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Full Length Research

Geo-electrical investigation of groundwater potential and subsurface structures in part of Pompo Village, Minna, North-central Nigeria

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ABSTRACTS: The electrical resistivity survey (VES) method was used to carry out groundwater investigation to delineate the aquiferous units in Pompo, which is a settlement in the neighbourhood of the Gidan Kwano campus of the Federal University of Technology, Minna. Pompo lies within the Pre-Cambrian Basement Complex of Northern Nigeria, and is mostly underlain by the Migmatic-Gneiss Complex, coarse-grained biotite granite and granodiorite. The survey was carried out on a grid of 500 m x 500 m. Interpretation of the data was done using IP2win software, in which a layering model was obtained with the digitized sounding curve for each of the six profiles. The results obtained show that the area is generally underlain by three geologic sections (lateritic top soil, weathered basement and fresh basement). However, in some sections, where the basement had experienced severe weathering leading to fracturing of the basement rocks, four layer models were obtained. The weathered basement that is the aquifer system of the study area is generally characterized by low resistivity that is less than 400 Ωm with basement depth between 20.0 m and 35.0 m found in the eastern and south-eastern zones.

Keywords: Aquifer, Pompo village, resistivity, Vertical Electrical Sounding (VES).

INTRODUCTION

The successful exploration of basement terrain ground water requires a proper understanding of the characteristics of the aquifer units in relation to its environmental susceptibility. This is particularly important of the discontinuous (localized) nature of the basement aquifers. The method has been extensively used in groundwater investigation in the basement complex terrains of Africa. However, groundwater occurs either in the weathered mantle or in the joints and fractured system in the unweathered rocks (Shehu et al., 2018).

Groundwater is an important water resources in both the urban and rural areas in Nigeria. The availability of quality water resources has always been the primary concern of every society in the semi-arid and arid regions (Alhassan et al., 2017).

Among several geophysical methods employed in groundwater exploration (electrical resistivity, gravity, seismic, magnetic, remote sensing and electromagnetic), the electrical resistivity method is the most effective and reliable tool in locating productive wells and aquifers for continuous and regular water supply (Todd and mays, 2005). The method is regularly used to solve a wide variety of groundwater problems (Osagie, 2010)

Ejepu and Olasehinde (2014) evaluated groundwater potential in the Crystalline Basement of Gidan Kwano Campus, Federal University of Technology, Minna, North Central, Nigeria using Geoelectric Methods. The result show three geologic layers, the top soil (0.2 to 7.4 m), weathered layer (0.3 to 58.8 m) and fresh basement. The study area has been found to have a very high potential for groundwater development.

This research work is necessary because the problem of obtaining adequate supply of quality water due to ever increasing population and urbanisation. Therefore, the quest for viable potable water sources has been an important issue to the villages and towns. Therefore, the aims of this research are to delineate aquiferous zones suitable for groundwater exploitation and exploration as the safest and quality means of drinking water, and also to delineate areas good for civil and engineering work.

GEOLOGY OF THE STUDY AREA

Pompo is an urban sprawl in the neighbourhood of the Gidan Kwano campus of the Federal University of Technology, Minna. The growing settlement and rising population puts a lot of pressure on existing source and supply of usable water. Hence, the need to delineate regions with aquifer potentials where groundwater can be sourced to meet the dire need of the populace. The village is located between latitudes 9°30' N and 9°31' N and longitudes 6°27' E to 6°28' E in part of Minna SW sheet 42. The investigated site is a square of 500 m by 500 m, covering an area of 250,000 m^2. It is about 30 m away from the major road (Minna- Keteregi- Bida road). This is within the basement complex of Nigeria as presented in Figure 1a.

The area is entirely underlain by rocks of the Nigerian basement complex consisting of a migmatite-gneiss complex, two low grade schist belts and an older granite suite according to Udensi et al. (1986). The schist belts are relics of super crystal cover that was infolded into migmatite gneiss complex as reported by McCurry (1976). Pompo consists predominantly of coarse-grained biotite granite and granodiorite. It is surrounded on its Northwest by medium-grained biotite and biotite-hornblende granite, on the North by coarse-grained biotite-muscovite granite and weakly foliated granodiorite, and on the South and Southwest by migmatite-gneiss complex (Figure 1b). The granites and the granodiorites together form part of the older granite.

Also, the Kushaka schist belt lies on the East of Pompo as presented in Figure 1b. Few barren joints were observed. Several prominent geophysical works have been carried out around the area which include; Salako and Udensi (2005), Udensi et al. (1986), Adesoye (1986), Adeniyi (1985) and Ajibade et al. (1979).

MATERIALS AND METHOD

An electrical resistivity survey involves laying out a series of electrodes, each driven into the ground about 50 cm. Their spacing is depends on the depth of penetration required. The further apart the electrodes, the deeper the resistivity measurements of the subsurface that can be taken. Typically, resistivity surveys range in depth from a few metres to more than 100 metres.

$$\rho = \pi \left[\frac{\left(\overline{AB}/_2\right)^2 - \left(\overline{MN}/_2\right)^2}{\overline{MN}} \right]$$

Where: A = Current electrode (+), B = Current electrode (-), M = Potential electrode, N = Potential electrode, a = Distance between successive electrodes, $\overline{AB}$ = Distance between current electrodes, $\overline{MN}$ = Distance between potential electrodes and ρ = the geometric factor, to be multiplied by resistivity reading to obtain apparent resistivity i.e the resistivity contrast of various rocks.

