuration for Vertical Electrical Sounding (VES). Electrical sounding is the process by which the variation of resistivity with depth below a given point on the ground surface is deduced and it can be correlated with the available geological information in order to infer the depths (or thicknesses) and resistivity of the layers (formations) present. The procedure is based on the fact that the current penetrates continuously deeper with the increasing separation of the current electrodes.

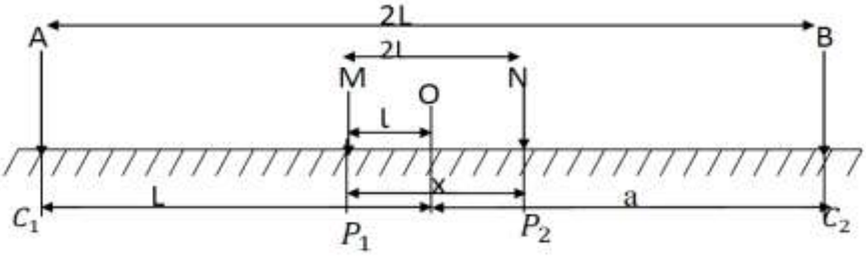


Figure 2: Showing Schlumberger array

In Schlumberger array, the current electrodes, C_1 and C_2, are spaced much further apart than the potential electrodes, P_1 and P_2. The potential electrodes remain fixed while the current electrodes are expanded symmetrically about the centre of the spread.

Where;

P_1 and P_2= Potential electrodes; C_1 and C_2 = Current electrodes; AB = Current electrodes Spacing = 2L; L = AB/2; MN = Potential Electrodes Spacing = 2l; l = MN/2 and O = sounding point. Equation (1) gives the measured resistivity value

$$\rho = \frac{KV}{I} \qquad (1)$$

K is the geometric factor and only a function of the geometry of the electrode arrangement. Resistivity can be found from measuring values of V, I and K.

$$\rho = KR \qquad (2)$$

Where:

ρ= apparent resistivity and

K= is the geometric factor and only a function of the geometry of the electrode arrangement (Schlumberger array)

2.3 Data Acquisition

Information was acquired from the field using the tools discussed on section 2.2 above using the Schlumberger array method. The current **I** is applied at points **A** and **B** via **C_1** and **C_2** current electrodes and the potential **ΔV** is measured between **M** and **N** through **P_1**and **P_2** potential electrodes. A mathematical model is generated for each configuration type with parameter as current **I**, differential potential geometric factor **K** for the calculation of apparent resistivity of the earth material in the subsurface. This stage however worked with a crew of five; two manning the two current electrodes, two manning the potential electrodes and one person operating the Terameter. Electrical resistivity data are difficult to interpret quantitatively especially in the absence of any other geophysical and geological information from same area. However, mathematical analysis and calculation models for the calculation of structure with varying resistivity and thickness is very well developed and utilized for quantitative interpretation but because of the realities of inhomogeneities of the subsurface, the value obtained from the model system is either apparent or ambiguous. For this reason we use the geometric factor for Schlumberger array to multiply the observable values obtained from the Terameter unit during the data acquisition. In general, the apparent resistivity values are plotted against spacing. For Vertical Electrical Sounding, the spacing is half the current electrode spacing and both. From the plot, the points are joined gradually to produce a smooth field curve.To solve the problem of ambiguity caused by the natural variability of surface soil and rock and by instrument capabilities the interpreter must compute at VES curve for the interpreted section and compare it with the field curve. These curve obtained are interpreted by partial or complete curve matching. The process involves the matching of sounding curves using resistivity model curve, which could be master curve and a corresponding auxiliary curve. These are curve that are plotted in logarimithic scale both vertically and horizontally, and are normalized by plotting the ratio of apparent resistivity to the layer resistivity ($\frac{\rho}{\rho a}$) first layer thickness ($\frac{a}{dl}$). For vertical electrical sounding, the types of curves usually identified are the A, K, H and Q etc. type curves. The **A**-type curve known as the rising curve indicates the continuous rising in resistivity value across the formation with depth. The **Q**-type curve, which is the decreasing curve, indicates the continuous decrease in resistivity value across the formation depth. The **H**-type curve denotes an initial decrease and a later increase in resistivity value across the layer with depth. While the **K**-type curve denotes initial increase and later decrease in resistivity value. Moreover, we can have a combination of two or more curves during sounding. The results that will be obtained from the interpretation will be uploaded into the computer for further iteration. This computer will then generates a final curve from these parameters, which help in preparing the geo-electric section of the subsurface layer and as well as pseudo sections. Figure 3 shows diagrams illustrating the various forms of curves. Moreover, we might have a combination of two curves or more during sounding.

