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Geophysical Investigation for Engineering Site Development around Galadimawa-Aleita Area, Abuja, North Central Nigeria

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Abstract: *Fifty five (55) geo-electric resistivity soundings (VES) were carried out in profiles at interval of 250m and station interval of 200m around Galadimawa-Aleita area, Abuja in an attempt to have some detailed geotechnical information for planning purposes as regards infrastructural development which include buildings, roads, bridges and water supply through groundwater resources.The computer aided VES data interpretation enabled the determination and delineation of geo-electric layers and structures that have significance in infrastructural development and water supply.Geo-electric sections revealed 3-4 geo-electric layers/lithologic units of topsoil, laterite, weathered basement and resistive bedrock and are characterised by resistivity values of 122 to 600 ohm-m, 800 to 3385 ohm-m, < 100 to 5000 ohm-m and 120 ohm-m to infinity respectively. Variable thicknesses of 0.8 to 8m, 0.1-1m, and 4-8m were recognized for topsoil, laterite and weathered basement respectively. Depth to bedrock is variable from 0.8-24m across the area.Fractures were identified across the area with complex and major deformation around the central area, near the two abandoned quarries. These quarries were submerged by water issuing out of the sub-surface fault system which led to their abandonment by the quarry operators.The study revealed that overburden materials overlying bedrock are thin and characterized by minor and major fracturation which are significant in infrastructural development planning.*
Keywords: *Geophysical investigation, geotechnical planning, infrastructural development, Galadimawa-Aleita area, Abuja.*

I. Introduction

The use or application of geo-electric resistivity method for engineering site investigation and groundwater search in the last few decades has been on the increase due to its level of success, relatively cheap cost, appreciable accuracy and speed. Its application is mainly in the determination of depth to bedrock, nature of superficial deposit and structural mapping (Olorunfemi and Mesida 1987, Olorunfemi and Okhue 1992, Omosuyi et.al, 2003, Idornigie and Lawal (2006); Akintorinwa and Adeusi, 2009). The success of the method depends mainly on its significant and detectable contrast in the earth materials.

Galadimawa-Aleita old settlements in Lugbe District, Abuja along the Abuja Airport Express Way are potential areas for modern physical infrastructural development such as buildings, roads and bridges and possibly water supply. Therefore, the need to have detailed geotechnical information about the area has become necessary for planning purposes. It is in view of this fact that geophysical investigation employing vertical electrical soundings (VES) were carried out to determine the depth to bedrock, nature of superficial deposits, subsurface geological structures and groundwater potentials to provide a data base that will assist in any infrastructural development planning.

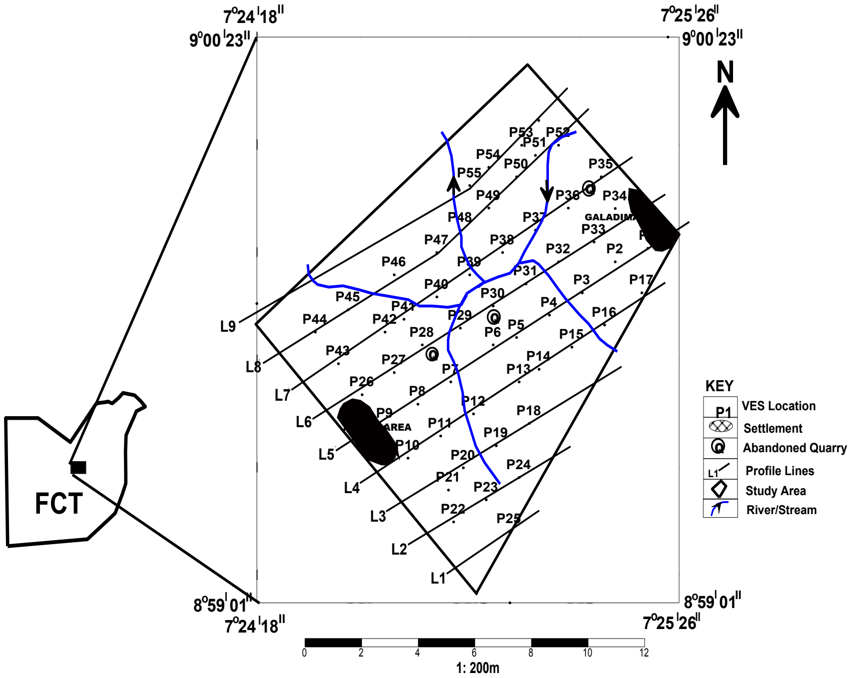

Fig.1a: Location and Drainage Map of the Study area.

