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Groundwater Targeting Within The Basement Complex Rocks Of Federal Capital Territory Abuja Using Remotely Sensed And Vertical Electrical Sounding Data

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ABSTRACT: Federal Capital Territory, Abuja largely falls within the North-Central Basement Complex of Nigeria, which is underlain by crystalline basement rocks. Groundwater resources in the crystalline basement complex are restricted to features produce by weathering and tectonic processes and therefore the reason to locate fracture/weathered zone to ensure maximum and sustainable yield. This study was carried out to illustrate the application of vertical electrical sounding (VES) and remote sensing techniques for efficient groundwater resources. The advent of computer software and associated numerical modeling aided such approach for groundwater exploration more especially in a regional scale. The modeling of the VES measurements carried out at Nineteen (19) stations has been used to derive the sub-surface geo-electric sections for the various profiles. Geologic sequence in the study area is composed of three to six sub-surface layers. The first layer is the top soil with resistivity ranging from 32.32- 73.1 ohm-m and a thickness range from 0.6m – 1.96m, Second layer is a lateritic layer ranging from 112.6 to 190.8 ohm-m with a thickness range of 0.65 to 1.96m, weathered basement ranging from 68.26 to 796.4 ohm-m with thickness range of 2.96 to 5.44m as the third layer. The fourth layer with resistivity value range between 50.2 to 205.6 ohm-m and thickness range of 4.23 to 43.95m is noted as the weathered/fractured basement (water bearing). The layer is extensive and thickest at VES station 5and 6, thus serve as a good reservoir for groundwater exploration. The fifth layer is presumably fresh basement whose resistivity values vary from 1049Ωm to 49334Ωm with an infinite depth.

KEY WORDS: Layer, VES, Weathered basement, Tectonic, Remote Sensing

INTRODUCTION

Discontinuity as structural trends can be studied in many forms, such as faults, joints, bedding planes or foliations which are useful in studies such as hydrogeology, mineral exploration and environmental studies. Lineaments are detected by ground mapping as a discontinuity as well as by the use of remotely sensed data such as conventional aerial photographs and satellite imagery. In the cause of this study a SPOT 5 satellite imagery covering FCT, Abuja was digitized for lineaments. Lineament in this study is defined as a mappable linear feature of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differ from the pattern of adjacent features and presumably reflect some subsurface phenomenon (O'Leary et al. 1976). Morelli and Piana (2006) shows that the good correlation between structures mapped in the field and using the lineament system enable the lineament to be regarded as representative of the structural indication of a particular area. It's certain that remote sensing approach provides a means for regional understanding of groundwater system, such that data from it provides information on spatial patterns of groundwater. Interpretation of remotely sensed data for linear features mapping is noted as an integral part of groundwater exploration programmes in hard rock terrain (Gustafsson, 1993). Remote sensing with advantages of spatial, spectral and temporal availability of data capturing of large-inaccessible areas within short time became a remarkable and approachable tool in monitoring and evaluation of potential groundwater resources. Syed and Saeid, (2004) noted that the application of satellite imagery for geological structural analysis is becoming increasingly popular, therefore, structural interpretation cum vertical electrical sounding (VES) is seen a technique for mapping and predicting for groundwater phenomenon within the FCT, Abuja.

THE STUDY AREA

The Federal Capital Territory, Abuja (fig. 1) is situated in the central part of Nigeria, between latitudes 8° 25' and 9° 25' North and longitudes 6° 47' and 7° 40' East. It is bounded in the north by Kaduna State, in the west by Niger State, in the east by Nasarawa State and Kogi State in the south-west.

