GEOELECTRICAL INVESTIGATION FOR GROUND WATER POTENTIALS OF THE MAIN CAMPUS OF AHMADU BELLO UNIVERSITY, ZARIA USING THE AJAYI-MAKINDE TWO-ELECTRODE ARRAY

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Abstract: The provision of portable water has for sometime been a serious problem in the Main Campus of Ahmadu Bello University (ABU), Zaria. A geo-electric investigation employing vertical electrical soundings (VES) using the Ajayi-Makinde Two-Electrode array was carried out in the Main Campus to determine the groundwater potentials of the area. Results of the VES interpretation reveal that the depth-to-basement in the Main Campus is variable with values ranging from 10.5 to 42.0 m while the aquifer thickness varied from 4.0 to 32.0 m. The aquifer is thicker at the upper northwestern part of the Main Campus and thinner around the west central part of the Main Campus. Also, the Ajayi-Makinde Two-electrode which is a new array has proved to be effective and can therefore be used as a geo-electric method of prospecting.
Keywords: Two-Electrode Array, Aquifer thickness, depth-to-basement, Vertical Electrical Sounding (VES)

Introduction

Groundwater is one of the most important natural resources found in aquifers below the surface of the earth. An aquifer is a unit of rock or an unconsolidated deposit that can yield a usable quantity of water (Vanessa, 2000). It can also be described as a layer of porous substrate that contains and transmits groundwater. Groundwater is commonly used for public water supplies because it is often cheaper, more convenient and less vulnerable to pollution than surface water. Groundwater makes up about twenty percent of the world's fresh water supply, which is about 0.61% of the entire world's water, including oceans and permanent ice (Vanessa, 2000).

There are quite a number of different electrode arrangements used in electrical D.C. resistivity survey. These include the two-electrode arrangement, the three-electrode arrangement, the common four-electrode arrangement and the six-electrode arrangement (Jain and Roy, 1973). The Ajayi-Makinde two-electrode array used in this study is a new method based on Ohm's law, just like other electrode arrays.

In the Ajayi-Makinde two-electrode array, Ohm's law is applied to the simple electrical circuit in which R, the resistance or load in the circuit represents the portion of the earth ''sampled'' or ''sounded'' by the current I flowing in and out of the ground (earth material) through the two electrodes across which a potential difference, or voltage V is applied (Ajayi and Makinde, 2000). As the separation of of the electrodes increases, the current I penetrates the earth deeper and deeper, thereby, sampling the various layers underlying the point sounded (Ajayi and Makinde, 2000).

The structural geology of an area has a very important effect on the groundwater potential of the area, more especially in areas of crystalline rocks such as that underlying the Kubanni Basin.

Previous workers such as Olowu (1967) and Eigbefo (1978) have classified the aquifer components in the Kubanni Basin into three categories as:

i. Weathered basement and fractures in the basement rocks
ii. The laterised (Older laterite) deposits which contain limited quantity of water and
iii. The alluvial deposits.

In recent years the provision of good water supply in the Main Campus of Ahmadu Bello University (ABU), Zaria has been a serious challenge more especially in the staff quarters. In most cases staff members resort to buying water from water tankers or wheelbarrow pushers hence the need to investigate the groundwater potentials of the area.

This study is aimed at carrying out a vertical electrical sounding using the Ajayi-Makinde Two-electrode array to determine the groundwater potentials of the Main Campus of ABU, Zaria.

Materials and Methods

Location of the study area

The Main Campus of A.B.U. Zaria is part of the Kubanni River Basin situated in the north – central part of Nigeria. It is approximately bounded by latitudes 11^0 09' N and 11^0 10' N and longitudes 7^0 38' E and 7^0 39' E. The area of investigation is a built up area comprising of staff quarters, students hostels, lectures halls, laboratories, workshops, office blocks, etc., as shown in Fig. 1.

Geology of the study area

As reported by McCurry (1970), the Nigerian basement complex rocks are exposed over more than half of the land surface of Nigeria. The rocks are exposed mostly in the northern and western parts and the eastern flank that has border with the Republic of Cameroun. The Main Campus of A.B.U. Zaria being part of the Kubanni Basin is underlain by rocks of the Precambrian age (Wright and McCurry, 1970). Biotite gneiss predominates in the basin and outcrops mainly in stream valleys where they are deeply weathered (Wright and McCurry, 1970). The superficial deposits that cover most of the basement rocks in the Kubanni Basin act as recharge areas where they are underlain by weathered basement (Eigbefo, 1978).