The survey area was inspected and gridded. Six North-South (NS) trending profiles labelled A-F were marked out with inter-profile distance of 100 m and inter-grid distance of 100 m. The length of a profile was 500 m. The vertical electrical sounding (VES) points were marked with pegs at each sounded point and they were thirty-six (36) in all (Figure 2). Schlumberger array was chosen for this study. It is particularly suitable for the electrical drilling technique (Telford et al., 1990). VES has been the most effective geophysical method for water prospecting in areas with horizontal, gently dipping or flat lying beds and areas of deep *in situ* weathering with fresh bedrock underneath (Salako and Udensi, 2005).

The ABEM Terrameter SAS 4000 with all other peripheral accessories was used to collect the data. There was no need for data reduction or repeated measurement since the receiver of SAS 4000 discriminates noise and measures voltages correlated with transmitted signal current. More so, the system has the built-in function to average the best measurement of maximum of four staking with the standard deviation of unity or even less (ABEM Instrument AB, 1999). The data collected were processed by reducing the resistance data obtained to apparent resistivity, using the equation;

$$\rho = \frac{\pi \Delta V}{I} \left(\frac{L\left(L^2 - a^2\right)}{a^2} \right)$$

Where; ρ = Apparent resistivity, L = Current electrode spacing, a = Potential electrode spacing, V = Voltage and I = Current.

Note: $\pi \Delta V / I = \pi R$.

Data interpretation was done using IP2win software, in which a layering model was obtained with the digitized sounding curve for each of the six profiles. Pseudo-sections, resistivity cross sections, digitized resistivity

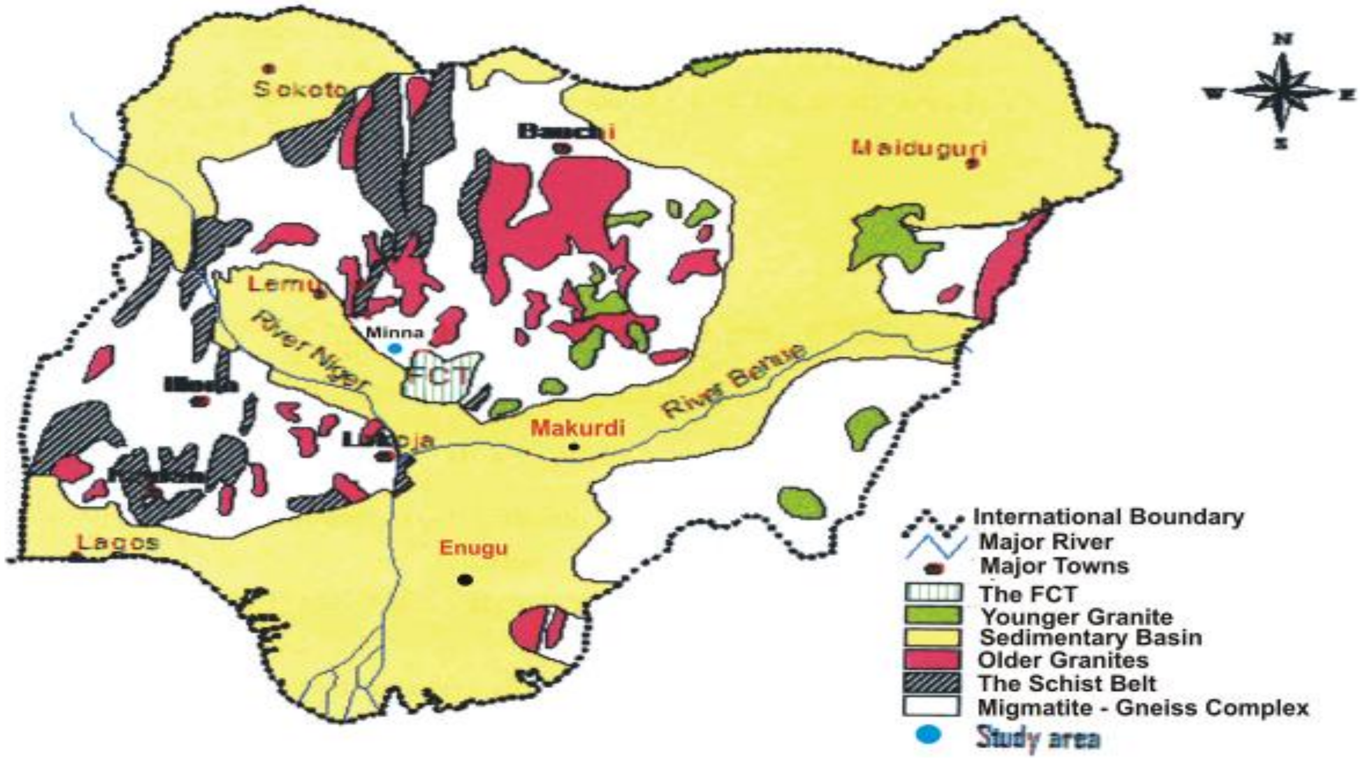


Figure 1a. General geologic map of Nigeria (GNS, 1999).