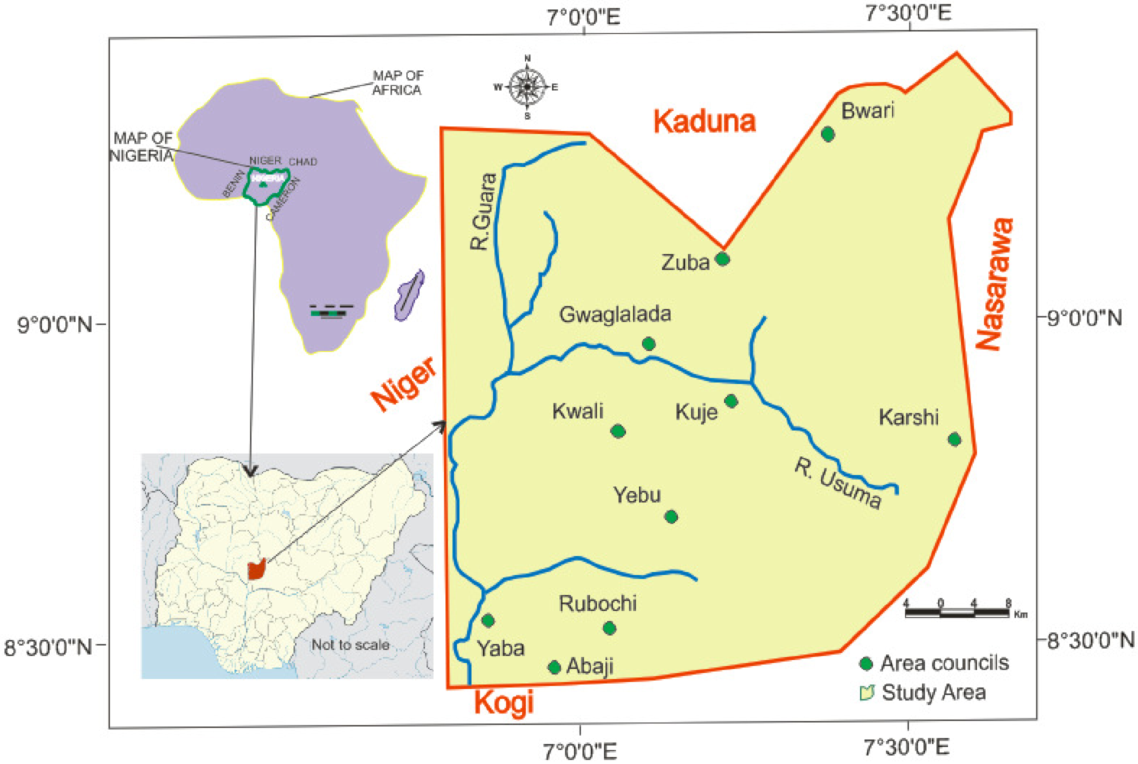

Figure 1: *Location Map of Federal capital Territory, Abuja*

Geology of the FCT, Abuja

The Federal Capital Territory, Abuja is majorly underlain by crystalline rocks of north-central basement complex. The Nigerian basement complex lies in the Pan-African mobile belt which has been affected by Pan-African events through the ages of orogenic, tectonic and metamorphic cycles (Oyawoye 1964). Geologically, the lithological units in the FCT, Abuja include migmatite, granite gneiss, Quartzo-fedspathic gneiss, Undefferentiated schist, porphyritic biotite, marble and Nupe sandstone of lower Turonian age covering less than 5% within the FCT, Abuja (Fig. 2).

Hydrogeology and Geomorphology

In tropical and equatorial regions, weathering processes create superficial layer with varying degree of porosity and permeability. If significantly thick, unconsolidated overburden could constitute reliable aquifer (Bala and Ike, 2001). Also, the concealed basement rocks may contain highly faulted and folded area, joint and fracture systems resulted from multiple tectonic events they have experienced. These structures may house abundant groundwater in a typical basement setting. The detection and delineation of such structural trends that are diagnosed by lineament may facilitate location of groundwater prospective zones. The FCT, Abuja lies within the Guinea savannah vegetation belt and experiences two seasons, namely dry and wet seasons. The dry season starts in November to March while the rainy season starts from April and ends in October.

METHODOLOGY

The SPOT 5 Imagery

In this work, SPOT 5 satellite imagery (Fig. 3) was used. The use of this imagery is due to the higher spatial resolution of 5m. This has also proved useful for mapping smaller features not resolvable on Landsat TM data. The SPOT 5 imagery covering the FCT, Abuja was geo-referenced using the identifiable features such as river etc on the geological map of the FCT, and was then subsisted and used for the lineament mapping.

Lineament Mapping

Structural features in hard rock, such as the crystalline rocks of the Basement complex underlying the FCT, Abuja are often visible on remote sensing data as topographic, drainage, vegetation or soil tonal anomalies. One of the common assumptions of lineaments mapping for groundwater exploration is that these features represent vertical zones of fracture concentration (Blanchet, 1957). Lineament mapping is normally undertaken based on geomorphologic features such as aligned ridges and valleys, displacement of ridge lines, scarp faces and river passages, straight drainage channel segments, pronounced breaks in crystalline rock masses and aligned surface depression (Koch and Mather, 1997). For the FCT, Abuja, the main interest was pronounced breaks in crystalline rock masses, which may represent joints, faults and probably shear zones. Lineaments in the FCT, Abuja (Fig. 40) were processed and interpreted in the Arc GIS 9.3 computer's software environment developed by ESRI, 2008 copyright edition.

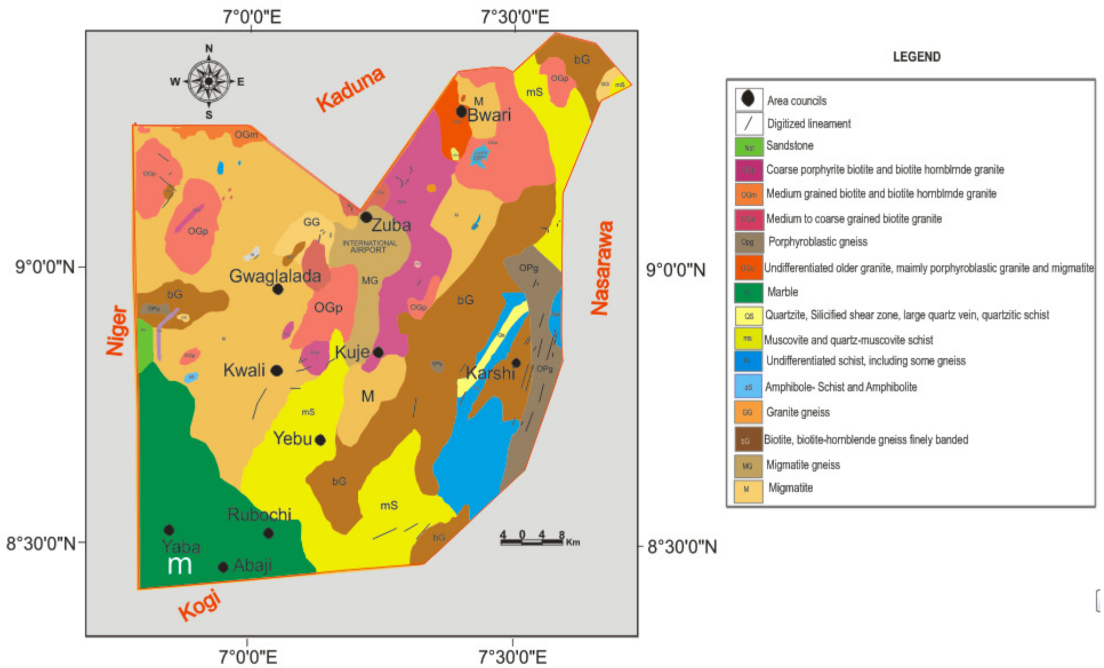

Figure 2: *Geological Map of Federal Capital Territory, Abuja (modified from NGSA, 2006) and superimposed on digitized lineaments from SPOT 5 Imagery*