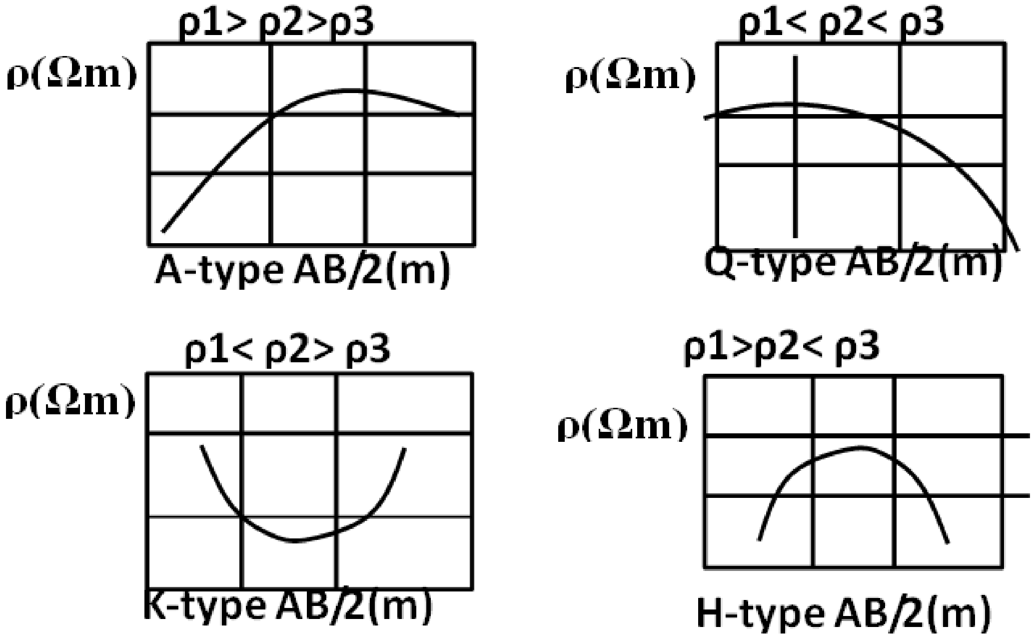
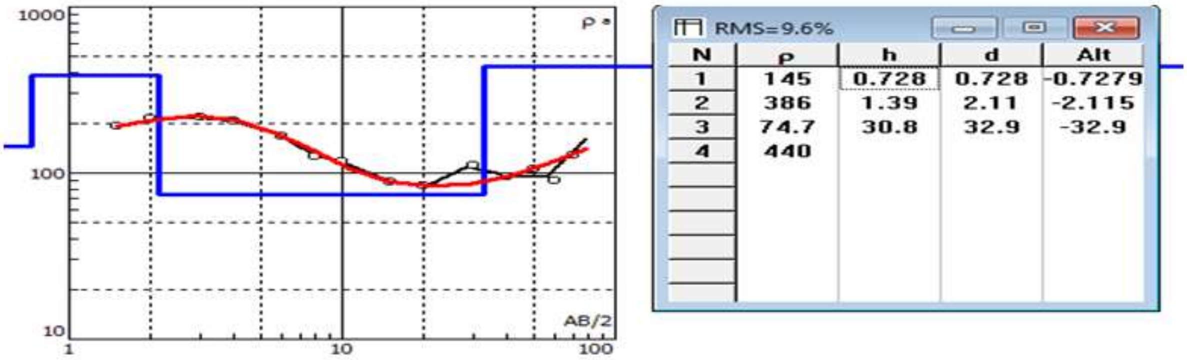


