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Groundwater Potential of Some Parts of the Federal Capital Territory, Abuja, Nigeria.

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Abstract

A hydrogeophysical study was carried out in some parts of the Basement Complex terrain of Abuja, the Capital of Nigeria, to investigate the groundwater potential of the subsurface layers. Severe water shortage due to increase in population, social and economic activities has prompted this study on the development of the groundwater resources. Schlumberger Vertical Electrical Soundings (VES) for groundwater exploration in the Nigerian Police barracks in some parts of the Federal Capital Territory, Abuja, Nigeria were carried out with a view to establish the different subsurface geoelectric layers and the aquifer units. Data were collected from several VES stations at Utako, Dei-Dei, Wuse 2 and Kuje Junction barracks. From the quantitative interpretations of the data collected, using the usual method of curve matching with the Orellana-Mooney Master curves and 1-D forward modeling with WinResist 1.0 version software, between three and four lithologic units were identified in these areas. These include: the topsoil, the weathered basement, the fractured basement and the fresh bedrock. The weathered layer and the fractured basement constitute the main aquifer units. The depth to bedrock at the chosen VES locations vary from 3.8 to 15.1 m in the study area. The geoelectrical interpretations of data obtained in these areas have permitted the delineation of some lobes or areas of low resistivity which constitute the prospective zones for water exploration in these areas.

Keywords: Basement, Groundwater, Electrical, Soundings, Weathered and Fractured).

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1. INTRODUCTION

The Federal Capital Territory (FCT) Abuja is bounded by latitudes $8^{\circ}25^{'}N$ and $9^{\circ}20^{'}N$ and longitudes $6^{\circ}45^{'}E$ and $7^{\circ}39^{'}E$, covering a total area of approximately 7,315 km2 (City Population.De, 2016). However, the study locations (i.e. Utako, Dei-Dei, Wuse 2 and Kuje Junction barracks) are bounded by latitudes $8^{\circ}53^{'}N$ and $9^{\circ}9.3^{'}N$ and longitudes $7^{\circ}17.5^{'}E$ and $7^{\circ}35.2^{'}E$,covering a total area of approximately 952.12 km2 within the the FCT, Abuja (Fig. 1). The study area is underlain by the Basement Complex rocks of the North Central Nigeria (Fig. 2). Communities located on Basement Complex terrains commonly have problems of potable groundwater supply due to the crystalline nature of the underlying rocks which lack primary porosity. Groundwater storage capacity in those areas is dependent on depth of weathering and intensity of fracturing of the underlying rocks. For Basement Complex rocks to become good aquifers, they must be highly fractured and/or deeply weathered (Anudu *et al.,* 2008).