According to Olowu (1967) and Eigbefo (1978), the weathered basement is the main storage element which is mostly found along stream channels. Their thicknesses range from 5– 15 m (Olowu, 1967). The geologic map of the study area is shown in Fig. 2.

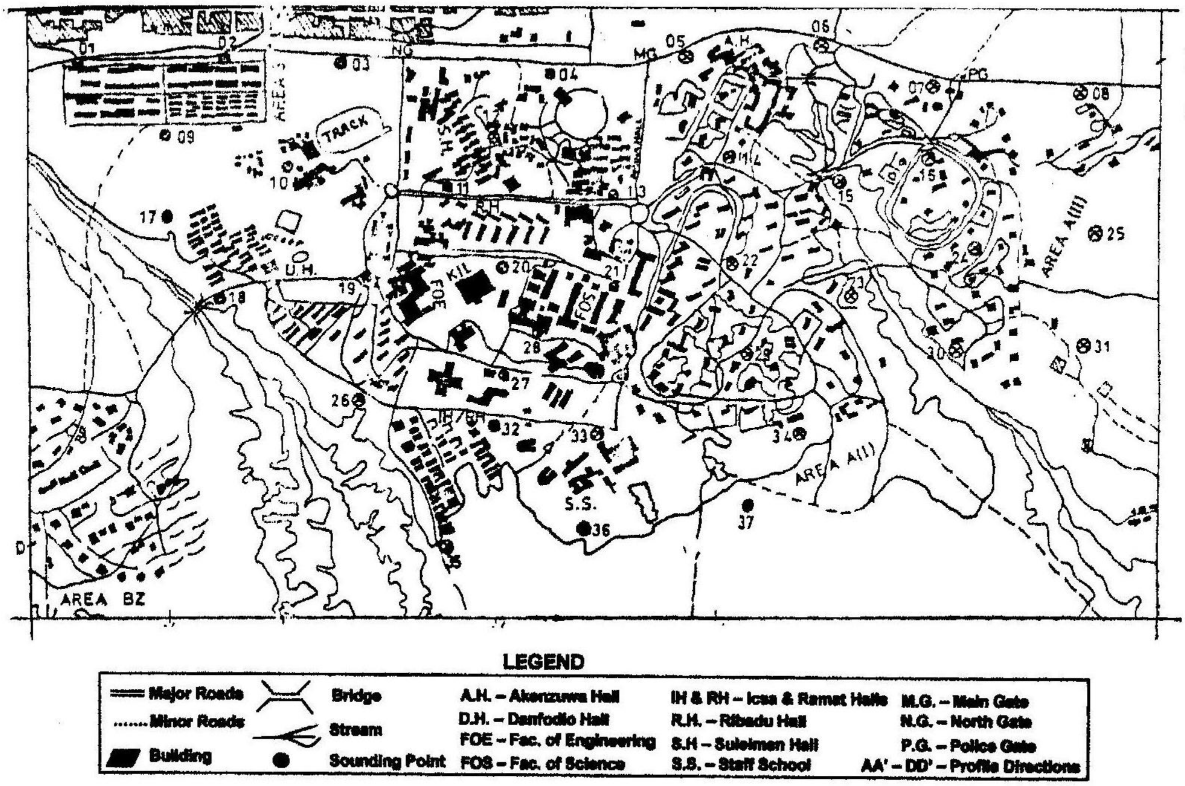

Fig. 1: Location of sounding points in the study area (Courtesy of URP Department ABU, Zaria)

