

Vertical Electrical Sounding (VES) for the Appraisal of Groundwater at Senior Staff Quarters B Federal University of Kashere, Gombe.

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Abstract

Insufficient and poor quality of water for domestic use is a common challenge in Federal University of Kashere (with only few existing boreholes). Increase in population increases demand for quality water. This research was carried out to locate the most suitable locations for the drilling of productive boreholes for quality drinking water within the study area. Vertical Electrical Sounding (VES), using Schlumberger array was carried out to investigate the subsurface layer parameters of area. Federal University of Kashere which is under Akko Local Government Area of Gombe State, North East Nigeria. It lies between Longitude; 09°57'00"E and 10°0'00"E and Latitudes; 11°06'00"N and 11°09'02"N and covers an area of about 25Km². A total of 24 VES points at 100m interval where sounded with a 100m maximum half inter current electrode spacing ($ab/2$). Result revealed that the study area is underlain by five (5) geoelectric layers. The second layer with resistivity value of 5281.5 Ωm , thickness of 0.4m and depth of 2.4m is the Fresh basement/Gravel basement. The layer will accommodate more fresh water.

Keywords: Ground water, resistivity, lithology, Vertical electrical sounding

Introduction

Groundwater is the water located under the ground surface in the fracture of lithologic formation. A unit of rock or unconsolidated deposit is called an aquifer when it can yield a usable quality of water (Anomohanran, 2011). Groundwater plays a fundamental role in human life. Despite its indispensable characteristics, it is unfortunate that groundwater is often associated with low yield. The expanding demand for water and the cost involved in drilling boreholes therefore require the application and the proper

use of groundwater investigation techniques to locate high yielding aquifers (Riyawat, 2018). Groundwater has become immensely important for different water supply purposes in urban and rural areas of both the developed and developing countries. Though there are other sources of water; streams, rivers ponds, etc., none is as hygienic as groundwater because groundwater has an excellent natural microbiological quality and generally adequate chemical quality for most uses. Exploration of groundwater in hard rock terrain is a very challenging and difficult task, if the promising groundwater zones are associated with fractured and fissured media. In such an environment, the groundwater potentiality depends mainly on the thickness of the weathered/ fractured layer overlying the basement. Most groundwater projects recorded in basement complex aquifers have revealed geophysical survey as a compulsory prerequisite to any successful water well drilling project.

The electrical resistivity is a geophysical method which involves the vertical electrical sounding (VES). Current is injected into the ground and the resistivity of the soil is been recorded to infer about other lithological properties. It was is applied extensively in environmental, groundwater and engineering geophysical investigations (Ayodele, 2021). Electrical sounding gives information on water bearing structures and easily determine the vertical variation of the earth electrical properties which can be related to the geology of the area (Sani, Killian, Usman, & Sale, 2020).

exploration The electrical resistivity technique have been used in a wide range of geophysical investigations such as mineral exploration, engineering studies, geothermal exploration, archeological investigations, permafrost mapping and geological mapping. Using this method, depth and thickness of capabilities can be inferred (Rao,G.Venkata; Kalpana,P; Rao, R. Srinivasa,, 2014) .Electrical resistivity method has been used by researchers to successfully map geologic structures for ground water monitoring (Sani *et al.*.,2020; Rao*et al.*, 2014; Raji, 2014; Zainab*et al.*, 2012; Ayodele, 2021).

Insufficient and poor quality of water for tedious usage has been an enormous challenge over a year in Federal University of Kashere (with only few numbers of existing boreholes). High population increase brought about by development has led to high demands for water over the years. Hence, there is need to carry out comprehensive geophysical investigation for groundwater prospecting in order to explore and exploit

the groundwater potentials in the area. This will help to locate the most suitable locations for the drilling of productive boreholes within the study area that will help to ameliorate the problem.

This research focuses on detailed geophysical investigations in order to delineate the groundwater potential zones in the study area which will help the borehole drilling companies as well as concern government authorities in citing a productive borehole in an appropriate location in the study area. Also, the research will help to tackle the problem of drilling abortive boreholes which may be due to the lack of understanding of the aquifer geometry. Moreover, the knowledge of aquifer protective capacity will help to understand whether the subsurface lithological units have good protection capacity to protect the aquifer systems from surface water contamination in the study area or otherwise, this will also help to suggest the mitigation measures to eliminate such problems if observed from the synthesis of the research analyzed data.