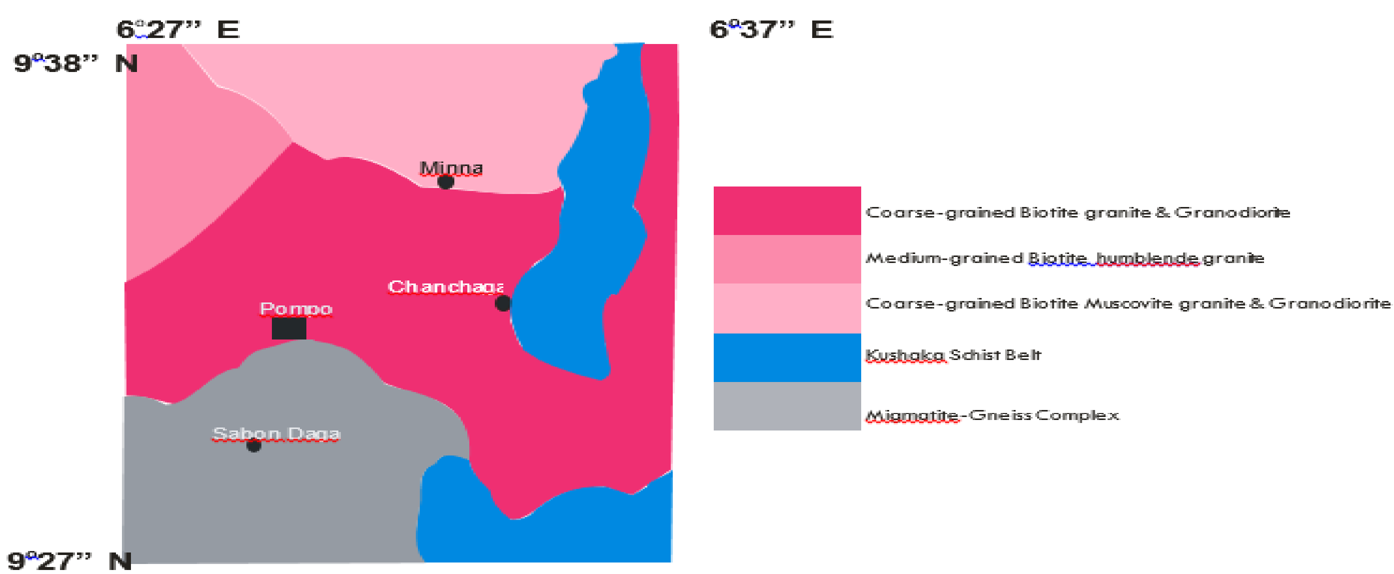


Figure 1b. Geological map of the study area (Nigerian Geological Survey Agency, 2000).

layer curves or log graphs and resistivity-depth tables were generated. Regolith and depth to basement maps were generated using the software Minitab 14.

RESULTS AND DISCUSSION

The interpretation of VES data will only concentrate on

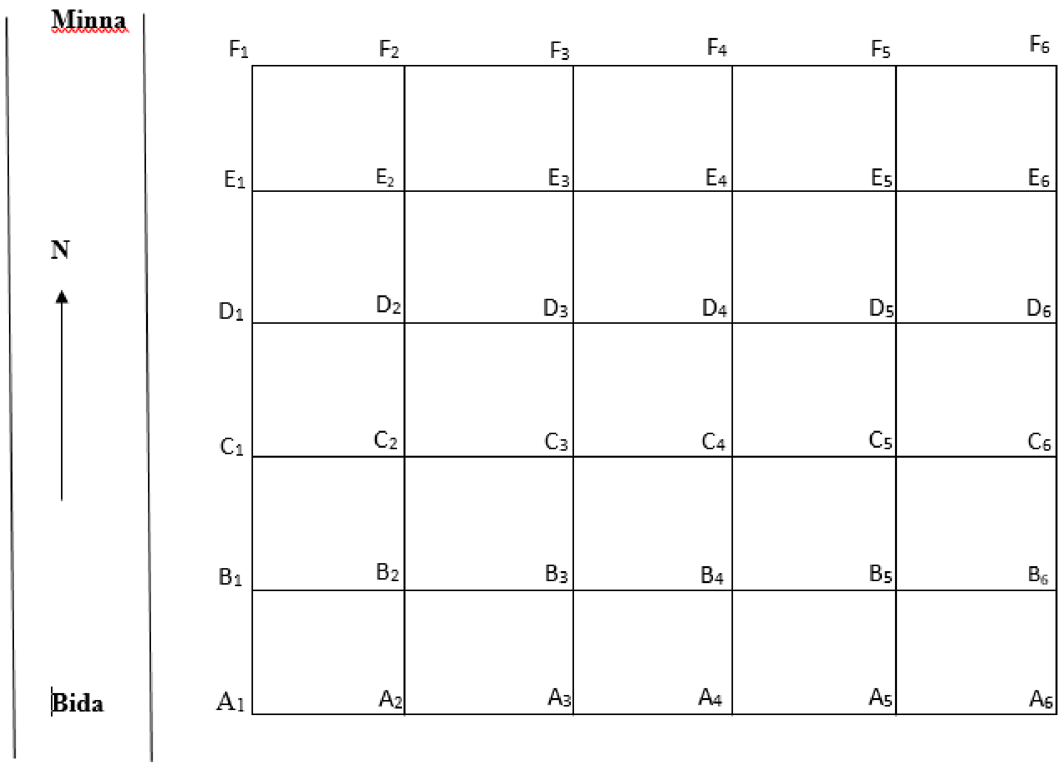


Figure 2. Profile layout of VES data collection.