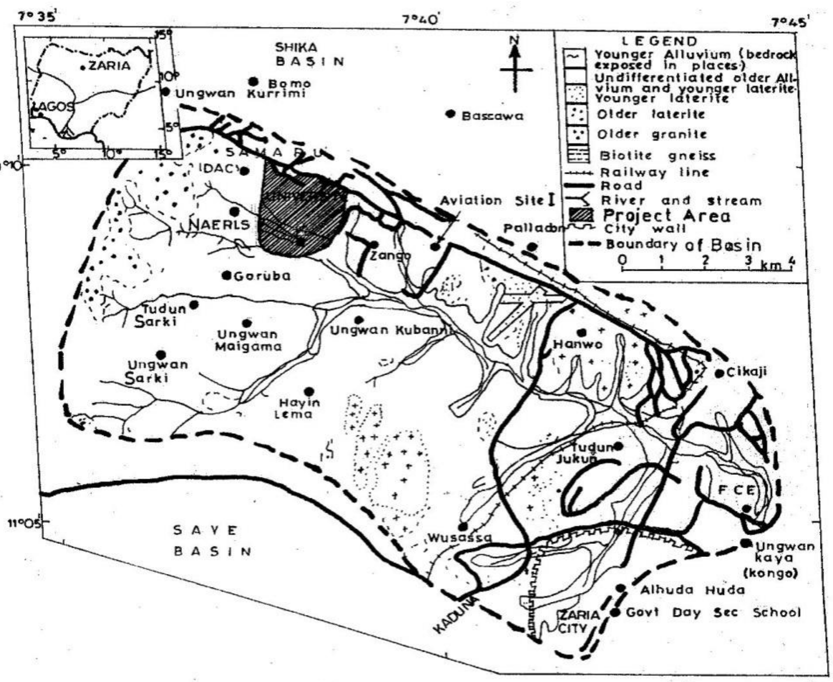

Fig. 2: Location of the project area within the geological map of theKubanni Basin (Adapted from Shemang, 1990)

Instrumentation and field technique

As the Ajayi - Makinde Two-electrode array is a new technique, no equipment had, as at the time of the fieldwork, been fabricated for it. Hence an arrangement which basically consist of an electric generator as the power source, a voltmeter, an ammeter, two copper electrodes, two reels of wire and connecting wires were used (Figure 3). The electric generator is an ET 500 YAMAHA with an output of 250 V, 50 Hz, capable of delivering a maximum current of 300 mA. A high tension laboratory power pack was used to convert the alternating current (A.C.) to direct current (D.C.), which was then passed into the ground through the copper electrodes. A voltmeter with a range of 0 - 300 V was used to measure the potential difference (V) across the electrodes while an ammeter with a range of 0 - 300 mA measures the current (I) passed into the ground. The fieldwork in this study was carried out in the month of March, at the peak of the dry season.

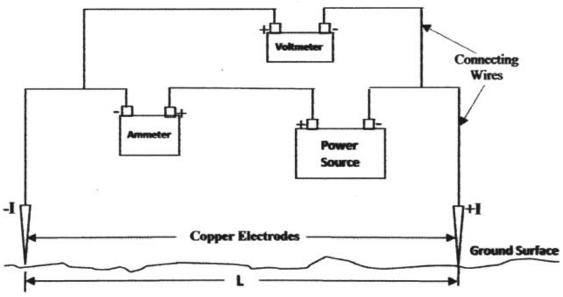

Fig. 3: Arrangement of the field equipment used. L is the Electrode separation

The field procedure involved the expansion of half the current electrode spacing (L/2) symmetrically about the centre point or point being sounded. Half the current electrode spacing L/2 was expanded in steps from 0.5 m to a maximum of 100 m. For each measurement, I, V and the electrode spacing L were recorded. The ratio of the potential difference, V, to the current, I, is a measure of the electrical resistance of the ground between the two electrodes at the corresponding given spacing. A total of thirty-seven (37) points were sounded. The points "sounded" or "stations established" were carefully selected to ensure adequate and uniform coverage of the study area as shown in Figure 2. The area could not be gridded because it is a built up area.

Data Processing and Interpretation

The data collected consists of the measured current, I, passed into the ground, the voltage, V, across the power source and the electrode spacing, L. The resistance of the ground was calculated using Ohm's law (i.e. R = V/I). The "bulk" or apparent resistivity ρ_b of the layers sounded were calculated using the equation by Ajayi and Makinde (2000) as in Equation 1.

$$\rho_b = k\frac{V}{I} \qquad \ldots\ldots\ldots\ldots\ldots\ldots..(1)$$

Table 1 is a typical reduced data for Vertical Electrical Sounding (VES) station 25.