Figure 3: Major Curve Types

III. Results and Discussion

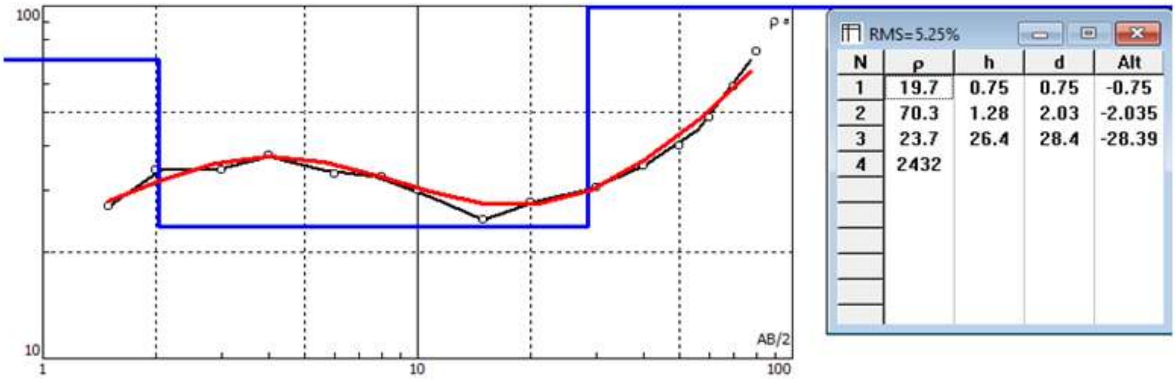
Figure 3 & Figure 4 are typical curves with layered resistivity models produced from the interpretation of the sounding data for VES18 and VES1 respectively. And the field curves are generally made up of Four (4) geologic sections and curve types are KH, HK, HA, & QH. The results for Data interpretation for the Twenty (20) Vertical Electrical Soundings are presented in Table 1 below.



RMS=9.6%

N	ρ	h	d	Alt
1	145	0.728	0.728	-0.7279
2	386	1.39	2.11	-2.115
3	74.7	30.8	32.9	-32.9
4	440			

Figure 3: Curve for VES18



RMS=5.25%

N	ρ	h	d	Alt
1	19.7	0.75	0.75	-0.75
2	70.3	1.28	2.03	-2.035
3	23.7	26.4	28.4	-28.39
4	2432			

Figure 4: Curve for VES1

Table 1: Layer resistivity, thickness and curve type

VES NO	Layer	Resistivity(Ωm)	Thickness(m)	Depth(m)	Curve type
VES01	1	19.7	0.75	0.75	**KH**
	2	70.3	1.28	2.03	
	3	23.7	26.4	28.4	
	4	2432			
VES02	1	22.7	1.79	1.79	**KH**
	2	28.6	13.3	15.1	
	3	12.6	8.78	23.9	
	4	2199			
VES03	1	23.9	0.73	0.73	**KH**
	2	8619	0.29	1.02	
	3	75.4	10.2	11.3	
	4	27609			
VES04	1	24.5	0.75	0.75	**KH**
	2	1144	1.44	2.19	
	3	131	16.70	18.9	
	4	27609			
VES05	1	56.2	0.75	0.75	**KH**