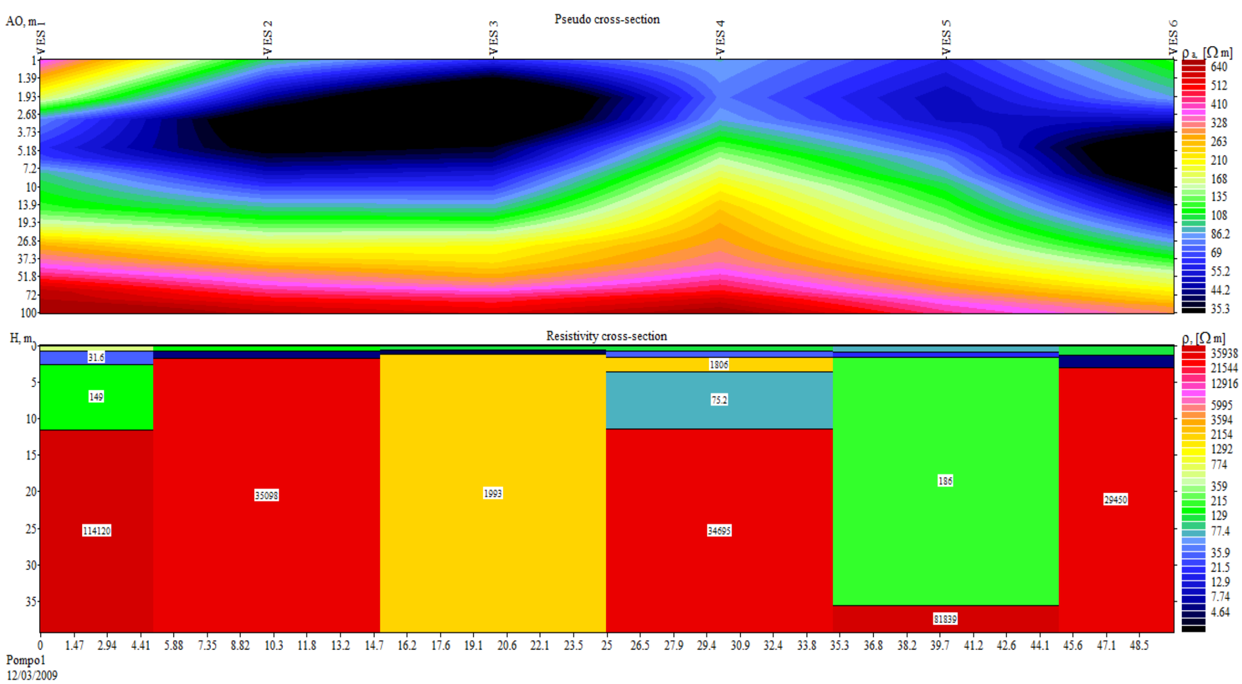
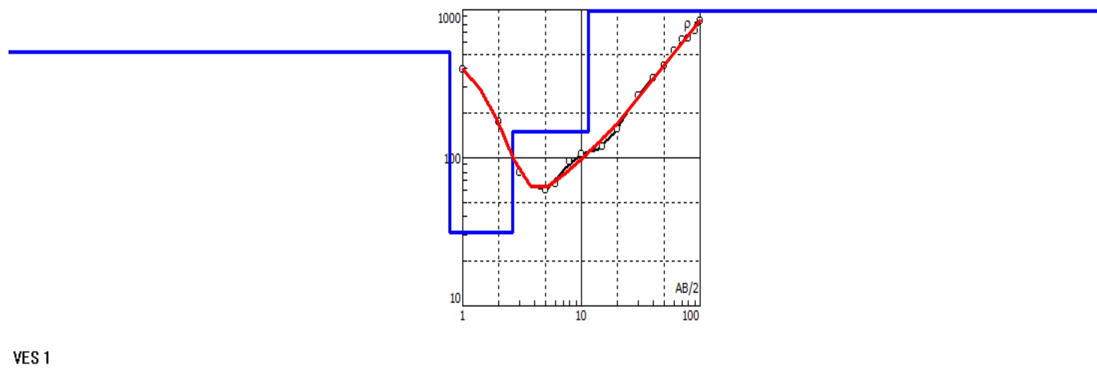
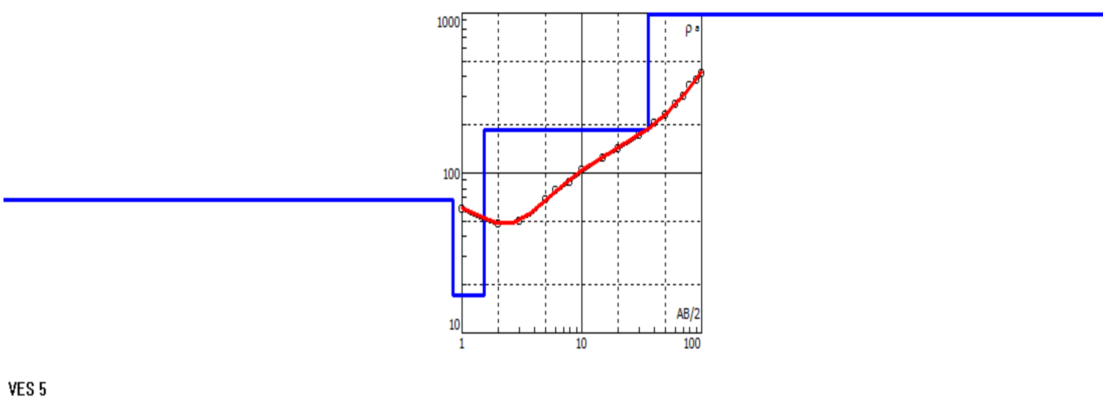


Figure 3a. Vertical geo-electric and geologic sections of profile A.

three profiles (A, C and D) out of the six delineated. Figures 3a and b shows the vertical geo-electric and the geologic sections of profiles A of the study area. The topsoil which is the first layer varies in thickness from 0.50



N	ρ	h	d	Alt
1	519	0.783	0.783	-0.783
2	31.6	1.83	2.61	-2.613
3	149	8.89	11.5	-11.5
4	114120			



N	ρ	h	d	Alt
1	68.3	0.834	0.834	-0.8335
2	17.3	0.7	1.53	-1.534
3	186	34.1	35.6	-35.59
4	81839			

Figure 3b. Log graphs and resistivity-depth tables of VES A_1 and VES A_5.