The values of ρ_b and their corresponding L/2values plotted on a semi-log graph sheet is expected according to Ajayi and Makinde (2000) to give a series of straight lines joined end-to-end. The intercepts on the L/2 axis at the points of intersection of the straight line segments gives the depth of the various layers Ajayi and Makinde (2000). Figure 4 is a typical example of such a plot for VES station 25.

Table 1: Typical reduced data for VES 25

L (m)	L/2 (m)	V (Volts)	I (mA)	ρ_b(Ω m)
1.0	0.50	188	42	659.2
2.0	1.00	174	32	1601.5
3.0	1.50	147	54	202.6
4.0	2.00	173	34	997.2
5.0	2.50	135	45	208.9
6.0	3.00	120	48	208.9
7.0	3.50	113	46	713.2
8.0	4.00	106	39	202.0
9.0	4.50	91	43	804.8
10.0	5.00	120	55	212.9
15.0	7.50	101	52	290.4
20.0	10.00	122	49	333.1
25.0	12.50	116	51	373.7
30.0	15.00	105	56	283.5
35.0	17.50	103	53	0016.6
40.0	20.00	72	44	9638.9
45.0	22.50	75	45	1044.7

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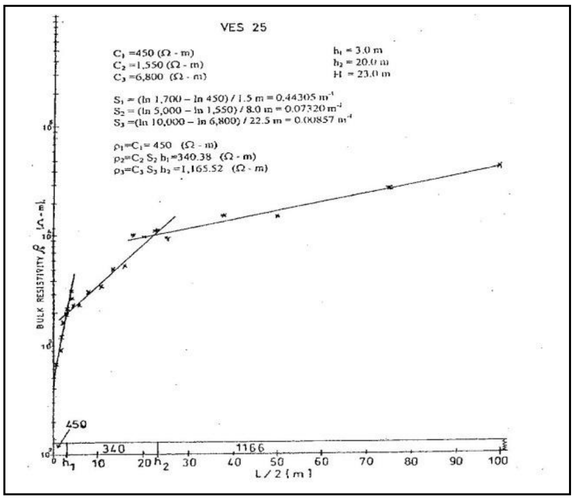

Fig. 4: Plot of ''Bulk resistivity'' against L/2 and Interpretation of data

The intercepts and slope values of the segments of the plots of ''bulk resistivity'' against L/2 were used to determine the layer parameters which include: the number of layers sounded at a VES station, the depth-to-basement values, the different layer thicknesses and the layer resistivity values as employed in Ajayi and Makinde (2000) and applied by Yusuf and Umego (2014).

From the interpretation of the data, the layer thickness values for each VES station were used to compute the depth-to-basement values for each VES stations presented in Table 2.

Table 2: Depth-to-basement values obtained from the interpretation of data

VES Station No.	Layer Thickness (m) 1st	2nd	3rd	4th	Dept-to-Basement H (m)
1	4.0	21.5	-	-	25.5
2	4.5	17.5	-	-	22.0
3	4.0	20.0	-	-	24.0
4	3.0	10.0	8.0	21.0	42.0
5	3.0	12.0	-	-	15.0
6	5.0	15.0	-	-	20.0
7	5.5	17.5	-	-	23.5
8	3.5	16.5	-	-	20.0
9	4.0	16.0	-	-	20.0
10	3.0	21.0	-	-	24.0
11	3.0	4.5	13.5	-	21.0
12	5.5	17.5	-	-	23.0
13	6.0	14.0	-	-	20.0
14	3.0	10.0	-	-	13.0
15	4.0	19.0	-	-	23.0
16	2.5	22.5	-	-	25.0
17	3.5	22.5	-	-	26.0
18	4.0	21.0	-	-	25.0
19	3.0	18.5	-	-	21.5
20	3.5	7.0	-	-	10.5
21	3.5	8.0	-	-	11.5
22	4.0	16.0	-	-	20.0
23	4.0	22.0	-	-	26.0
24	3.0	22.0	-	-	25.0
25	3.0	20.0	-	-	23.0
26	7.0	12.5	-	-	19.5
27	4.5	7.5	-	-	12.0
28	3.0	12.0	-	-	15.0
29	3.0	19.0	-	-	22.0
30	4.0	23.5	-	-	27.5
31	3.0	5.0	18.0	-	26.0
32	4.0	11.0	-	-	15.0
33	4.0	22.5	-	-	26.5
34	4.0	9.5	15.5	-	29.0
35	3.0	20.5	-	-	23.5
36	3.0	27.0	-	-	30.0
37	3.0	25.0	-	-	28.0
Minimum					**10.5**
Maximum					**42.0**

The depth-to-basement values were used to produce a contour map and a three-dimensional (3D) map of the basement of the Main Campus as presented in Figs. 5 and 6, respectively.