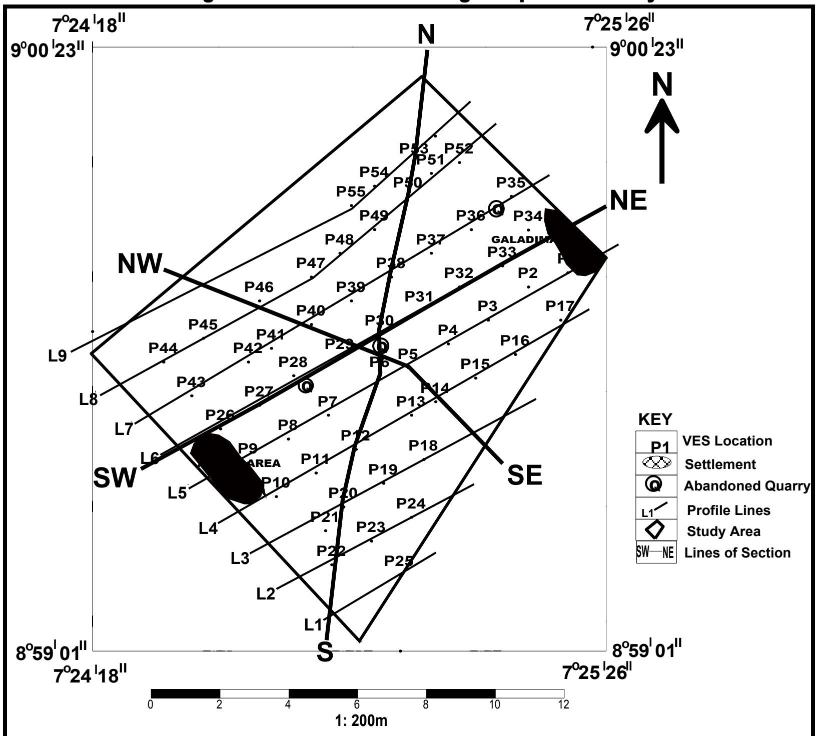

Fig.1b: Location Map Showing the VES Points.

Physiography

Galadimawa-Aleita area lies between longitude $7^{o}24^{I}18^{II}$ and $7^{o}25^{I}26^{II}$ and latitude $8^{o}59^{I}01^{II}$ and $9^{o}0^{I}23^{II}$ (Fig.1). The area is relatively undulating and generally slopes from the west and east towards the main drainage line and elevation varies between 410-453m above mean sea level.

The area is dissected by perennial streams to the east, south east, northwest and southwest. The predominant vegetation cover is typically of the Guinea Savannah and is characterized by the presence of palm trees, Parki spp, Anona Senegalensis, Daniella Oliveri, Pilios Tigma spp and Prosopis spp (ABU Consult, 1999).

The area is characterized by relics of rock quarries in the northeastern and central part. The central quarries have been flooded with water.

Geology

Offodile (2003) have described in some details the geology of the Federal Capital Territory(FCT), Abuja. It is underlain by two major rock formations - the Basement Complex and sedimentary rock formations (Fig 2). The stratigraphic succession is as follows:

S/No	Formation	Age
1.	Alluvium	Quaternary-Recent
2.	Nupe sandstone	Tertiary
3.	Basement complex	Pre-Cambrian

Basement Complex

The Basement Complex consists essentially of undifferentiated Precambrian rocks. This rock type underlies about 90% of the FCT and the rocks are distinguished in broad terms into migmatites, Older Granites and meta-sediments. The meta-sediments are generally restricted to the southeastern part of the Territory and occur as isolated strips and patches within the granite massifs.

The Nupe Sandstone

The Nupe Sandstone consists of argillaceous beds overlying sandy and gritty clays, clay stone and some conglomerates.

Alluvium

The Alluvium comprises of medium to coarse-grained river sands, silts and clays. It is generally confined to the riverbeds of the major drainage network of Gurara, Usuma and Robo.

Within the study area, the main lithologic units are migmatites, and migmatitic-gneiss which outcrops in the form of isolated hills in the north, northwest and southwestern segment of the area. The low lying areas are covered by soils derived mainly from the weathering of the basement rocks and occupies > 95% of the area.

The underlying rocks are only exposed at the quarries and within the stream channels.The general structural fabric strike 330NW.

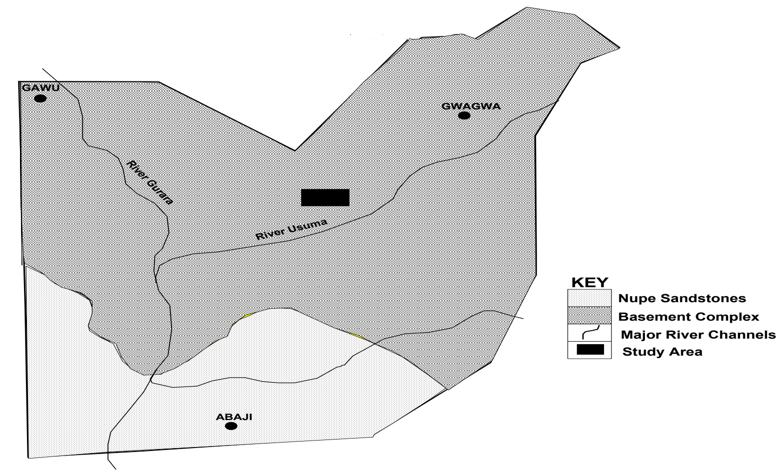

Fig 2: Geological Map of Federal Capital Territory, Abuja (Modified after NGSA (1984-1985)

Geophysical Investigation

The geophysical method used for the investigation programme was the geo-electrical resistivity sounding method employing the vertical electrical sounding technique (Schlumberger array) with current electrode or half electrode spacing AB/2 spreading from 1.5 to 125m. Measurements were made with increasing separation between current electrodes. The data for each spacing were recorded as apparent resistivity, which was multiplied by a geometric factor (K) to give apparent resistivity. A total of 55 VES numbered P1-P 55 were carried out at grid points established at intervals of 200m in profiles numbered L1 to L9 (Fig.1a). The earth resistivity measurement was carried out using ABEM Terrameter SAS 1000 model.

The VES were interpreted using VES interpretation software – Win Resist Version 1.0 (Vander Velpen, 1988, 2004) which is based on smoothness constrained optimization technique. The co-ordinates and elevation of the VES locations were obtained by the Garmin etrex 12 channel Global Positioning system.