The study area

Federal University of Kashere is situated in Kashere town, Akko Local Government Area of Gombe State, Nigeria. It lies between Longitude; 09°57'00"E and 10°0'00"E and Latitudes; 11°06'00"N and 11°09'020"N and covers an area of about 25Km². The study area is located within the Gongola arm of northeastern Nigeria.

Gombe state is underlain by two major lithological units that comprises of the crystalline basement rocks that out crops as an inlier towards the southern part of the state, around Billiri and Kaltungo areas and within Gombe town as 'Gombe inlier' (this covers 2% of the state lithology), whereas, the remaining part is covered by the cretaceous sedimentary rocks (98% of the state) this comprises of Bima sandstones (covers; 31.1%), Yolde formation (10.5%), Pindiga Formation (9.9%), Gombe Formation (10.3%), Keri-Keri Formation (34.2%) and Alluvium (1.2%). From hydrogeological point of view, the stratigraphic sequence in Gombe is provided by (Lovelyn, 2016) in table 1. The hydrogeology of Gombe State can be discussed under the two main environment; the crystalline and sedimentary environment. Crystalline has 3 to 4 zones, dominantly composed of top soil, weathered, fractured, and fresh crystalline basement rocks, with the weathered, and fractured parts being zones in the set up (Dike, 1995)