VES NO	Layer	Resistivity(Ωm)	Thickness(m)	Depth(m)	Curve type
	2	1284	0.83	1.58	
	3	130	19.9	21.5	
	4	38661			
VES06	1	31.8	0.75	0.75	**KH**
	2	2831	1.85	1.80	
	3	25.5	4.6	6.39	
	4	46250			
VES07	1	105	3.20	3.20	**HK**
	2	23.2	8.59	11.8	
	3	118	9.63	21.4	
	4	0.08			
VES08	1	81	1.15	1.15	**KH**
	2	446	0.80	1.94	
	3	67.9	19.7	21.7	
	4	27609			
VES09	1	55.8	2.46	2.46	**KH**
	2	1406	2.61	5.07	
	3	23.2	8.48	13.5	
	4	26085			
VES10	1	105	1.11	1.11	**HA**
	2	23.5	0.54	1.65	
	3	140	39.8	41.5	
	4	32069			
VES11	1	95.5	0.75	0.75	**QH**
	2	38.2	13.2	13.2	
	3	4.98	8.83	8.83	
	4	6685			
VES12	1	83.6	1.6	1.6	**KH**
	2	1598	2.42	4.02	
	3	58.9	8.7	12.7	
	4	45386			
VES13	1	386	1.34	1.34	**HA**
	2	179	4.4	5.74	
	3	464	23.1	28.8	
	4	51599			
VES14	1	83.5	1.6	1.6	**KH**
	2	1625	2.37	3.96	
	3	58.4	8.54	12.5	
	4	45386			

VES NO	Layer	Resistivity(Ωm)	Thickness(m)	Depth(m)	Curve type
VES15	1	23	0.75	0.75	**KQ**
	2	3662	0.65	1.4	
	3	196	68.6	70	
	4	4.15			
VES16	1	36.6	0.75	0.75	**KQ**
	2	908	0.99	1.74	
	3	114	32.6	34.3	
	4	0.28			
VES17	1	129	1.24	1.24	**HK**
	2	69.1	5.81	7.05	
	3	126	20.7	27.7	
	4	7.64			
VES18	1	145	0.73	0.73	**KH**
	2	386	1.39	2.11	
	3	74.7	30.8	32.9	
	4	440			
VES19	1	84.6	1.67	1.67	**KH**
	2	1677	2.63	4.29	
	3	47.6	8.74	13	
	4	45386			
VES20	1	35.1	0.75	0.75	**KH**
	2	2089	0.74	7.36	
	3	15.6	4.59	6.08	
	4	336			

3.1 Discussion

The models for the apparent resistivity of each sounding point displayed by IPI2win software were used to produce the geo-electric pseudo section in Figure 5, Figure 6 and Figure 7. The relevant geologic and resistivity values for rocks in the study areas were used as guide for the interpretation of the field data.

From the results of the interpretation, the study area is generally considered to be four layers. The third layers constitutes the weathered zone, which has resistivity range from 12.6Ωm to 179Ωm and its layer thickness varies between 8.78m to 30.8m, it depth varies from 23.9m to 32.9m. Thus the third layer will be good enough for groundwater exploration. Therefore, study considered VES 8, VES10, VES15, VES16 and VES18 as having very good features for groundwater exploration. However, the existing Boreholes close to the VES1, VES2, and VES5 respectively, were found to be ineffective, perhaps as a result of poor design and construction and or lack of good maintenance.

It will also be important to consider the overburden thickness because it play role in groundwater development in the basement terrain, because water get into the saturated zone through the overburden, the thickness of the overburden range from 0.75m to 3.2m in the study area.

The weathered zone beneath VES 15 has the highest thickness of about 68m and VES 4 having the lowest thickness 4.6m which was interpreted as poorest aquifer of the study area. Thus the thickness of the weathered layer for the study area is high enough to form groundwater accumulation and therefore recommended for a borehole sitting.

The weathered zone (aquifer zone) was classified based on their thicknesses in to three namely Good, Moderate and Bad aquifer. The good aquifers are the potential water-bearing zone and have aquifer thickness greater than 20m. The moderate aquifers have thickness values ranging from 10 to 20m. While, the Bad aquifer zones have aquifer thickness less than 10m, and are classified as Bad potential water-bearing zone. The Good aquifer occurred at VES 1, 10, 13, 15, 16, 17, & 18, Moderate aquifers at VES3, VES4, VES5, & VES8, and Bad aquifers at VES2, VES6, VES7, VES9, VES11, VES VES12, VES14, VES19 & VES20 which are the majority of the VES stations. Therefore, location of VES2, VES6, VES7, VES9, VES11, VES12, VES14, VES19, & VES20 are not recommended for groundwater exploration. The Resistivity Pseudo-Sections for the Twenty (20) VES stations are presented in Figure 5, Figure 6 and Figure 7