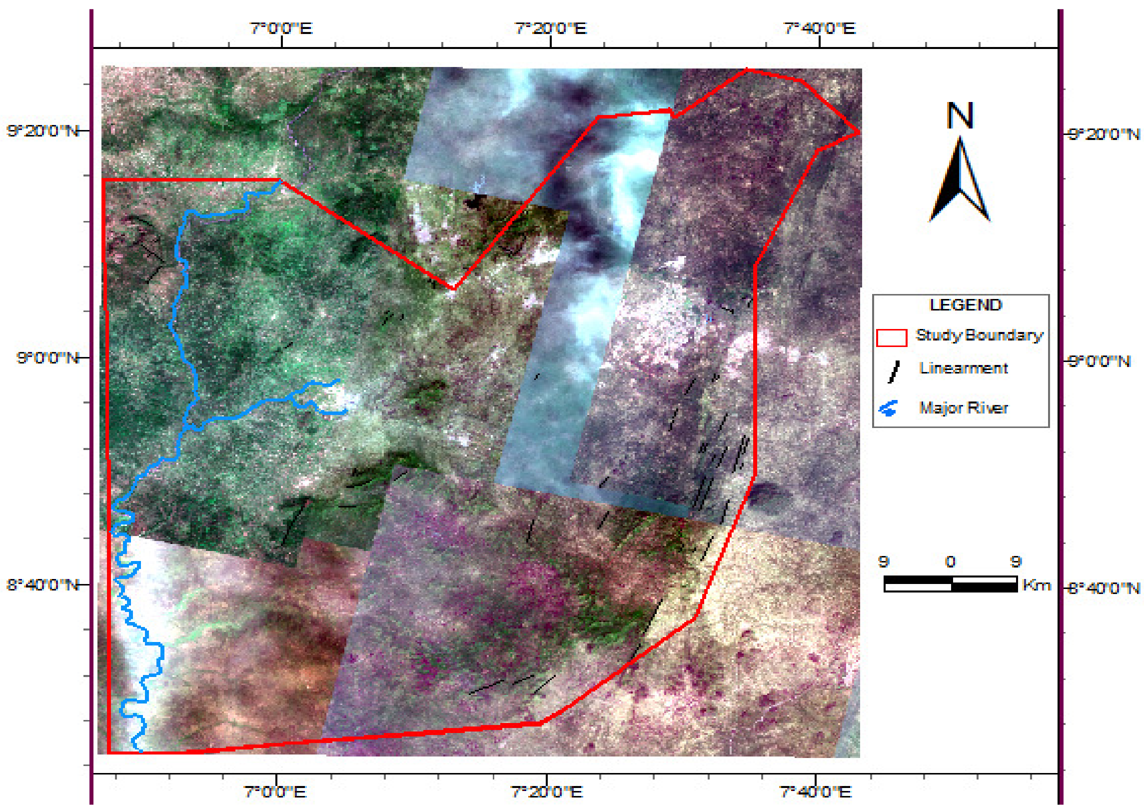

Figure 3: *SPOT 5 satellite imagery covering the FCT, Abuja*

Vertical Electrical Sounding (VES)

The Schlumberger array of electrodes provides for high signal-to-noise ratios, good resolution of horizontal layers, and good depth sensitivity (Ward, 1990). Vertical Electrical Soundings (VES) used for this study is the modified Schlumberger array carried out at fifteen (15) stations. One of the current electrodes, C2 is kept at infinity (≥100m) distance perpendicular to the centre of the spread hence not collinear with the other three electrodes; it is at right angle to the other collinear electrodes. The current electrode C1 spread AB/2 varies from 1m to 120m. The potential electrode separation MN was also increased accordingly but did not exceed 15m as suggested by (Dobrin and Savit, 1988) that potential difference should not exceed one-fifth of the half-current electrode separation. The apparent resistivity measurements at each VES stations of the modified array were plotted against electrode spacing on bi logarithmic graph sheets. The resulting curves were then inspected visually to determine the nature of the subsurface layering delineated using the IPI2win software. The instrument used for this survey is the ABEM SAS 1000 Terrameter.