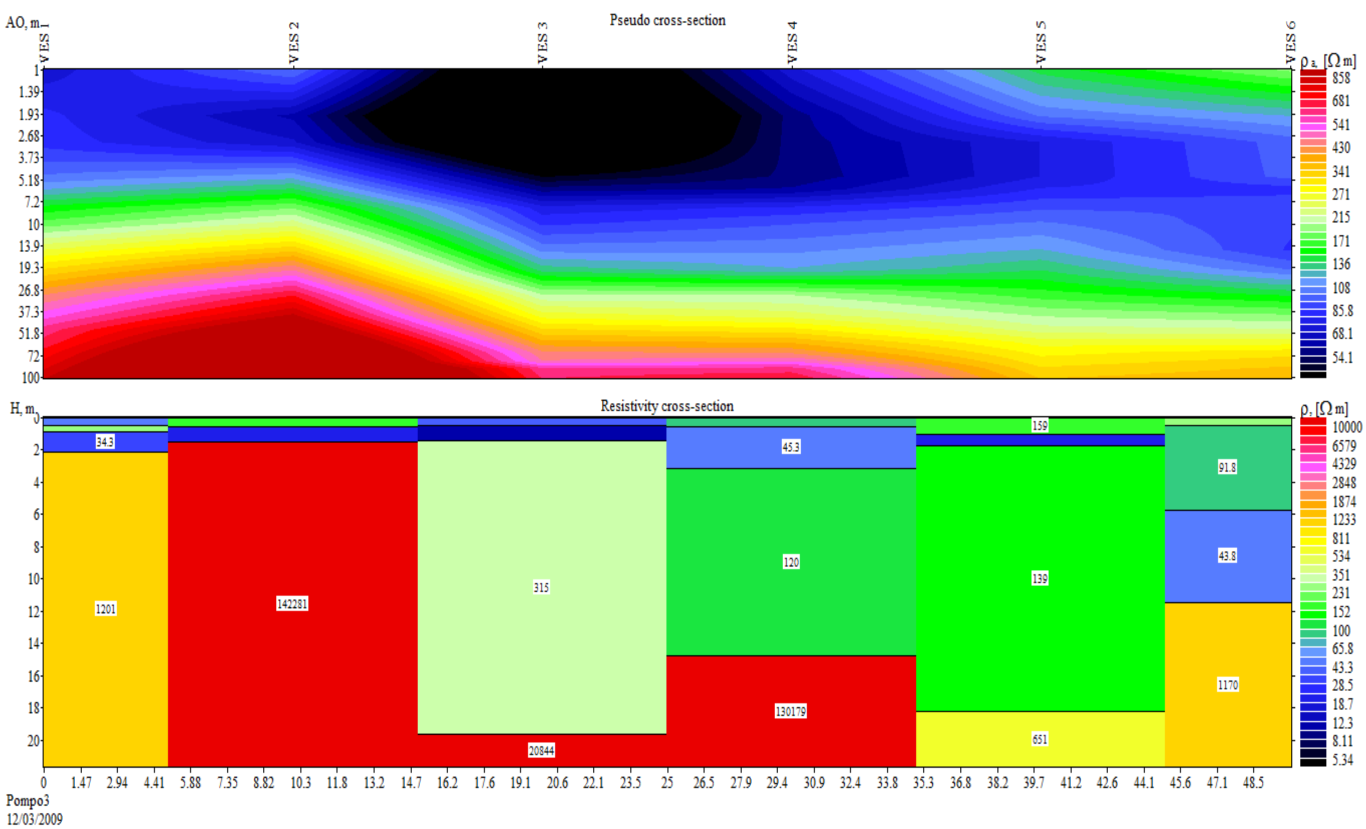
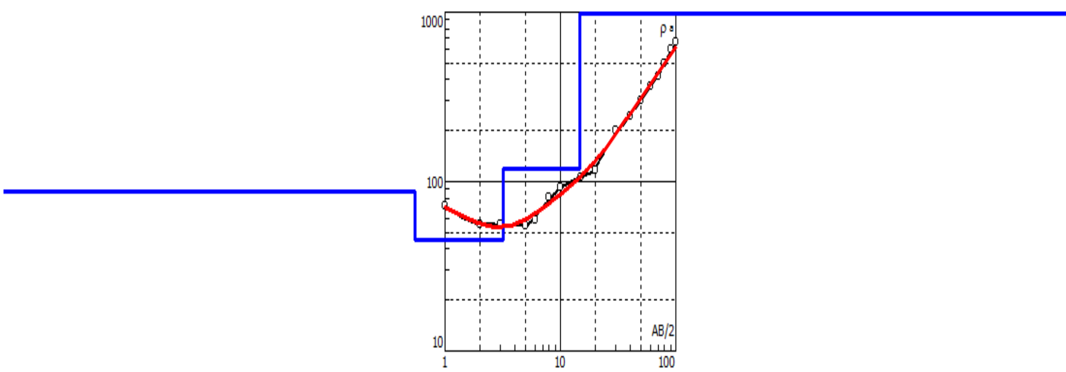
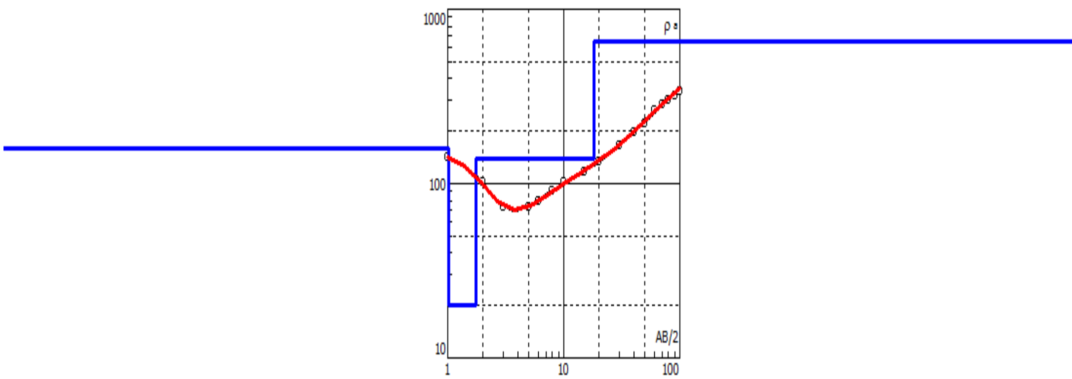