II. Results And Discussion

The VES curve types identified in the area include: - A, AK, H, HK, QH, HKA, HA with H as the predominant curve type. The typical curve types are as shown in Fig 3(a-c). Table 1 gives the summary of the VES interpretation.

Table 1: Summary of VES Interpretation Result

VES	Curve Type	Layer Resistivity (Ohm-m)				Layer Thickness (m)			
		ρ_1	ρ_2	ρ_3	ρ_4	h1	h2	h3	h4
P1	QH	513	1285	120	≥ 136	1.2	3.7	11.8	
P2	H	2488	173	383		4.4	4		
P3	H	219	98	397		1.2	4.27		
P4	H	287	172	323		1.7	3.74		
P5	H	794	188	351		1.2	3.72		
P6	AKA	175	389	305.5	382	1.1	3.82	5.68	
P7	H	347	159	402		1.2	4.27		
P8	H	525	188	931		1.3	11.8		
P9	A	196	394	-		3.35			
P10	AK	487	2027	1914		2.3	8.32	12.4	
P11	H	390	163	445		1.1	2.25		
P12	H	1162	90.7	392		0.7	2.65		
P13	H	365	130	383		2.5	5.5		
P14	AK	644	3478	2205		3.4	19.45		
P15	H	474	158.3	539		2.8	10.3		
P16	H	433	87	456		0.8	10.9		
P17	QH	1303	310	626		6.1	13.1		
P18	A	806	-	-		1.1	-		
P19	HK	1443	413	1914	1207	1.3	4.8	22	
P20	HK	255	137	448		0.7	2.36	10.6	
P21	H	694	165	501		0.8	7.2		
P22	HKA	1121	500	790	1000	0.9	3.5	6	7
P23	H	354	71	266		2.8	9		
P24	A	429	1047			4.9	∞		
P25	H	1284	375	904		1.4	15.5	904	
P26	H	248	171	434		1.3	12.1	434	
P27	H	566	82	329		0.8	4.7	329	
P28	AK	478	2105	454	1677	4.8	9	28	
P29	HK	1504	659	755	2440	1.7	1.9	5	9
P30	AK	7624	18508	3609	8505	1.2	4.3	19.5	
P31	H	919	138	699		0.8	1.74		
P32	H	693	143	391		1.73	3.77		
P33	H	366	110	363		1.1	2.62		
P34	HA	897	265	707	1538	0.8	2.92		
P35	HKA	429	1994.5	3638	2143	0.9	9.2	12.9	
P36	HA	137	88	399	1155	0.7	4.13	9.1	
P37	H	3043	826	1188		1.92	2.22		
P38	HA	525	161	368	1356	1.2	4.3	6.2	
P39	HKA	675	368	4699		0.9	3.2	8.96	12.2
P40	HA	482	126	524		1.2	4.3	9.3	
P41	H	978	168	442		1.3	11.8		
P42	HA	258	164	616	2781	1.2	2.5	9.3	
P43	HKH	1177	359	779	281	0.9	1.92	3.3	13.11
P44	QH	524	712	288	535	6.1	13.1		
P45	H	153	62	451	-	1.7	6.3	-	
P46	H	651	51	-	-	1.2	5.8		
P47	H	723	60	270		1.2	6.8		
P48	H	1007	183	679		0.8	7.2		
P49	A	155	478	-		8			
P50	AK	569	3761	2678	2549	1.2	4.3	29	
P51	H	712	126	501		0.9	8.1		
P52	H	389	223	481		0.8	7.2		
P53	HK	326	180	675	523	0.8	4.7	2.5	17
P54	H	523	248	1231	-	1.7	5.3	-	
P55	H	579	118	498		0.8	4.3		

The results and the interpretation of the various VES curves are presented accordingly as geo-electric sections, histograms and maps which are discussed below: -