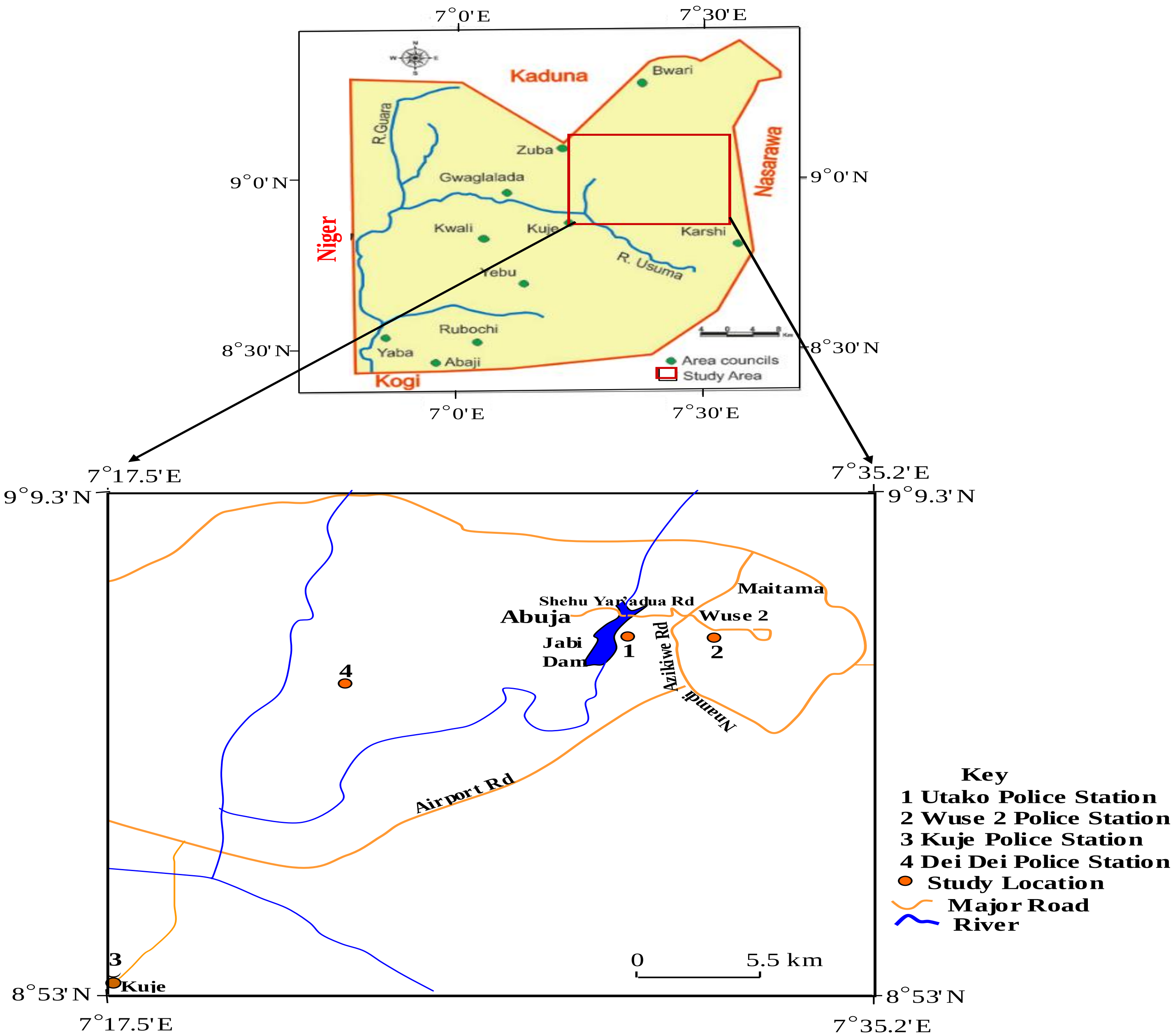

Fig. 1. Sketch Map of the Study Area Showing the Study Locations (Insert is the Location map of the Federal Capital Territory, Abuja, Nigeria) [Adapted from Friendsofthecity, 2008].

Groundwater potential of a Basement Complex area is often determined by geophysical means, which determines the thickness of the overburden and the network of fractures that may exist in the area (Mendoza and Dahlin, 2008). Groundwater occurrence in Basement rocks is limited to the upper weathered section and fractured portion of the underlying fresh rocks (Olorunfemi and Fasuyi, 1993). In order to evaluate the geologic and geoelectric characteristics of the aquifers, the boreholes drilling must be preceded by detailed geophysical investigations. The Vertical Electric Sounding (VES) method was preferred for its simplicity, easy interpretation and rugged nature of the associated instrumentation (Sharma and Baranwal, 2005).

The persistent problem of inadequate potable water supply in the Nigerian society, especially in the Federal Capital City, Abuja, Nigeria has compelled the Nigerian government, particularly the Police Affairs to embark on Barracks water supply scheme. A thorough investigation of the sites would not only ensure proper recommendations, construction and development, but a high success rate of the project, which is what necessitated this work.

1.1 Geology and Hydrogeology of the Area

The areas of investigation fall within the Federal Capital Territory, Abuja, Nigeria. It is underlain by Basement complex rock of northern Nigeria, comprising both igneous and metamorphic rocks of Precambrian age. Some of these rocks include: granites, quartzite, amphibolite, migmatites, schist and banded gneiss (Fig. 2).

Generally only a small amount of water can be obtained in the freshly unweathered bedrock below the weathered layers. Groundwater is found mainly in the variable weathered/transition zone and in fractures, joints and cracks of the crystalline basement (Clark, 1985). The highest groundwater yield in the basement terrains is found in areas where thick overburden overlies fractured zones (Olorunfemi and Fasuyi, 1993). Also, the concealed basement rocks may contain highly faulted and folded areas, joint and fracture systems that resulted from multiple tectonic events they have experienced (Agunleti and Arikawe, 2014).