Figure 4a. Vertical geo-electric and geologic sections of profile C.



N	ρ	h	d	Alt
1	86.6	0.547	0.547	-0.547
2	45.3	2.62	3.17	-3.167
3	120	11.6	14.8	-14.77
4	130179			

VES 4



N	ρ	h	d	Alt
1	159	1.03	1.03	-1.029
2	19.9	0.72	1.75	-1.749
3	139	16.5	18.2	-18.25
4	651			

VES 5

Figure 4b. Log graphs and resistivity-depth tables of VES C_4 and VES C_5.

to 1.30 m with its resistivity ranging between 68.3 and 519 Ωm. The layer is mostly fadama loam and lateritic soil except for VES points A_1 with isolated resistivity which is indicative of soil rich in organic matter (humus soil). The second lithological unit comprises of sandy, clay or highly weathered/fractured basement which is hydro-geologically called saprolite/saprock (Rao, 1987). It is a good site for optimum aquifer potential. The thickness varies between 0.64 and 34.1 m. VES A_5 happened to be the deepest having a depth of 35.6 m with a maximum resistivity of 186 Ωm (Figure 4b). The fresh basement is characterized by high resistivity values with negligible aquifer potential. It ranges between 1,993 and 114,120 Ωm.

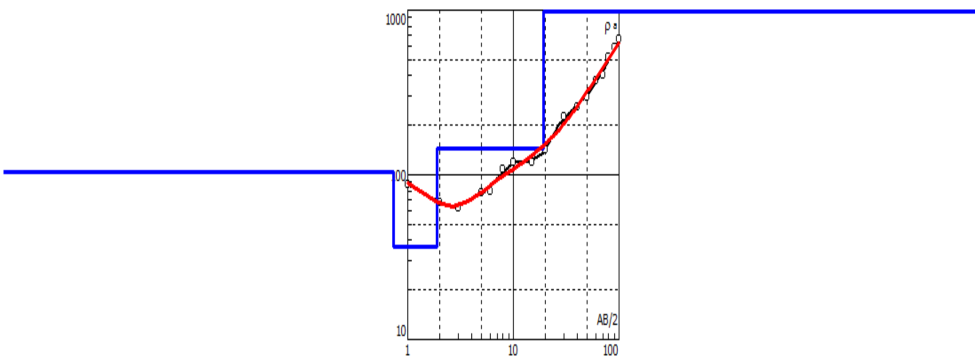
Maximum first layer thickness on profile C as indicated in Figure 4a is 1.03 m at VES C_5 and a minimum of 0.5 m at VES C_1, as resistivity ranges between 135 and 2663 Ωm. Second layer resistivity ranges between 21.7 and 315 Ωm with a maximum layer thickness of 18.2 m at VES C_3 and VES C_5 and the minimum thickness of 0.9 m at VES C_2. The last layer resistivity also ranges between 651 and 142,281 Ωm. The three geo-electric sections are a topsoil first layer, weathered/fractured basement second layer which has very low resistivity values and fresh basement that is the third layer.

The VES C_5 on this profile can be said to have optimum aquifer potential having a thickness of 16.5 m at the weathered/fractured basement, resistivity value of 139 Ωm and a depth of 18.2 m. Resistivity value of 315 Ωm at similar depth on VES C_3 makes it a less desirable aquifer on this profile (Figures 4a and 4b). This is in agreement with the work of Olayinka et al. (1997).

The first layer thickness on profile D as indicated in Figure 5a has a maximum of 1.08 m at VES D_5 and a minimum of 0.5 m at VES D_2, as resistivity ranges between 57 and 883 Ωm. Second layer resistivity ranges between 6.7 and 219 Ωm with a maximum layer thickness of 29.9 m at VES D_5 and the minimum thickness of 1.34 m at VES D_1. The last layer resistivity also ranges between 614 and 159,108 Ωm.