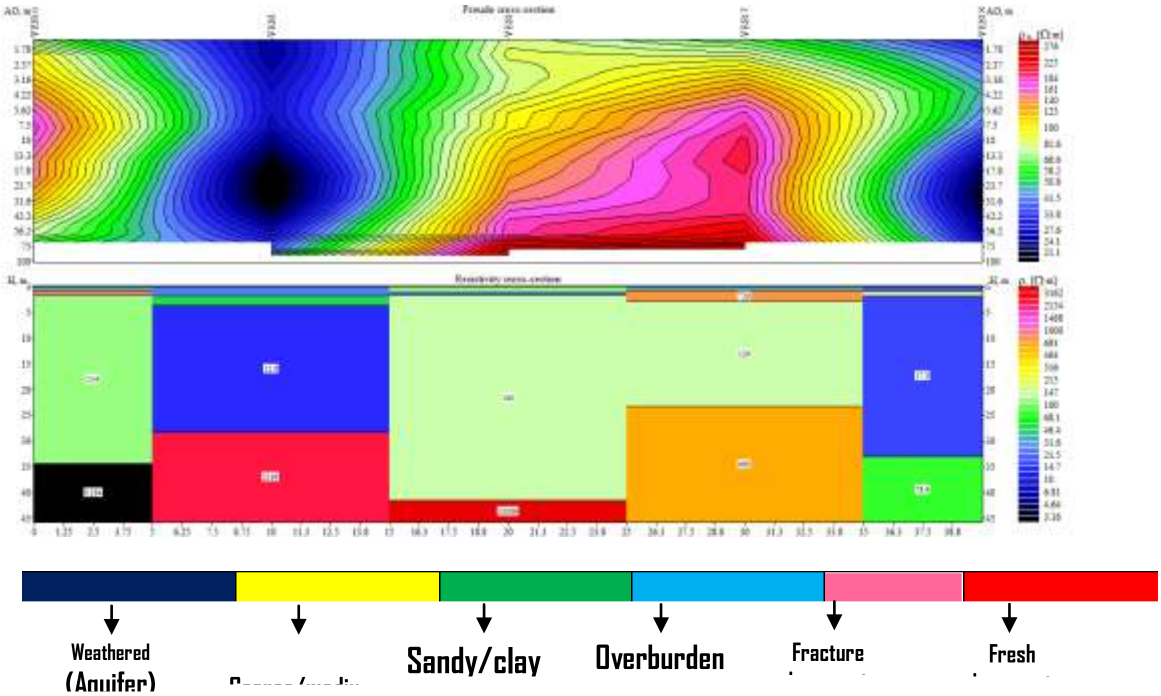


Figure 5: Resistivity Pseudo Cross Section and 2D inverse model for VES (16, 1, 10, 17 & 8).