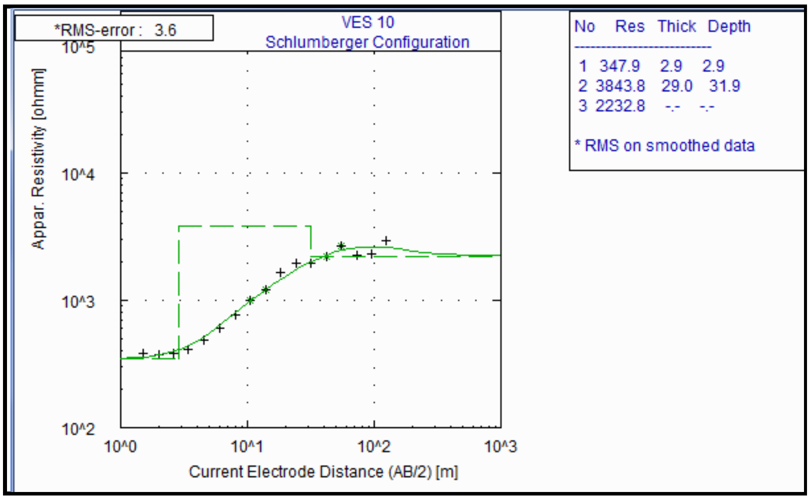

Fig.3a: A Type Curve

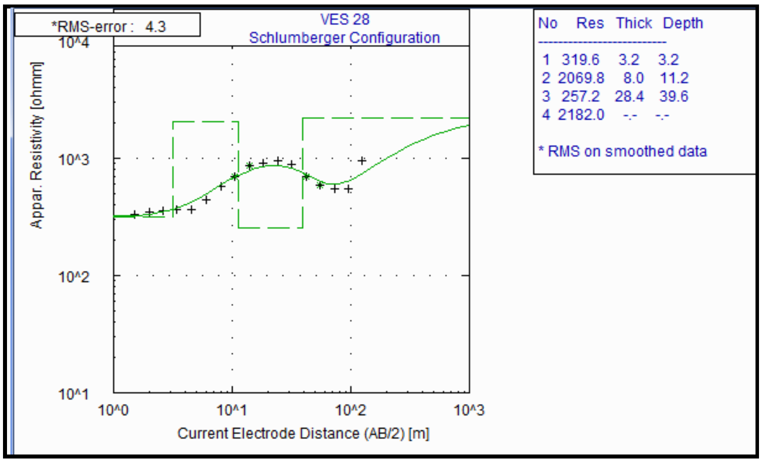

Fig.3b: AK Type Curve

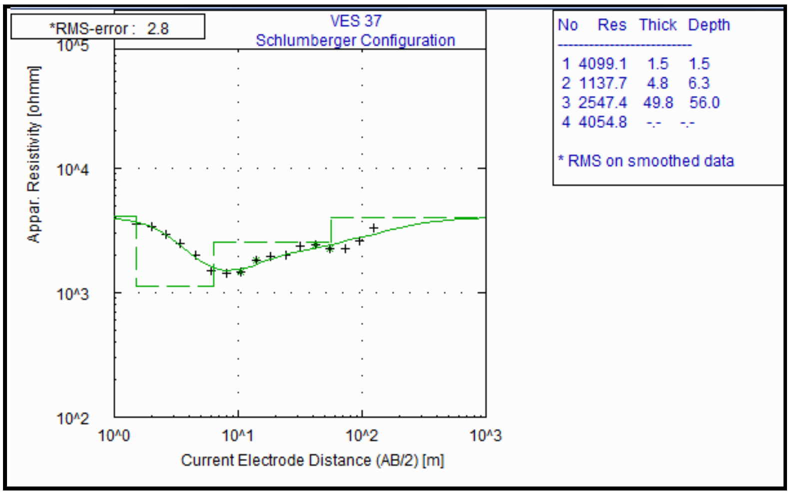

Fig 3c: H Type Curve

Geo-electric Sections

Four geo-electric sections are drawn in three directions N-S, NE-SW and NW-SE (Fig.1b) for correlation of the geo-electric sequence across the study area (Fig 4-6). A maximum of four geo-electric or subsurface layers are identified beneath these sections. Typical VES curves in the study area as shown in Fig.3. The layers identified include the topsoil, lateritic layer, weathered layer (comprising clay, sandy clay and sand) and resistive basement/bedrock.

Histograms of the delineated geo-electric layer resistivity are as shown in Fig.7. The topsoil resistivity is characterized by resistivity values ranging from 122 to 513 ohm-m. The low resistivity values of <200 ohm-m is characteristic of clayey sand/sandy clay, while moderate resistivity of > 200 to 600 ohm-m are characteristic of compact sand, lateritic sand and sands. The layer thicknesses range from 0.8-8m with the most frequent value range occurring in the 1-2 m thick range.

The second layer (lateritic layer) as shown in Fig. 7b shows resistivity values varying from 800-3385 ohm-m. Resistivity value of 800-1400 ohm-m is more or less lateritic sand, compact lateritic sand or laterite. High resistivity values of 2400-3200 are characteristic of lateritic iron stone (hardpan). The most frequent layer resistivity occurs in the 800-1200 ohm-m range with layer thicknesses varying between 0.1 and 1.0m (Fig 8b). The lateritic layer is generally absent in most of the VES stations except in the northeastern part around VES 1, 2 and 3.

The third layer (weathered basement) which consists of sand or sandy clay has an average resistivity range of <100 to 500 ohm-m (Fig 7c), with the most frequently occurring resistivity in the 100-200 ohm-m range. The most frequently occurring thickness range of this layer occurs in the 4-8m (Fig.8c).
This layer resistivity value is characteristically lower than other layers and this could be adduced to as a result of water saturation (Omosuyi et'al, 2003) of the weathered overburden overlying the fresh basement.

The bedrock layer has a resistivity value variable from 120 to 4800 ohm-m. The fresh bedrock resistivity is generally > 1000 ohm-m. Some VES locations revealed fractures (Fig 4-6) with significant drop in the resistivity values, which drop could be as a result of water saturation in the fractured basement. Fractures in the crystalline rocks acts as conduit for flow and groundwater storage.

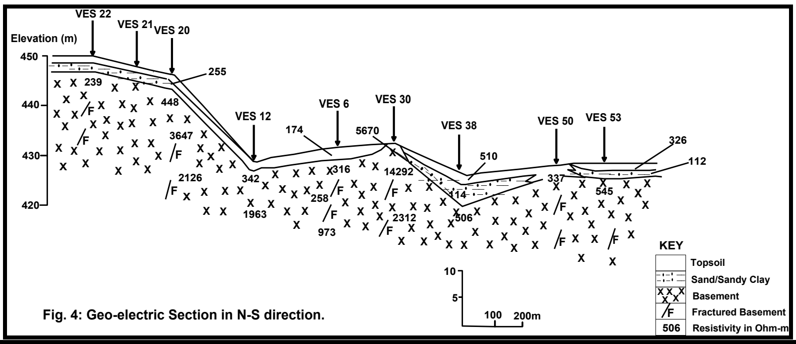

Fig. 4: Geo-electric Section in N-S direction.