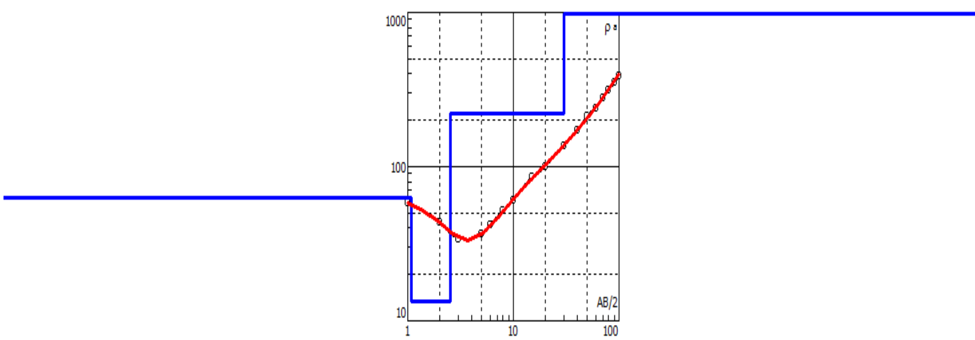
The three geo-electric sections are a topsoil first layer, weathered/fractured basement second layer which has very low resistivity values and fresh basement that is the third layer. It is noteworthy that on this profile, VES D_4 and VES D_5 all had four layers on the log table (figure 5b) which indicated well weathered/fractured points and desirable aquifers having depths of 19.2 and 29.9 m respectively.

Comparing the result of the interpreted VES data with information from available lithological logs of boreholes drilled by Cemaco Venture Limited (Jimoh, 1998) as indicated in Figure 6 that is an area lying in the same



N	ρ	h	d	Alt
1	103	0.736	0.736	-0.736
2	36.8	1.14	1.88	-1.876
3	145	17.3	19.2	-19.18
4	159108			

VES 4



N	ρ	h	d	Alt
1	62.8	1.08	1.08	-1.083
2	13.3	1.44	2.53	-2.526
3	219	27.4	29.9	-29.91
4	22592			

VES 5

Figure 5b. Log graphs and resistivity-depth tables VES D_4 and VES D_5.

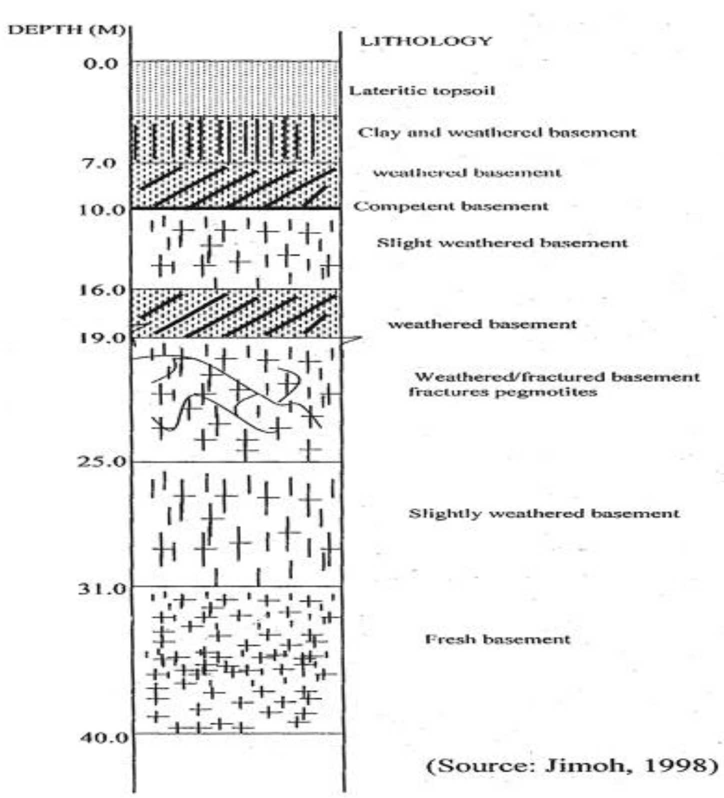


Figure 6. Drilling Log for the Borehole around the Students Hostel, Federal University of Technology, Gidan Kwanu, Minna.

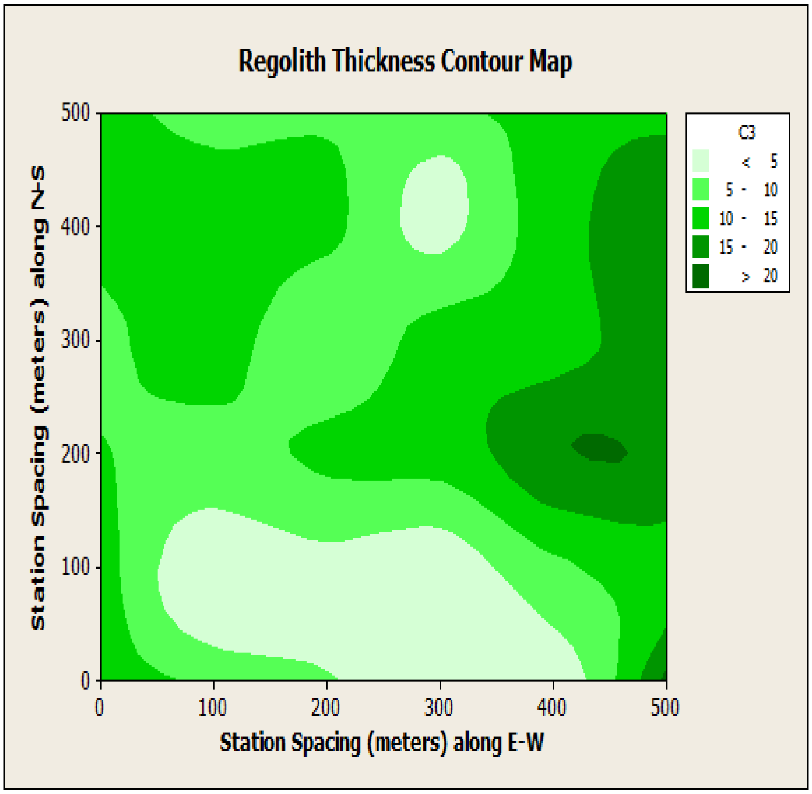


Figure 7. Regolith thickness contour map.