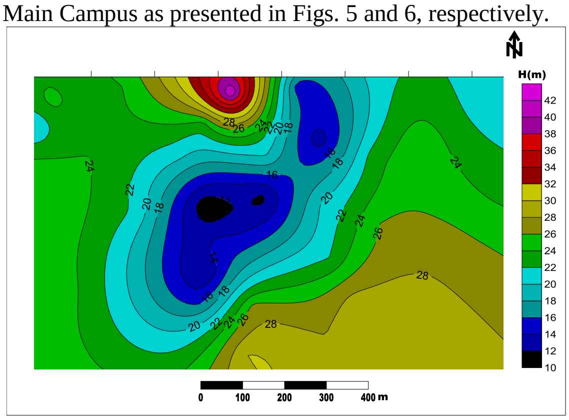

Fig. 5: Depth-to-basement contour map of the study area

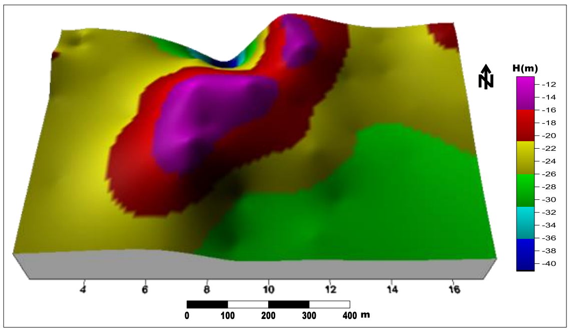

Fig 6: 3-D view of the basement in the study area

The aquifer thickness below each VES station was determined by subtracting the thickness of the first layer (topsoil) from the total depth to the basement at that VES point. These values were then used to plot a contour map and a 3-D view of the aquifer thickness as presented in Figures 7 and 8, respectively.

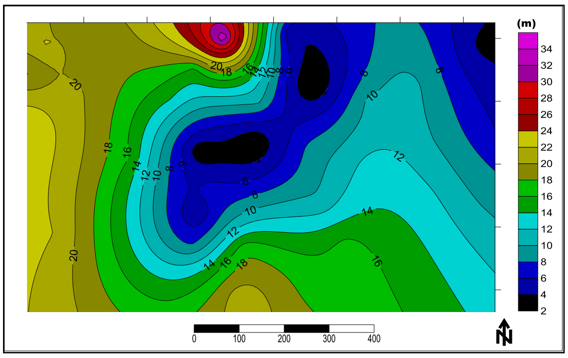

Fig. 7: Contour map of Aquifer thickness

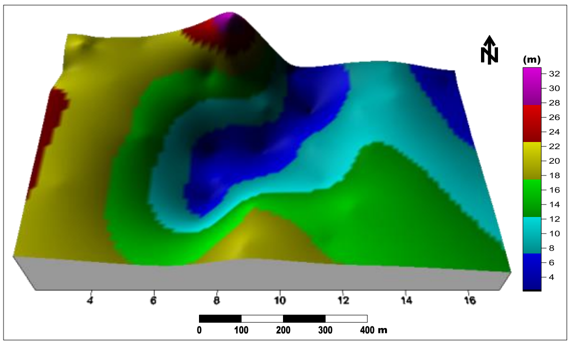

Fig. 8: 3-D view of Aquifer thickness

Discussion

The depth-to-basement values beneath the Main Campus varied from 10.5 m to 42.0 m as in Table 2. These values are within the range of depth-to-basement values obtained by previous workers such as; Ososami (1968), Hassan (1987), Shemang (1990), Makinde (1996), Rotimi and Ameloko (2010) and Yusuf and Umego (2014) in the Kubanni Basin. The basement is deeper at upper northwestern end and shallower at the upper northeasternend stretching out in a southwest direction to the upper southwestern part of the study area (Figs, 5 and 6).