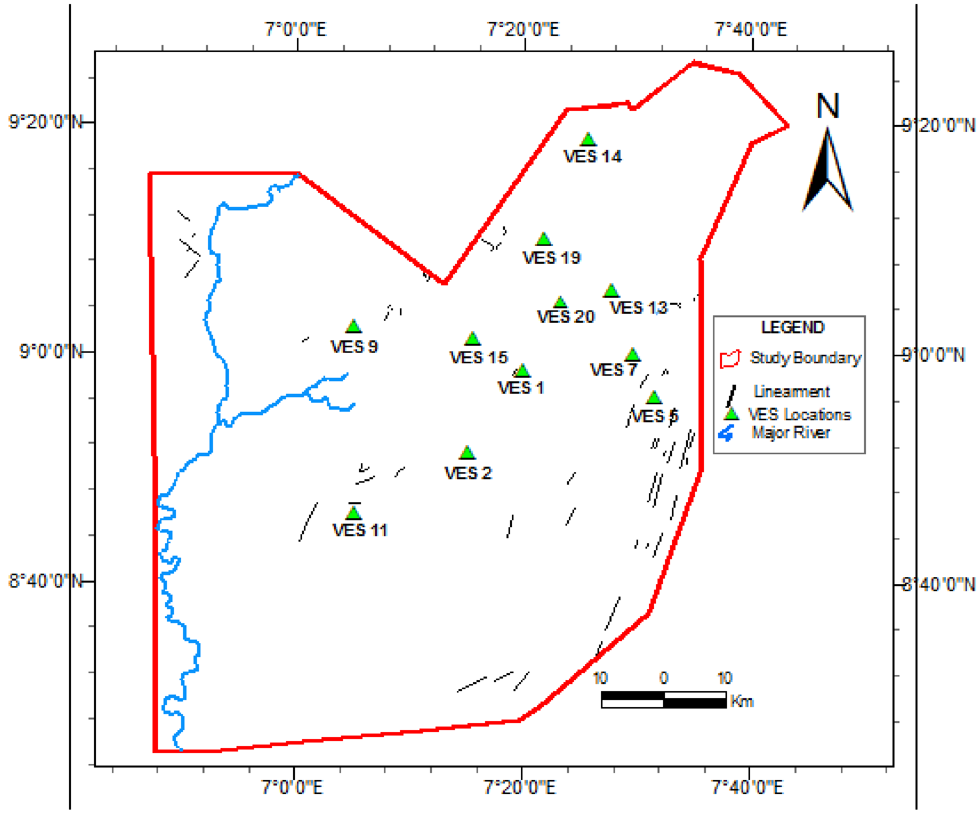

Figure 4: *Structural analyzed map of the FCT, Abuja from SPOT 5 satellite imagery showing some VES locations.*

RESULTS AND DISCUSSION

The digitized lineaments from SPOT 5 satellite imagery was superimposed on geological map covering the Federal Capital Territory, Abuja. An attempt to unravel the subsurface geo-electric section using vertical electric sounding method was also carried out. The geometric factor, K, was first calculated for all the electrode spacing using the formula; K= π (L2/2b – b/2), for Schlumberger array with MN=2b and 1/2AB=L. Resistance values obtained from the terrameter were multiplied with the calculated 'K' to obtain apparent resistivity, ρa. The field data were interpreted and processed qualitatively and quantitatively using partial curve matching computer software techniques *IPI2win* to obtain the resistivity values of Nineteen (19) VES locations of their different subsurface layers and corresponding thickness (Table 1). From interpretation of the VES curves, 3 to 6 subsurface layer where identified within the study area. The Federal Capital Territory, Abuja are studied for various curves (Fig. 5 to 16) which are prominently AKK, KA, KHA, HK, K, KHK, H, AKK, HKK, KQK AND KH. The presence of these curves suggests inhomogeneous nature of the sub-surface rocks as regards to groundwater exploration. These curves were interpreted using the two layer partial curve matching technique. The first layer is the top soil with resistivity ranging from 32.32- 73.1 ohm-m and a thickness range from 0.6m – 1.96m, Second layer is a lateritic layer ranging from 112.6 to 190.8 ohm-m with a thickness range of 0.65 to 1.96m, weathered basement ranging from 68.26 to 796.4 ohm-m with thickness range of 2.96 to 5.44m as the third layer. The fourth layer with resistivity value range between 50.2 to 205.6 ohm-m and thickness range of 4.23 to 43.95m is noted as the weathered/fractured basement (water bearing). The layer is extensive and thickest at VES 5and 6 within the lineament zone and thus serve as a good reservoir for groundwater exploration. The fifth layer is presumably fresh basement whose resistivity values vary from 1049Ωm to 49334Ωm with an infinite depth.

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Table 1: Summary of interpreted VES curves

VES Stations	Layer resistivity (Ωm)	Thickness (m)	Curve types	Number of layer	Name of VES location
1	112.6 796.4 68.26 1147 4.284	1.148 1.323 8.497 12.13 -	AKK	5	Lugbe
2	73.1 148 50.5 3934	0.6 0.65 4.23 -	KA	4	Kuje
3	258.1 476.6 175.6 59.71 1528	0.38 0.83 2.96 7.76 -	KHA	5	Apo
4	32.39 27.32 251.4 0.3959	0.9302 3.262 25.81 -	HK	4	Rubochi
5	60.33 141.5 88.97 114.6 281 49334	0.6 0.69 4.72 21.9 32.15 -	KHA	6	Karshi
6	158.8 205.6 0.5312	2.27 43.95 -	K	3	Kwali
7	470.4 144.8 3099 333.1 1049	2.462 2.642 5.448 8.106 -	KHK	5	Apo
8	197.7 106.6 1334	0.75 2.28 -	H	3	Zuba
9	190.8 663.3 196.6 909 59.2 4358	1.611 2.488 7.907 13.15 32.54 -	AKK	6	Gwagwagwala
10	153.7 221.1 149.9 621.1 42.66	0.241 1.867 3.112 32.17 -	HKK	5	Kwali
11	183.7 231.1 140.9 721.1 45.66	0.4207 1.695 2.112 38.47 -	HKK	5	Kwali
12	107 231 694 26 249 20.8	0.287 1.85 3.04 4.96 15.8 -	KQK	6	Mabushi
13	176.8	1.742	H	3	Kubwa