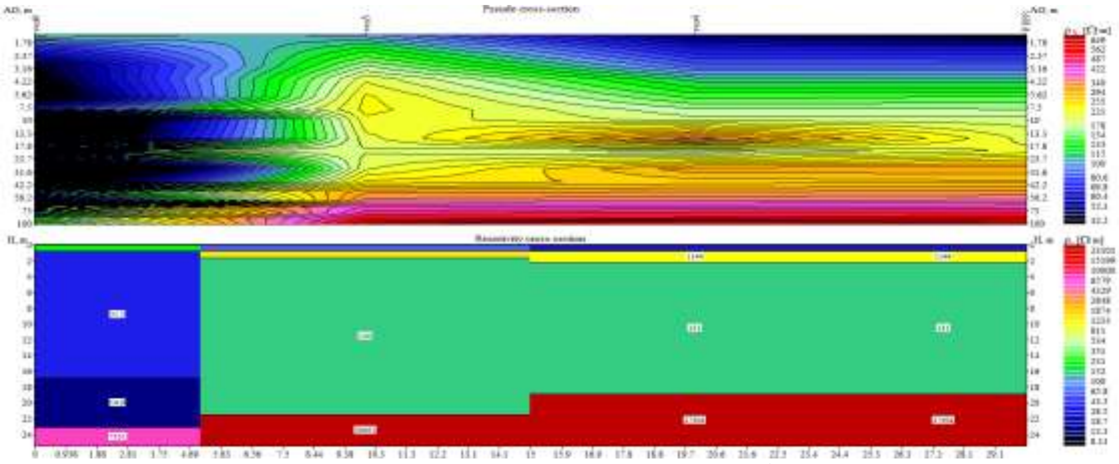


Figure 6: Resistivity pseudo section and 2D inverse model for VES (, 4, 5, & 8).

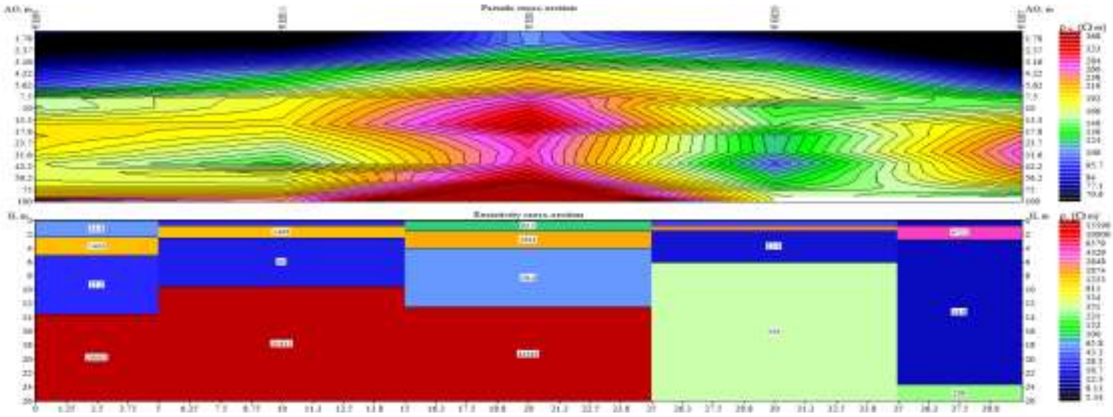


Figure 7: Resistivity pseudo section and 2D inverse model for
VES (9, 11, 12, 14, 20, & 2)

3.2.1 Total Transverse Resistance

Total transverse resistance denoted (T), has a direct relation with transmissivity of the aquifer such that the higher the value of T, the higher is the transmissivity of the aquifer zone and vice versa (Kumar, 2001). The total transverse resistance (T) for the VES stations that were considered aquifers is computed using the equation below:

$$T=\Sigma\ h_i\rho_i$$

Where h_i is the thickness of the i^{th} layer and ρ_i is the resistivity of the i^{th} layer

3. 2.2 Total Longitudinal Conductance (LC)

High values of LC usually indicate relatively thick succession and should be accorded high priority in terms of groundwater potential and vice-versa (Anudu*et al.*, 2011). Longitudinal conductance can be expressed as $LC=\Sigma\ (h_i/\rho_i)$ where h_i also is the thickness of the i^{th} layer and ρ_i is the resistivity of the i^{th} layer. The values of LC for the aquifer zones were also computed for VES points in the study area.

IV. Conclusions

The study has identified and determined the aquifers resistivities, thicknesses, and depth. Similarly, the transverse resistance and longitudinal conductance of VES points were also determined which further gave additional information on the water-bearing zones of the study area. All the VES points are generally four layers. In all the VES points, the third layers constitutes the weathered zone, which has resistivity range from 12.6*Ω*m to 179*Ω*m and its layer thickness varies between 20m to 68m, its depth varies from 23.9m to 32.9m. Thus the third layer will be good enough for groundwater exploration. Therefore, study considered VES1, VES10, VES13, VES15, VES16, VES17 and VES18 as having very good features for groundwater exploration.