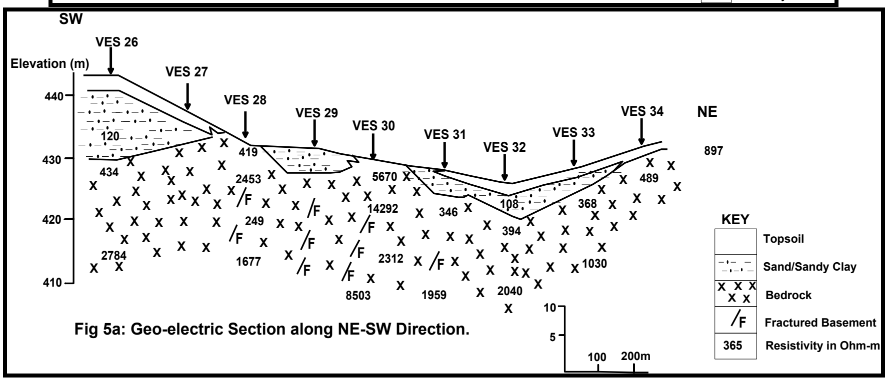

Fig 5a: Geo-electric Section along NE-SW Direction.

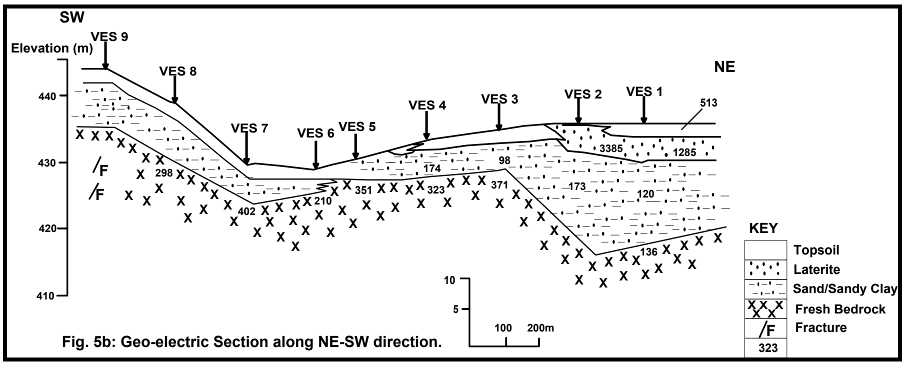

Fig. 5b: Geo-electric Section along NE-SW direction.