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	56.09 676.6	9.243 -			
14	491 161 1442 427 147	1.27 1.25 1.41 26.4 -	HKQ	5	Bwari
15	68 26.8 16040	1.96 2.07 -	H	3	Deidei
16	188.7 104.6 1354	0.65 2.18 -	H	3	Kurudu
17	292.8 585.1 134 50.15 1234	0.6 0.654 4.223 5.97 -	KHA	5	Karu
18	552.4 303.5 1441 650.4	1.294 111.65 47.12 -	HK	4	Zuba
19	162 2738 103 304	1.06 1.45 2.67 -	KH	4	Gwarinpa

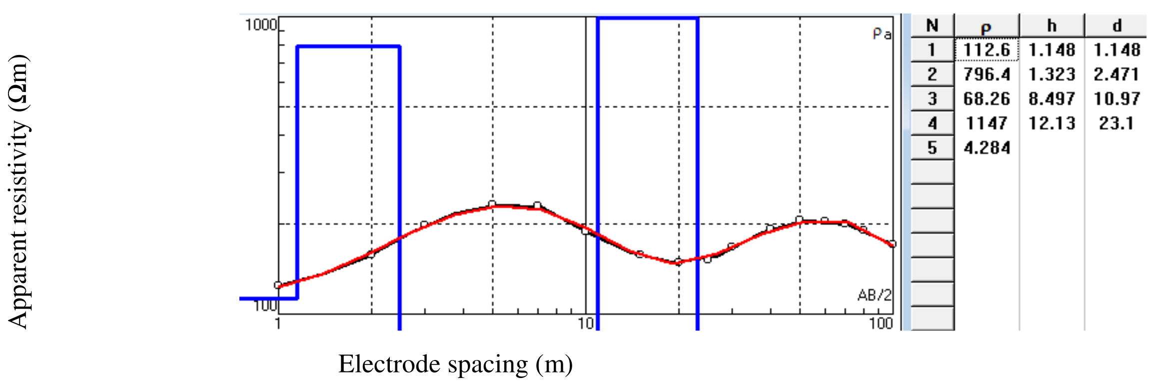

Fig. 5: *VES 1 Station at Lugbe*

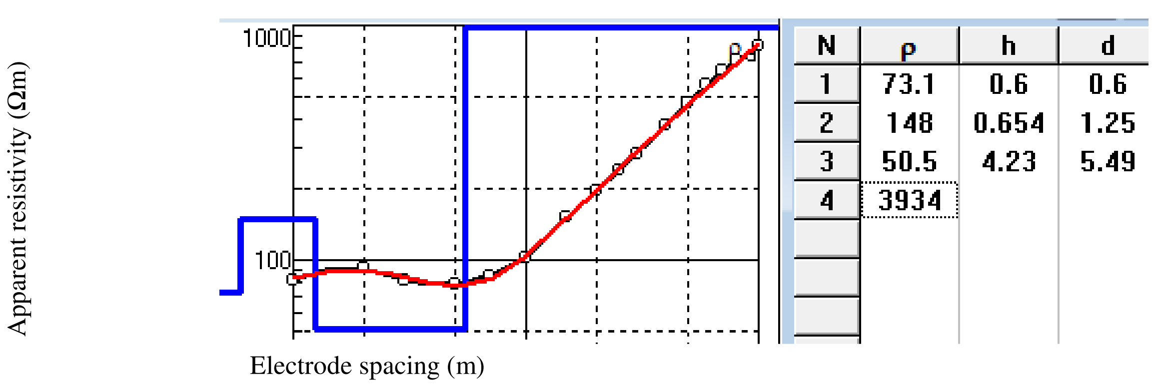

Fig. 6: *VES 2 Station at Kuje*

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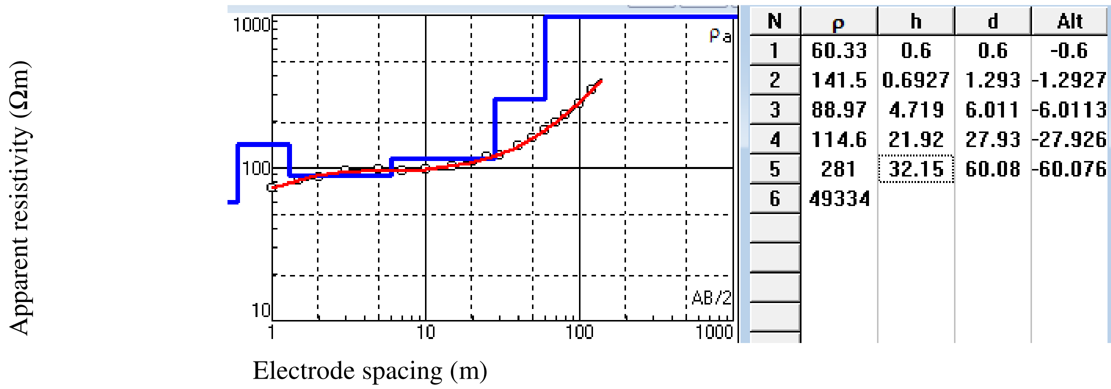
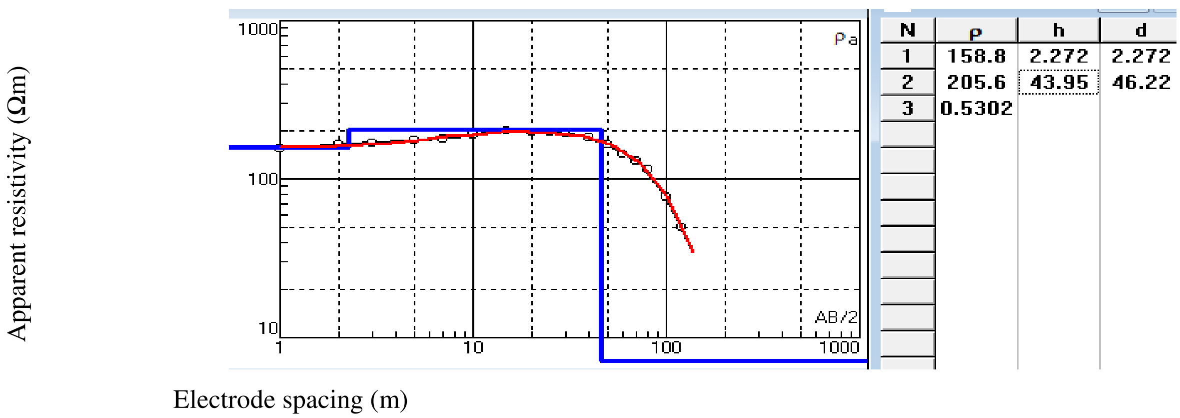