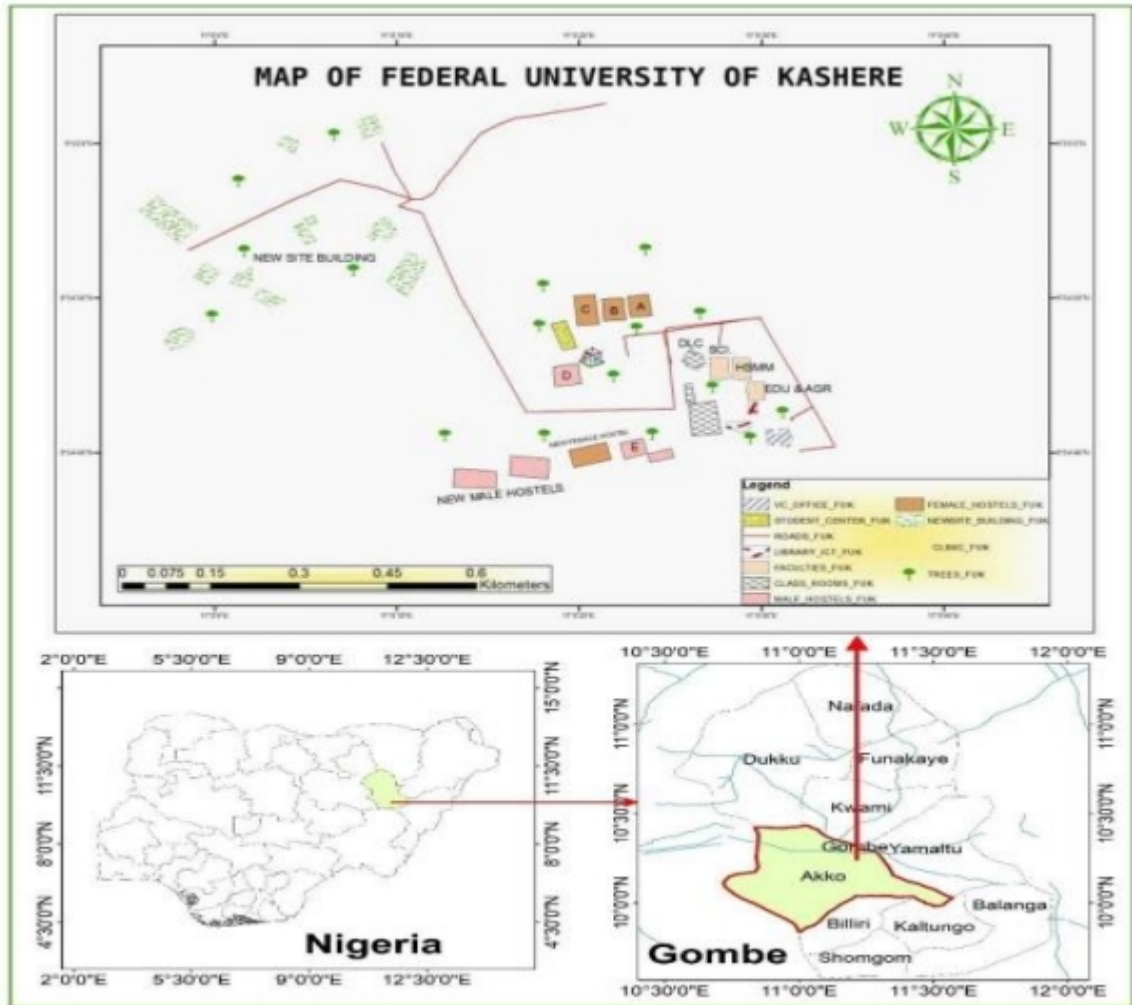


Figure 1: Map of the study area.

Table 1: Lithology and storage of formations in Gombe state adopted from (Lovelyn, 2016)

S/No	Formation	Lithology	Storage
1	Keri-Keri	Mainly silt, sandy clay and sandstones	Deep layer aquifer
2	Gombe	Sandstones, Siltstone, Clay and iron Stone	Aquifer-Aquiluides
3	Pindiga	Shale with limestone	
4	Yolde	Shaly clay, Sandstones	Aquifer
5	Bima	Medium to coarse grained feldsparitic sandstone	Aquifer
6	Basement	Granite, Gneiss	Weathered, Fracturedzone

METHODOLOGY

The materials used for this survey include Terrameter, Handheld Global Positioning System (GPS) device, Measuring tapes, Electrodes, Cable Reels, Ribbons, Pegs, Hammer.

The Terrameter Signal Averaging System (SAS) model 4000 and its accessories were used to carry out the vertical electrical sounding (VES). The inter traverse and inter VES point spacing were 100 m and the Schlumberger array pattern with half inter electrode spacing ($AB/2$) ranging from 1-100 m was adopted. Through a pair of current electrodes A and B, direct current (DC) was supplied into the ground and the potential difference was measured by means of another pair of electrodes M and N called the potential electrodes. To increase the depth of investigation, the current electrode separation was increased while the potential separation remained constant. The geometric factor, K, was first calculated for all the electrode spacing using the formula:

$$K = \pi \frac{\left(\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right)}{MN} \quad (1)$$

For schlumberger array, apparent resistivity (ρ_a) is given by; (EBUTE, 2021)

$$\rho_a = KR \quad (2)$$

Where R is the earth resistance,

K is the k-factor,

AB is inter current electrode spacing and

MN is inter potential electrode spacing.

Also, the apparent resistivity values obtained were plotted against $AB/2$ using winResist software and from the plots; the resistivity, depth and thickness of each of the subsurface layer were deduced.

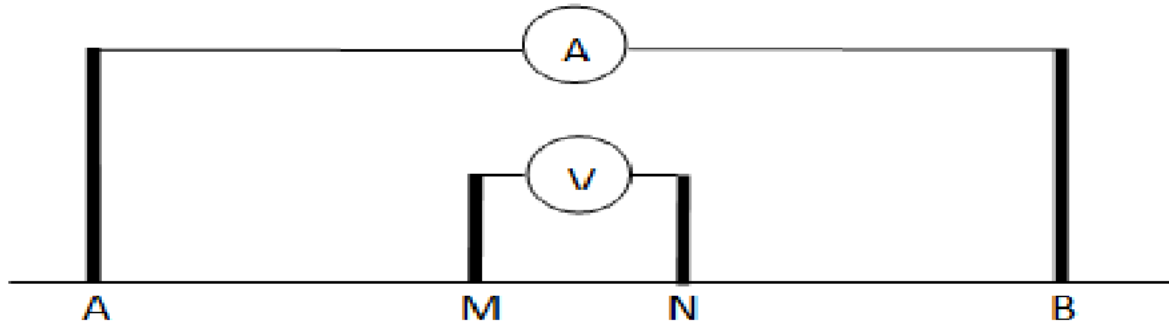


Figure 2 Schematic diagram of the schlumberger array used in the survey.