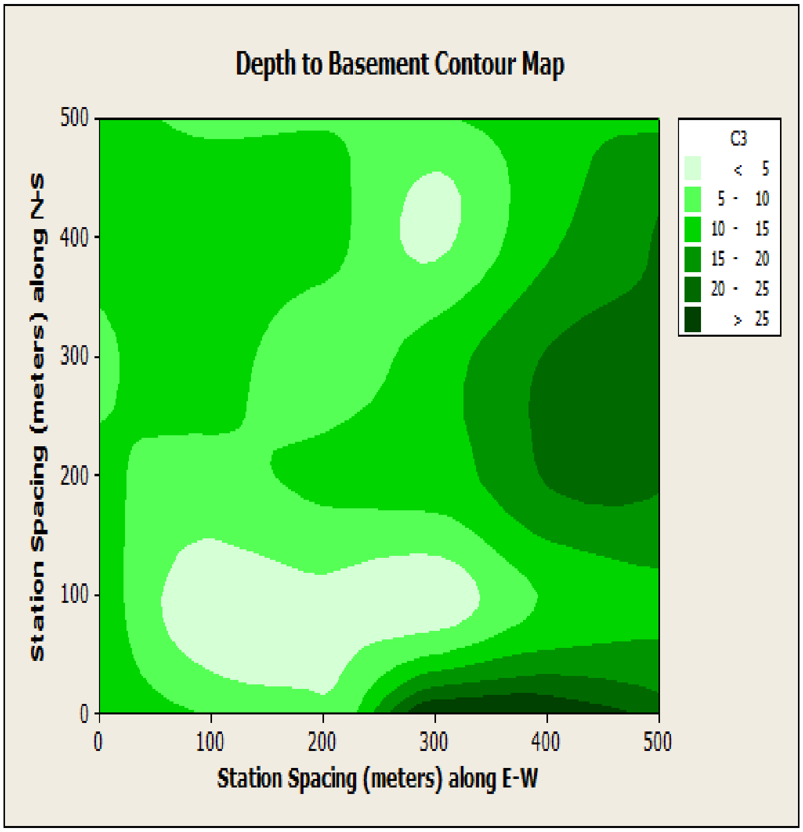


Figure 8. Depth to basement map.

Table 1. Resistivity Values of Rock Types in Basement Area {(Compiled from Previous Work in and around Kaduna) after Ajayi and Hassan, 1990}.

Rock type	Resistivity (ohm-m)
Fadama loam	30 – 90
Sandy	100 – 200
Sand and Gravel	100 – 180
Weathered Lateritic	150 – 900
Fresh Lateritic	900 – 3500
Weathered Basement	20 – 500
Fractured Basement	500 – 1000
Fresh Basement	>1000

Table 2. Thickness of geologic layers in hard rock areas (Rao, 1987).

Layer No.	Particular soil	Thickness (m)
1.	Soil	1 – 2
2.	Weathered layer (Saprolite)	10 – 20
3.	Semi-weathered/ fractured hard rock (Saprock)	10 – 30
4.	Fresh bedrock	Up to infinity

Table 3. Calibration of Regolith Resistivity in Terms of Aquifer Potential (Wright, 1992: Olayinka, 1997).

Regolith resistivity (ohm-m)	Aquifer potential
< 20	Clay with limited potential
20 – 100	Optimum weathering and groundwater potential
100 – 150	Medium conditions and potential
150 – 300	Limited weathering and poor potential
> 300	Negligible potential

Table 4. Aquifer potential as a function of bedrock resistivity (Wright, 1992: Olayinka *et al*, 1997).

Fractured bedrock resistivity (ohm-m)	Aquifer potential
< 750	High fractured permeability as a result of weathering: High aquifer potential
750 – 1500	Reduced influence of weathering: Medium aquifer potential
1500 – 3000	Fairly low effect of weathering: Low aquifer potential
> 3000	Little or no weathering of bedrock: Negligible potential

coordinates, it was deduced that there are basically three lithological units in the study area.

The regolith thickness contour map (Figure 7) clearly gave indications of the nature of weathered layer with depth and extent of fracture. This further aided the interpretation of areas with good aquifer potential and these are the areas with regolith thickness above 15 m.

The map of depth to basement showed areas that have their basement uplifted and therefore having shallow overburden. This is prominent at the southwest and north central part of the study area. The areas with basement depth between 20.0 m and 35.0 m are the areas characterized by low land and fadama good for ground water. These areas could be found around the eastern region (C_5-C_6 and D_5-D_6) and are characterized by very thick overburden as seen in Figures 7 and 8.

Other works that further confirms the lithological composition of Pompo, the study area and it results are Ajayi and Hassan (1990) (Table 1), Rao (1987) (Table 2), Olayinka et al. (1997) (Tables 3 and 4). Table 2 and 3 are respectively the calibration of saprock resistivity and regolith resistivity in terms of aquifer characteristics as modified by Olayinka et al. (1997) after Wright (1992).

Conclusion

Weathered and fractured basement constitute the aquifer system found in the study area. The best areas identified for groundwater exploitation are the eastern region (VES points C_5-C_6 and D_5-D_6). The south-western part of the study area where basement is prominently shallow with light fracture, is however good for civil engineering works at low risk.

Recommendations

Finally, the areas characterized as good aquifer should be drilled and the water collected and analysed to ascertain its portability. Rock samples from those areas stated as good for civil and engineering works could be collected for further analysis.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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