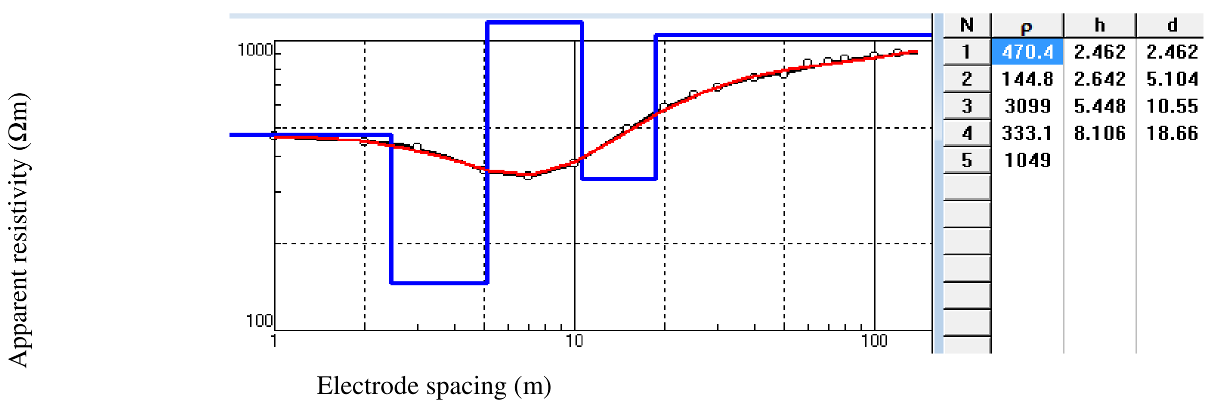
N	ρ	h	d	Alt
1	60.33	0.6	0.6	-0.6
2	141.5	0.6927	1.293	-1.2927
3	88.97	4.719	6.011	-6.0113
4	114.6	21.92	27.93	-27.926
5	281	32.15	60.08	-60.076
6	49334			

Fig. 7: *VES 5 Station at Karshi*



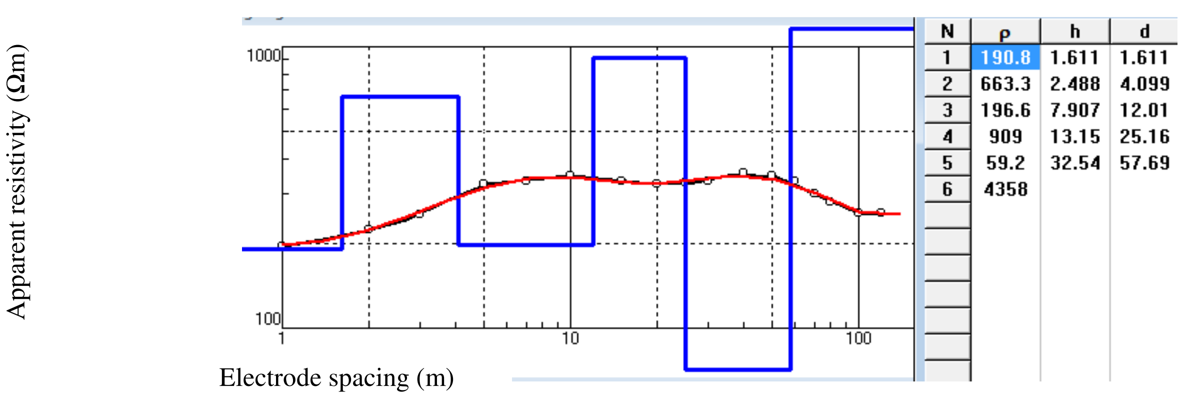
N	ρ	h	d
1	158.8	2.272	2.272
2	205.6	43.95	46.22
3	0.5302		

Fig. 8: *VES 6 Station at Kwali*



N	ρ	h	d
1	470.4	2.462	2.462
2	144.8	2.642	5.104
3	3099	5.448	10.55
4	333.1	8.106	18.66
5	1049		