Areas of maximum aquifer thickness shown in Figs. 7 and 8are:

i. The Southeastern part of the Main Campus

ii. The Upper northwestern part of the Main Campus, i.e. just to the west and southwest of Danfodio Hall and

iii. The western and southwestern part of the area.

These areas can be considered as the most probable areas that contain and can retain more groundwater in the Main Campus. Areas with higher depth-to-basement values were observed to coincide with maximum aquifer thickness.

Conclusion

An attempt has been made to determine the groundwater potentials of the Main Campus of Ahmadu Bello University Zaria using the Ajayi-Makinde two-electrode array. This survey was able to reveal that the bedrock within the study area is undulating and shallower around the northern part of the study area while they get deeper towards the southern part as reported by Hassan *et al.* (1991) and other workers in the basin. The depth-to-basement values obtained in this study have compared well with those obtained by previous workers in the Kubanni Basin. The Ajayi-Makinde two-electrode array used in this work has proved to be effective as a new geo-electric prospecting method as reported by Yusuf and Umego (2014). The depth-to-basement values in the Main Campus ranged from 10.5 to 42.0 m while the thickness of the aquifer varied from 4.0 to 32.0 m. The upper northwestern part of the study area where the aquifer is thicker can be considered as the most viable area for groundwater

References

Ajayi CO & Makinde V 2000. The “Ajayi-Makinde” Two-Electrode D.C Resistivity Array. *A brief Brochure to the Patent Office, Abuja.*

Eigbefo C 1978. Hydrogeology of the Kubanni Basin, Zaria. *Unpublished M.Sc. Thesis, Ahmadu Bello University, Zaria.*

Hassan M 1987. Geoelectrical Investigation of the Western Half of the Kubanni River Basin, Zaria. *Unpublished M.Sc. Thesis, Ahmadu Bello University, Zaria.*

Hassan, M.; Ajayi, C. O. and Ojo, S. B. (1991); A Basement structure determined from Geoelectric mapping of the Kubanni River Basin, Zaria: *Nig. J. Physics,* 3: 166-173.

Jain SC & Roy A 1973. Comparison of Electrode Arrays in Time Domain Induced Polarization. *Geophysical prospecting.* 21 (4) pp 626 – 634.

Makinde V 1996. A Field Investigation of a Variant of the Two-Electrode D.C. Resistivity Array within the Kubanni Basin. *Unpublished Ph.D. Thesis, Ahmadu Bello University, Zaria.*

McCurry P 1970. Geology of Degree Sheet 21, Zaria. *Unpublished M.Sc. Thesis, Ahmadu Bello University, Zaria.*

Olowu J 1967. Preliminary Investigations of the Groundwater Conditions in Zaria Sheet 102 S. W. *Geological Survey of Nigeria (GSN) Report No. 1462.*

Ososami IA 1968. Assessment of the Groundwater in the Kubanni Valley. *Unpublished M.Sc. Thesis, Ahmadu Bello University, Zaria.*

Rotimi OJ & Ameloko AA 2010. 2-D Electrical Imaging And Its Application In Groundwater Exploration In Part Of Kubanni River Basin-Zaria, Nigeria. *World Rural Observations,*2(2): 24–29.

Shemang EM 1990. Electrical Depth Sounding at Selected Well Sites within the Kubanni River Basin, Zaria. *Unpublished M.Sc. Thesis, Ahmadu Bello University, Zaria.*

Vanessa B 2000. Volume of Earth's Groundwater**.** Edited by Glenn Elert. *The Physics Fact Book.* http://hypertextbook.com/facts/2000/VanessaBallenas.shtml.

Wright JB & McCurry P 1970. The geology of the Zaria Sheet 102 S.W. and its Region In: Mortimore, M. J. (Ed.). *Department of Geography Occasional Paper No. 4. Ahmadu University, Zaria.*

Yusuf DB & Umego MN 2014. Effectiveness of the Ajayi–Makinde two-electrode array as a geoelectric prospecting method in depth-to–basement determination. *Global J. Pure & Appl. Scie.,* 20: 65–76.