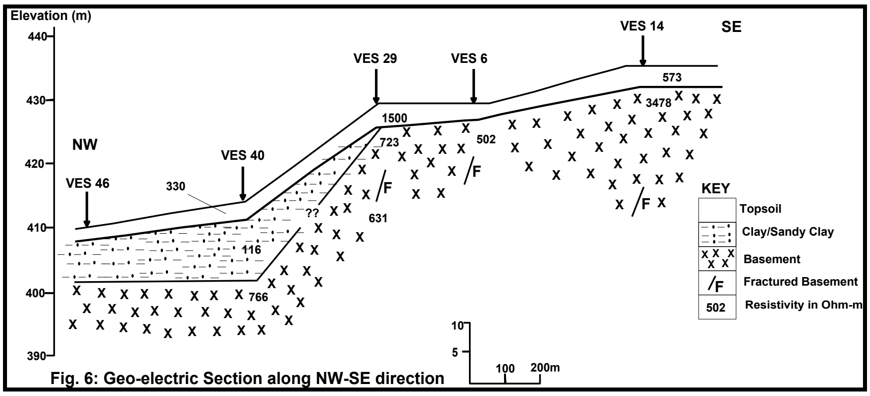

Fig. 6: Geo-electric Section along NW-SE direction

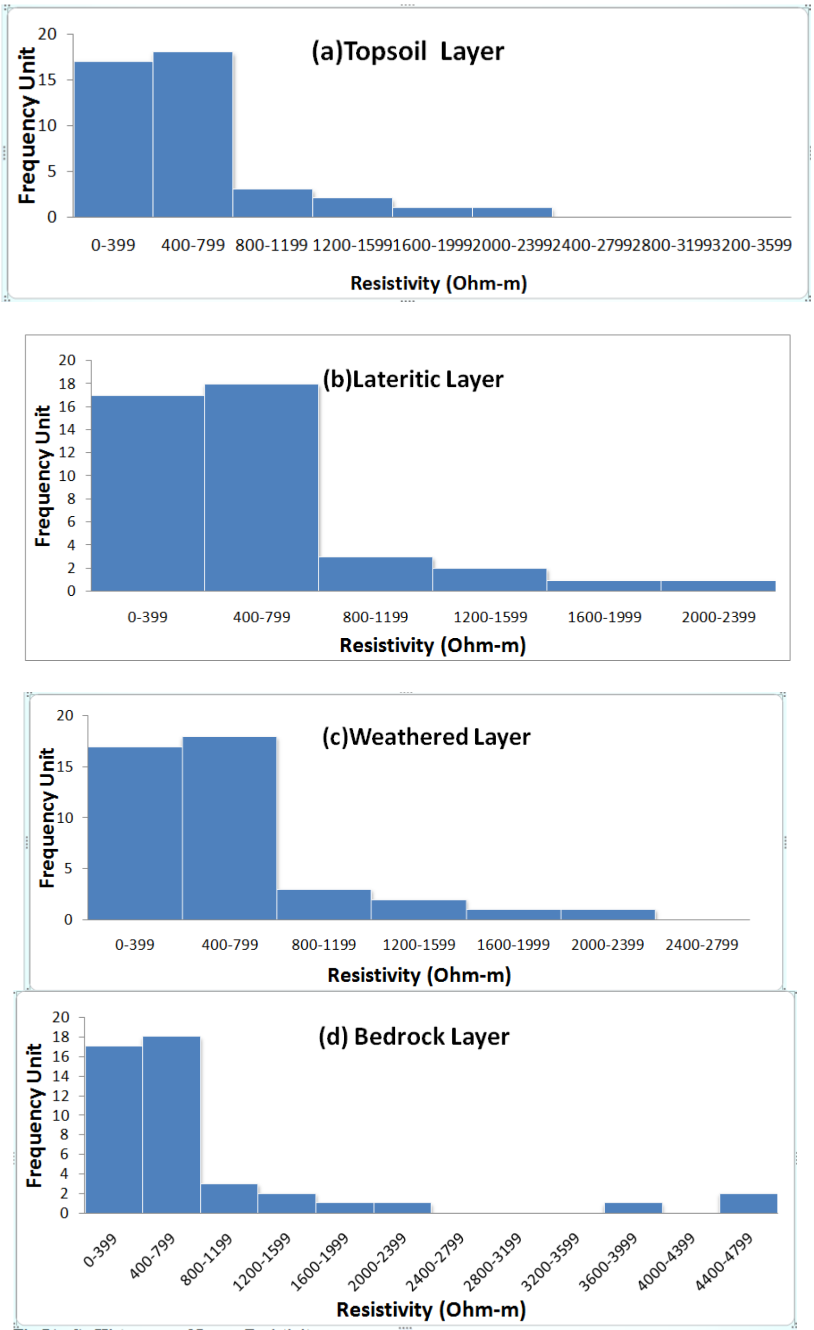

Fig 7(a-d): Histogram of Layer Resistivity

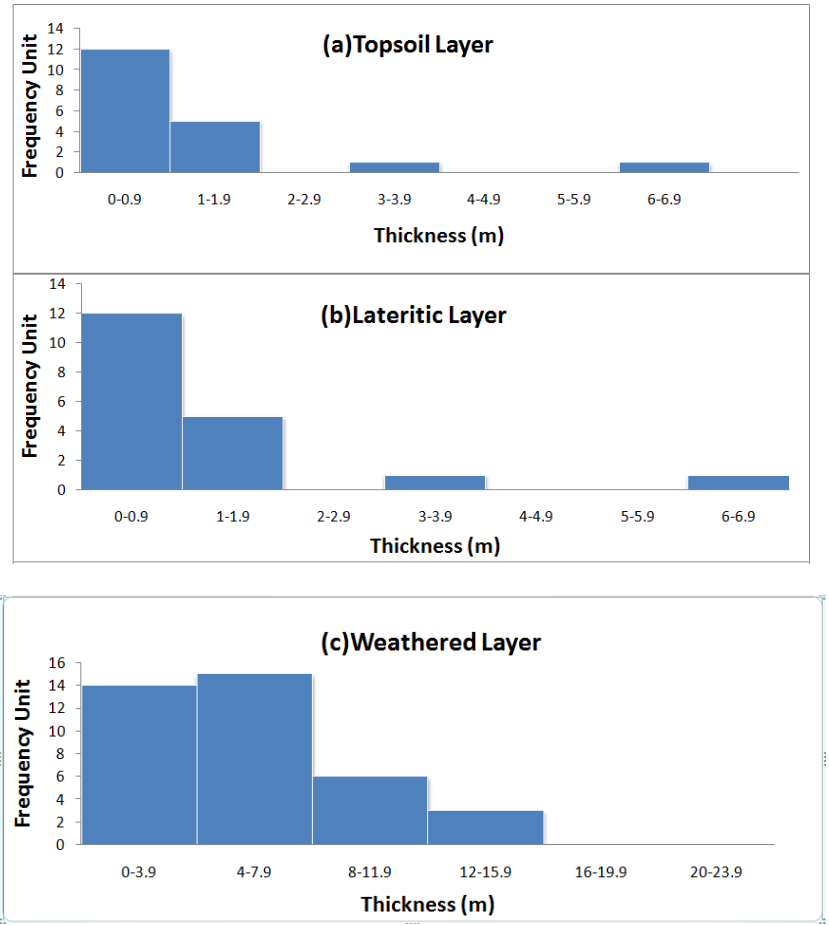

Fig 8(a-c): Histogram of Layered thickness

Geo-electric Structure

Although all the geo-electric sections (Fig.4-6) revealed some level of subsurface fractures, the VES 27-28-29-30 axis (Fig 5a) is characterized by complex fracturation and structural deformation at about 8m dept. The two large quarries sited west of VES 28 and 29 have been abandoned by the former operator as a result of subsurface fault systems of the area. The quarrying activities may have intercepted the major fault mapped by VES stations 27, 28, 29 and 30 which started at about 8m depth and continued past 40m. The quarries located to the south of the area also intercepted the fault and its extension.

Isopach Map of the Overburden

Fig.9 shows the contour map of the overburden thickness established over the VES stations in the surveyed area. The map shows a variable overburden thickness from <2-24m.

The northeastern extreme of the area together with some isolated areas in the south west has relatively thick overburden cover of between 10-24m. The other areas have relatively thin overburden ranging between < 2 and 5m. Where the basement outcrops, the overburden thickness is virtually zero. The rock outcrops are in the form of isolated hills. For engineering purposes, the shallow depth to basement is an indication of shallow depth to firm foundation bed across the study area.