Fig. 9: *VES 7 Station at Apo resettlement*



N	ρ	h	d
1	190.8	1.611	1.611
2	663.3	2.488	4.099
3	196.6	7.907	12.01
4	909	13.15	25.16
5	59.2	32.54	57.69
6	4358		

Fig. 10: *VES 9 Station at Gwagwalada*

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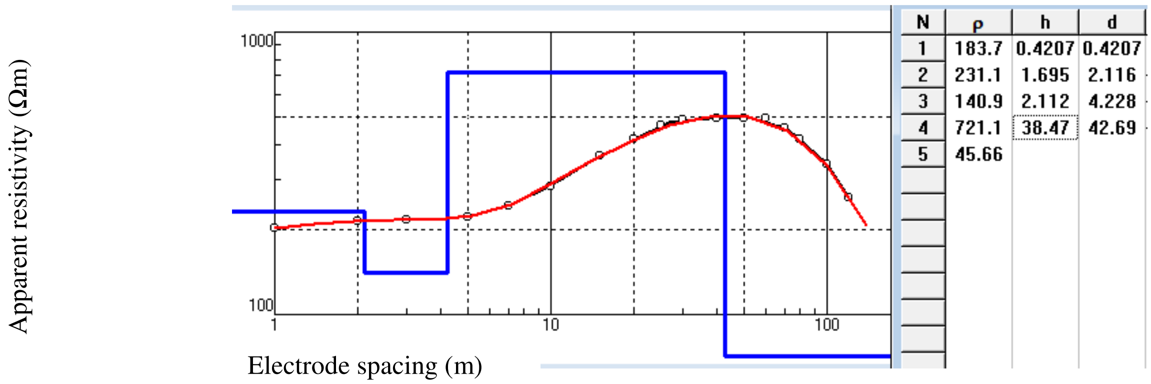
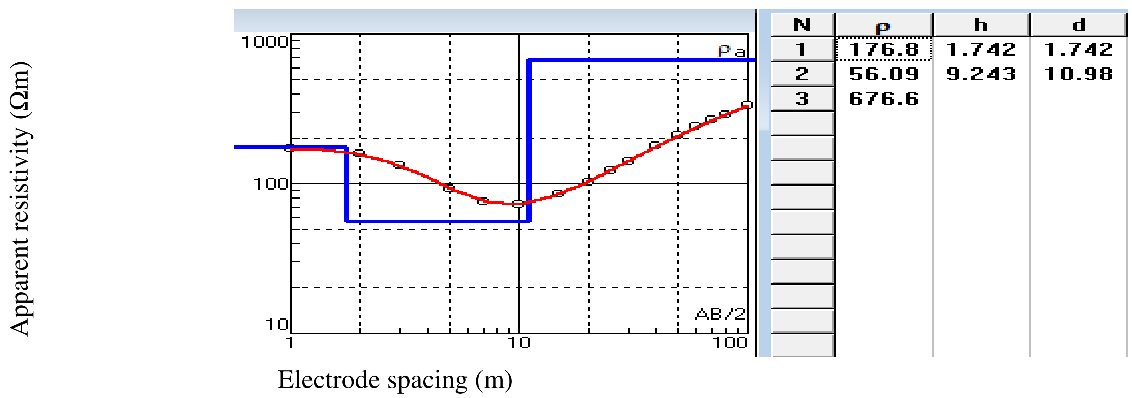


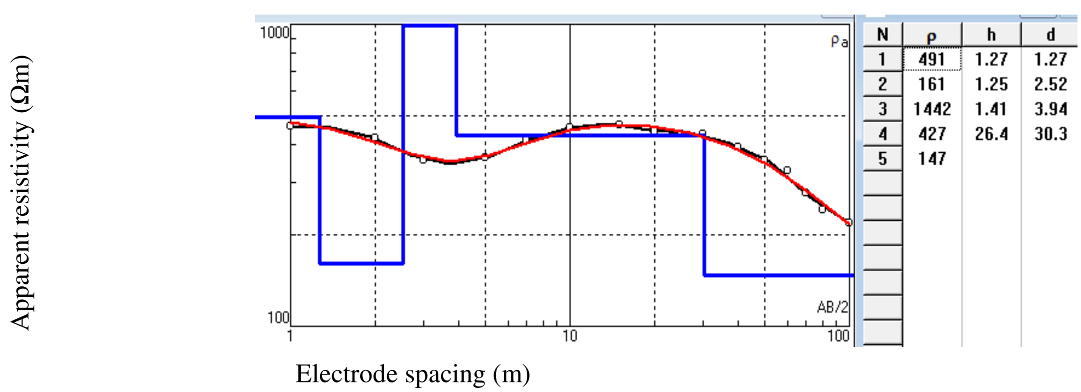
N	ρ	h	d
1	183.7	0.4207	0.4207
2	231.1	1.695	2.116
3	140.9	2.112	4.228
4	721.1	38.47	42.69
5	45.66		