Table 2: Ranges of resistivity of various rocks component in basement complex

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	$300-10^5$
Sand	500-5000
Quartzite (various)	$10-2 \times 10^8$
Gravel	100-5000
Fractured basement	500-1000
Fresh basement	>1000

RESULT AND DISCUSSION

After the field the value of V, I and R of 24 point were obtained. Table of result containing V.I.R as measured in the field is in table 3

Table 3: The values of V, I and R of 24 point SENIOR STAFF QTRS B LATITUDE: 9.93
LONGITUDE: 11.00 ELEVATION: 437yd

CC/2(m)	PP/2(m)	V(v)	I(A)	R(Ω)
1	0.5	518.92	0.65	7525.138
2	0.5	413.12	1.21	16091.19
3	0.5	172.12	2.42	7821.503
4	0.5	41.95	1.63	5094.377
5	1	87.09	3.57	3679.15
6	1g	28.11	2.68	2306.908
7	1	27.98	5.53	1526.16
8	1	16.54	5.66	1156.9
9	1	10.88	6.15	889.3648
10	1	5.51	4.38	782.6162
15	2	3.48	3.33	725.6605
20	2	3.68	6.63	690.6144
25	2	1.89	5.00	737.5468
30	2	0.14	2.92	134.9769
35	5	2.58	5.89	660.6202
40	5	1.92	6.04	629.2323
45	5	1.91	4.96	967.9387
50	10	3.81	3.75	1532.291
60	10	4.11	5.10	1772.458
70	15	6.90	8.53	1584.26
80	15	2.69	6.91	1007.062
90	15	3.10	9.08	1126.345
100	20	2.06	0.00	#DIV/0!

Subsequently using the value of V.I.R the value of K and pa was obtain using equation

2.7 and 2.8

Table 4: Senior staff quarters B

S/N	AB/2	MN/2	MN	V	I	R	K	Pa
1	1	0.5	1	518.92	0.65	798.3385	9.426	7525.138
2	2	0.5	1	413.12	1.21	341.4215	47.13	16091.19
3	3	0.5	1	172.12	2.42	71.12397	109.97	7821.503
4	4	0.5	1	41.95	1.63	25.7362	197.946	5094.377
5	5	1	2	87.09	3.57	24.39496	150.816	3679.15
6	6	1	2	28.11	2.68	10.48881	219.94	2306.908
7	7	1	2	27.98	5.53	5.059675	301.632	1526.16
8	8	1	2	16.54	5.66	2.922261	395.892	1156.9
9	9	1	2	10.88	6.15	1.769106	502.72	889.3648
10	10	1	2	5.51	4.38	1.257991	622.116	782.6162
11	15	2	4	3.48	3.33	1.045045	694.382	725.6605
12	20	2	4	3.68	6.63	0.555053	1244.232	690.6144
13	25	2	4	1.89	5	0.378	1951.182	737.5468
14	30	2	4	0.14	2.92	0.047945	2815.232	134.9769
15	35	5	10	2.58	5.89	0.438031	1508.16	660.6202
16	40	5	10	1.92	6.04	0.317881	1979.46	629.2323
17	45	5	10	1.91	4.96	0.385081	2513.6	967.9387
18	50	10	20	3.81	3.75	1.016	1508.16	1532.291
19	60	10	20	4.11	5.1	0.805882	2199.4	1772.458
20	70	15	30	6.9	8.53	0.80891	1958.513	1584.26
21	80	15	30	2.69	6.91	0.389291	2586.913	1007.062
22	90	15	30	3.1	9.08	0.34141	3299.1	1126.345
23	100	20	40	2.06	0	#DIV/0!	3016.32	#DIV/0!

The Geoelectric section (VES curve) as shown provides information about the subsurface layer resistivity, depth and thickness as summarized in table 4.