Bedrock Relief

The bedrock relief map (Fig.10) is a contoured map of the bedrock elevations established beneath the VES stations. According to Olorunfemi and Okhue (1992), the significance of the bedrock relief map is to show the reflection of the bedrock topography and its structural disposition.

From Fig.10 a series of ridges and depression which are marked R and D respectively can be recognized. The main depressions are found in the SSW and SSE zones of the study area and in some isolated areas (Fig 4, 5 & 6). The width of the depressions varies between 20-400m. The depressions are covered with variable thickness of overburden between < 2-21m (see Fig 9).

The depressions serve as collecting troughs for surface and groundwater. Where thick overburden overlies depressions, they are potential zone for groundwater development. It appears that the thick overburden overlying the depressions must have been washed away as a result of the streams that flow within the depressed areas and exposing the bedrock in some places.

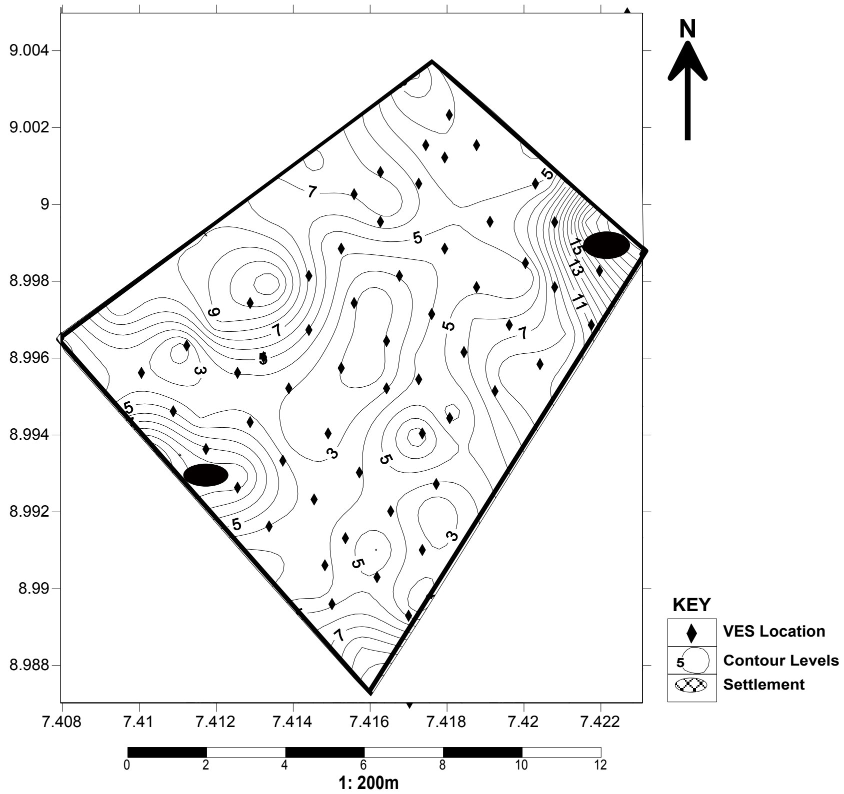

Fig. 9: Isopach Map of the Overburden

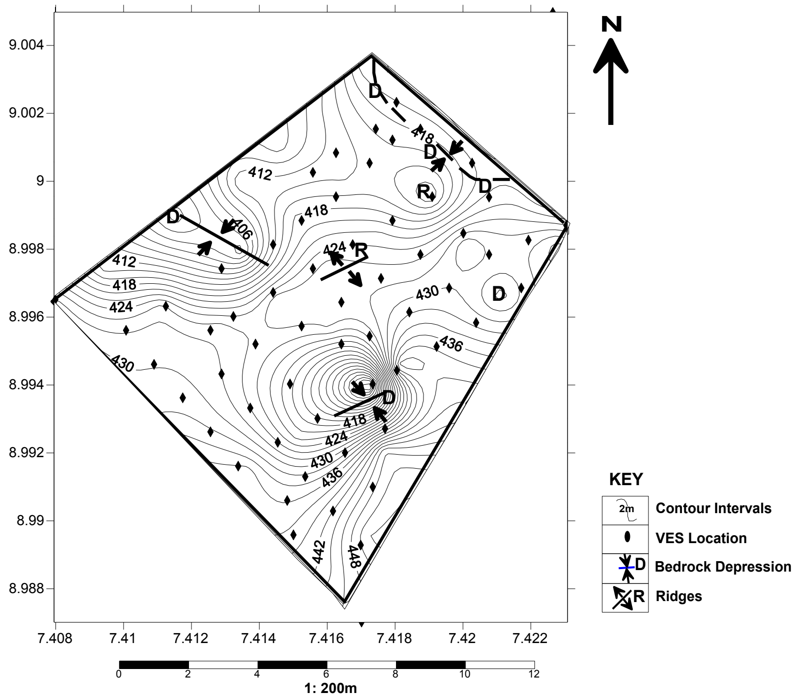

Fig. 10: Bedrock Relief Map

Geological Structures

Fig 11 shows the structural map of the area as derived from the bedrock relief map and geo-electric sections. The major structural trends strike NE-SW, although the long axis of the bedrock ridges trend in the NNW-SSE and NNE-SSW directions. The ridge marked R2 is separated from R3 by steep, deep subsurface depression which appear to influence the stream flowing from the SE to the NW (Fig.11). The quarries which have been abandoned due to complete submergence by groundwater from the fractures are evidences which point to the fact that the central area have been tectonically affected and should be the target zones/areas for groundwater development. However, for high rise buildings and civil engineering structures, the faulted areas should be avoided.