***Fig. 11:** VES 11 Station at Kwali*



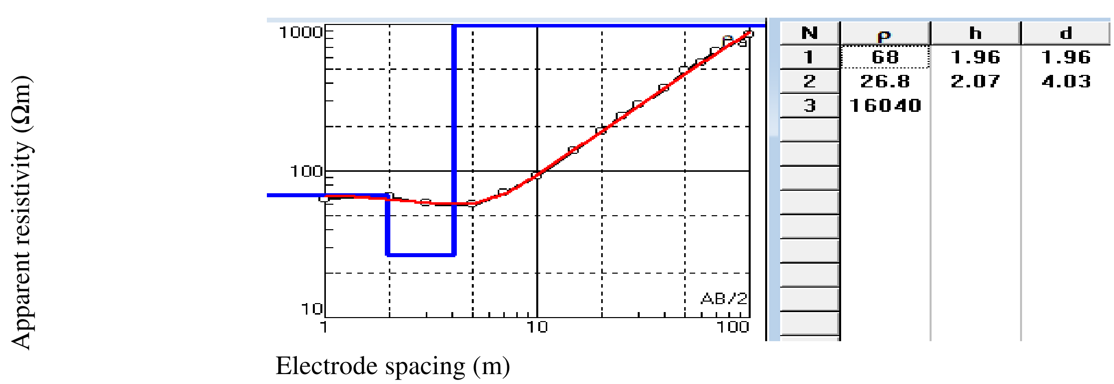
N	ρ	h	d
1	176.8	1.742	1.742
2	56.09	9.243	10.98
3	676.6		

***Fig. 12:** VES 13 Station at Kubwa*



N	ρ	h	d
1	491	1.27	1.27
2	161	1.25	2.52
3	1442	1.41	3.94
4	427	26.4	30.3
5	147		

***Fig. 13:** VES 14 Station at Bwari*



N	ρ	h	d
1	68	1.96	1.96
2	26.8	2.07	4.03
3	16040		

***Fig. 14:** VES 15 Station at Deidei*

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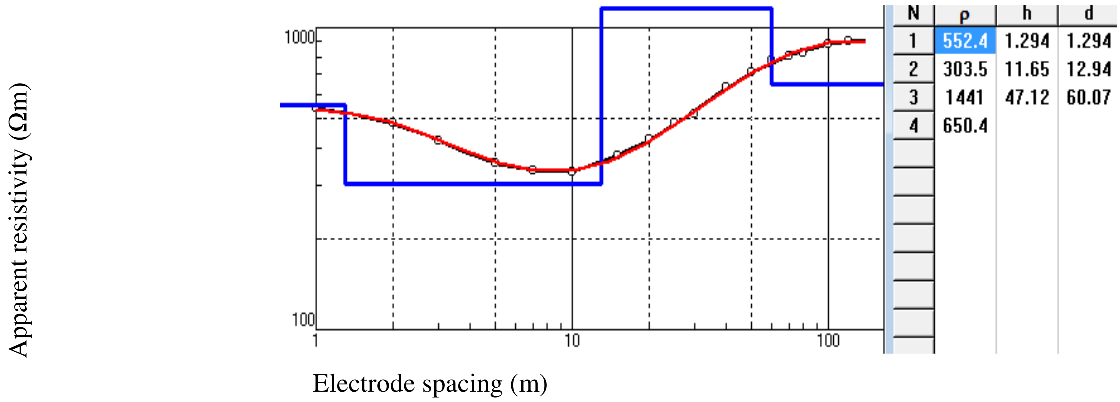

Fig. 15: *VES 18 Station at Zuba*

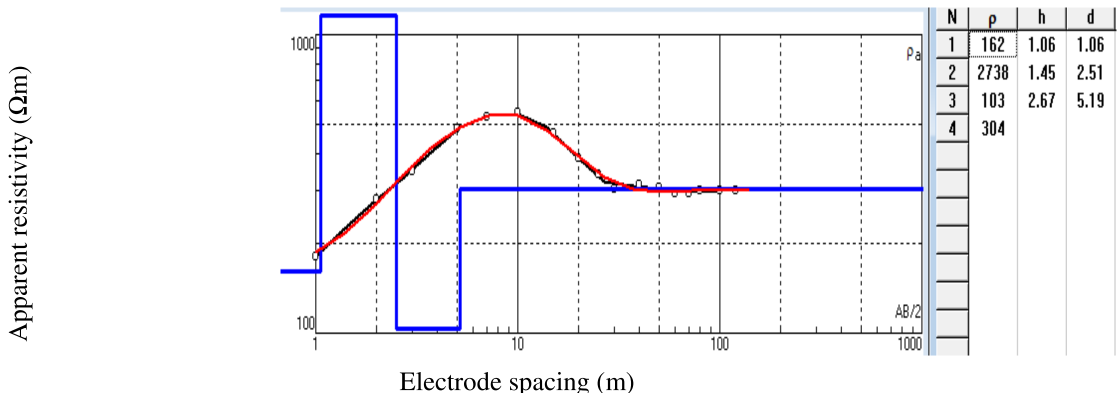

Fig. 16: *VES 19 Station at Gwarinpa*

***NOTE**: N= Number of layer, p= Apparent resistivity and h= Thickness*

CONCLUSIONS

Increase in the movements of people from other part of the country to seek for better job into the Federal Capital Territory, Abuja especially in the suburb in turn increases the demand for portable water. Meanwhile portable water within and outside the city is only assessed through the sinking of borehole apart from the pipe borne water by the government which is not widely distributed. Remote sensing has proved to be a useful tool in lineament identification and mapping especially for groundwater study. Present work has also shown that in a hard rock environment, Vertical Electrical Sounding (VES) proved to be very reliable for underground water studies and therefore the method can excellently be used for shallow and deep underground water geophysical resistivity investigation. This study demonstrates lineament interpretation in a Basement Complex environment of Federal Capital Territory, Abuja and result indicates that the area has numerous long and short fractures whose structural trends are mainly in northeast-southwest direction which corresponds with the major tectonic structural trend of the basement complex. Combination of the geo-electric data with the extracted lineaments will serve as a guide for borehole drilling and completion for groundwater.

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