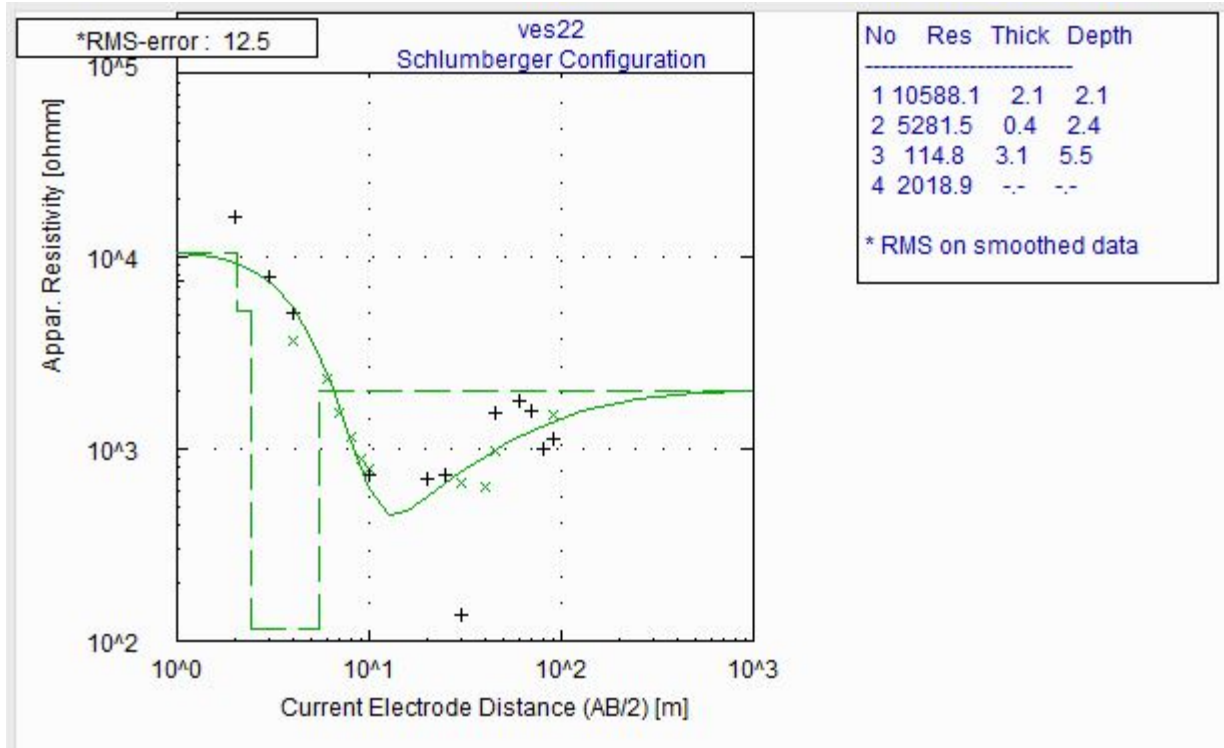


Figure 2: Model curve for senior staff quarter B

Figure 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 four (4) geoelectric subsurface layers. The first layer which is the top layer has resistivity value of 10588.1 Ωm , its depth and thickness 2.1-2.1m respectively which corresponds to the geoelectric parameters of Fresh laterite, Granite, Sand and Gravel and the first layer contain little amount of water because of the fresh laterite sand parameters. This is when compared with the values in table 2. The second layer has resistivity value of 5281.5 Ωm , thickness of 0.4m and depth of 2.4m; the second layer refers to the Fresh basement/Gravel basement when compared to range of values in table 2. The second layer will

accommodate fresh amount of water. The resistivity of the third layer is 114.8 Ωm , thickness and depth of 3.1m, 5.5m respectively; the third layer refers to weathered basement/Alluvium and sand basement. When compared to range of values in table 2, the third layer will accumulate water because of weathered basement and sand basement parameters. The fourth layer has resistivity value of 2018.9 Ωm , its thickness and depth are undefined. The third layer is the layer that will contain more fresh water because it is thicker than the second layer even though both of them contain fresh water. The result is similar to the findings of Nur (2022) in his research carried out at Pindiga, few meters to kashere (Nur *et al.* , 2022). It also agrees with the finding of Rauff (2025) in his research work carried out in Gombe (Rauff *et al.* , 2025).

Conclusion

VES is carried along the study area have revealed five (5) geoelectrical layers. The second layer of the aquifer is the best environment for sustainable water supply because the second layer is the layer that contain more fresh water than the other layers. The results clearly showed that the electrical resistivity method is suitable for and very efficient in investigating the parameters of the subsurface structure. The research did not only pave way for a clear picture of the hydrogeological knowledge of Federal University of Kashere but also gives information on the productive and prolific aquifer for sustainable groundwater supply. It will also serve as a guide to both the government and individuals especially those involved in groundwater development on the areas and depths boreholes could be sited and drilled for sustainable water supply.

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