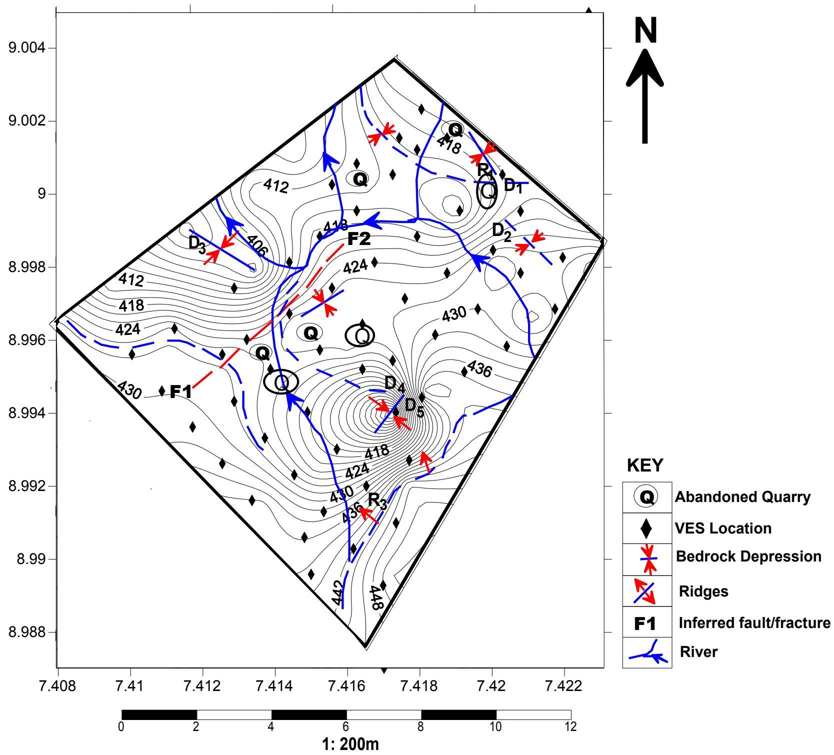

FIG.11: Structural Map of the Bedrock

Hydro geologic Significance of Weathered Overburden and Bedrock Relief/Structures.

In basement terrain, weathered overburden thickness, bedrock relief and structural setting are of significance in groundwater resources evaluation (Omosuyi et'al, 2003). Weathered overburden, if significantly thick and resistivity suggest saturated condition, is considered significant as water bearing layer.

Also, basement fractures/sheared bedrock may likely contain groundwater as a result of water accumulation in the fractures or joints. Based on the sections, maps and the VES interpretation, groundwater potential of the area is characterized (Fig. 12).

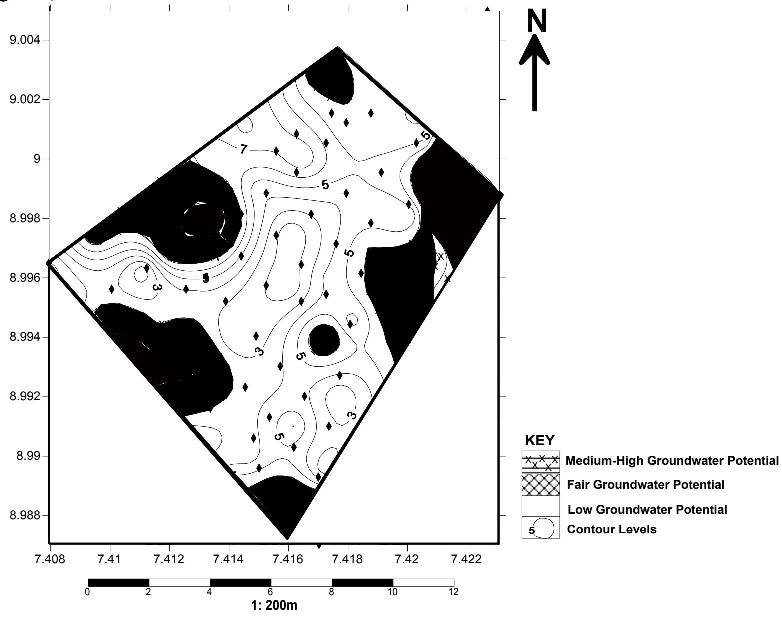

FIG.12 : Groundwater Potential Map

The sections (Fig.4-6) and map (Fig.9) reveal relatively thick overburden (10-24m) in some isolated areas and may constitute target areas for groundwater development. The highly fractured or faulted area around the middle sections, near the abandoned quarries is potential area for groundwater resources development. However, for civil and building structures, the area could be problematic which can lead to structural failures.

III. Conclusion And Recommendation

The geo-electrical parameters obtained from the geo-electrical resistivity sounding (VES) data interpretation were used to establish the depth to basement, geological structures and groundwater potential of the study area. These parameters or factors are important in infrastructural development planning.

These findings are envisage to provide reliable background or baseline information for an elaborate geotechnical investigation for the area taking into consideration that all sectors of the FCT, Abuja have been earmarked for infrastructural development.

It is therefore, pertinent to note that the area investigated, most especially in the middle section, where it has been affected tectonically should be investigated further using integrated geophysical method and satellite imagery to give a clearer geological and geophysical disposition of the structures, which is very important for groundwater development and for decision in siting of building and civil engineering structures.

Acknowledgement

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