V. Recommendations

The study will serve as guide to update groundwater information of the study area for those whose responsibility is the provision of safe drinking water to the general population of the area. The study may be expanded to also determine the Groundwater Quality, assessment of `factors resulting to the ineffective boreholes around the present study area.

Acknowledgements

We acknowledged and appreciate the Management of Tertiary Education Trust Fund (TETFund) for the financial support to undertake this research, under the Institutional Base Research (IBR) Grant (TETF/DR&D/UNI/WUDIL/RG/2018/VOL.I), that is targeted towards proving solution to the cute water shortage in the study area. Also, our gratitude goes to the Management of Kano University of Science and Technology, Wudil, Technical staff of the Departments of physics of Kano University of Science and Technology, Wudil and Bayero University Kano for proving the technical assistant during field data acquisition and to all co- researchers for their objective criticism of the study.

References

[1]. Abubakar Y. Ismail, A and Lawal Y. (2012). Geoelectrical Investigation of Groundwater Potential of Dawakin Tofa Local Government Area of Kano State Nigeria; American International Journal of Contemporary Research Vol. 2 No.9; September 2012, pp 1-10

[2]. Abdulazeez Issah (2017). Geoelectrical Investigation using Vertical Electrical Sounding at Male Student's Hostel Isa Kaita College of Education Dutsinma, Katsina State; Undergraduate Student Project Department of Physics Federal University Dutsinma.

[3]. Anudu, G.K., Onuba, L.N. and Ufondu, L. S. (2011). Geoelectric Soundings for Groundwater Exploration in the Crystalline Basement Terrain Around Onipe and Adjoining Areas, Southwestern Nigeria. *Journal of Applied Technology in Environmrental Sanitation, 1* (4), 343-354.

[4]. Hotoro M. Abubakar, (2016). Integrated Remote Sensing and Geophysical Technique in the Assessment of Groundwater Potentials of Northeastern part of Kano State, Northern Nigeria; unpublished PhD Thesis, Department Physics Ahmadu Bello University Zaria

[5]. Hazell J.R.T, Cratchley C.R, Preston A.M (1988). The Location of Aquifers in Crystalline Rocks and Alluvium in Northern Nigeria using Combined Electromagnetic And Resistivity Techniques. Q. J. Eng. Geol., 21:159 175.

[6]. Kano State Agricultural and Rural Development Authority, KNARDA (1989). Rural Water Supply Project, Vol. II, Summary of Hydrogeological Data of Kano State. Final Report, WARDROP Engineering Inc. Pp24

[7]. Kumar, S. A. (2001). Identification of Aquifer Zones by VES Method: A case study from Mangalore Block, Tamil Nadu, S.India. *Scholars Researchers Library, 3* (2), 414-421.

[8]. Molua, O.C. And J.U. Emabetere (2005). Determination of Water Table Using Electrical Sounding Technique; A Case Study of Afuze, Edo State, Nigeria, Journal Nigeria Association of Mathematics And Physics.5; 457- 464.

[9]. Reynolds, J. (1997). *An Introduction to Applied Environmental Geophysics*. New York: Wiley.

[10]. Temenu F. (2019), Investigation of ground water capacity of Okada and its Environs using Electrical Resistivity Method in Aquifer potential map; 42nd Nigerian institution of physics Annual Conference paper.

[11]. Telford, W. G. Geldart, L.P., Sheriff, R. E. and Keys, D. A. (1990). *Applied geophysics.* England: Cambridge University Press.

Abubakar Maitama Yusuf Hotoro, et. al. "Evaluation of Groundwater Potential Using Electrical Sounding Technique at the General Hospital Wudil, Kano State, Nigeria." *IOSR Journal of Applied Physics (IOSR-JAP)*, 14(02), 2022, pp. 06-15.