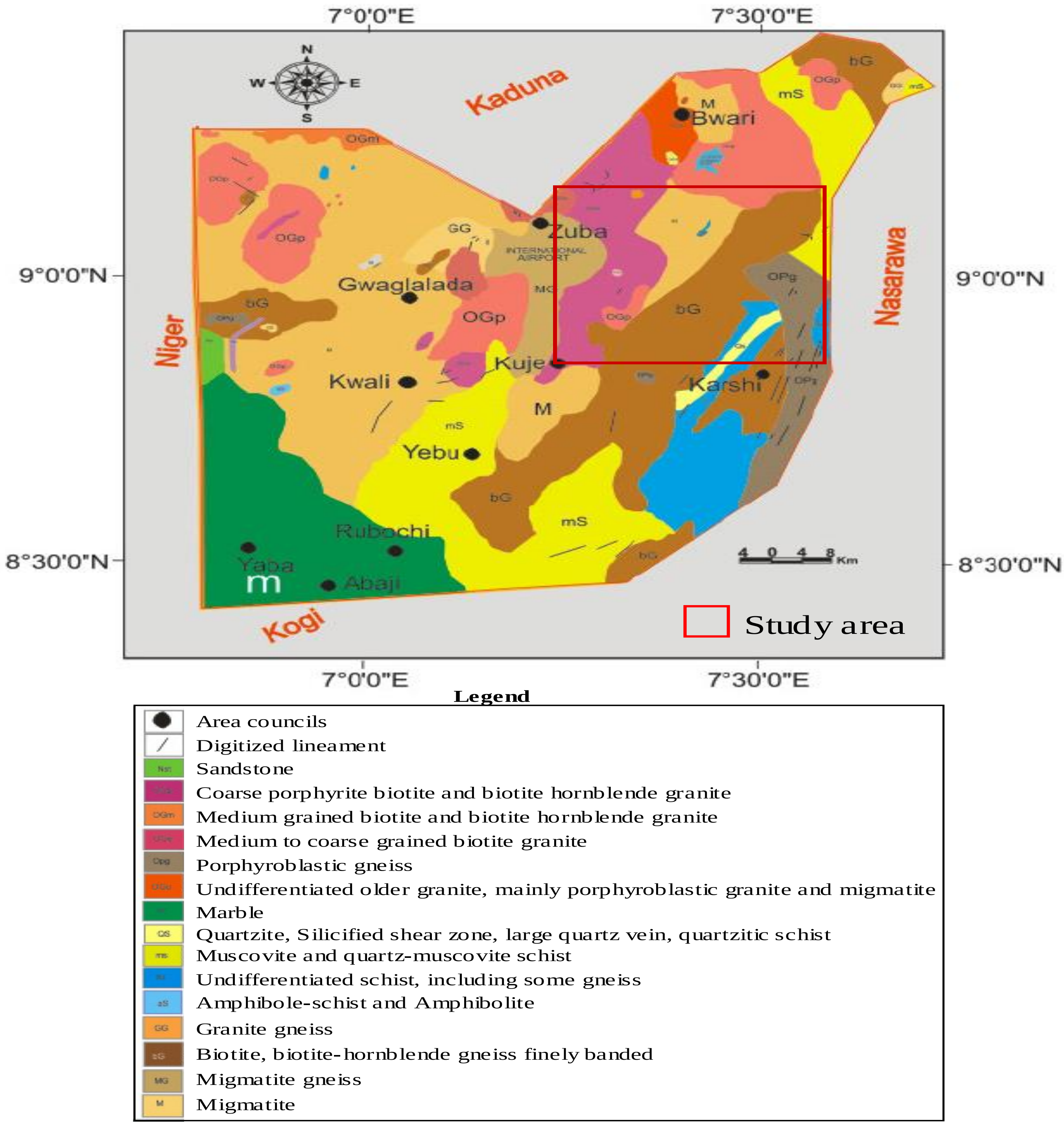

Fig. 2. Geologic Map of the Study Area (Adapted from Agunleti and Arikawe, 2014)

2. MATERIALS AND METHODS

The method of study involves geophysical investigation using electrical resistivity method and analysis of data on some of the boreholes within the study area. The Schlumberger array of the Vertical Electrical Soundings (VES) method was employed in this work with the use of ABEMS Terrameter SAS 1000 Resistivity Meter. The electrode spreading followed the description (Sharma, 1997) where half electrode spacing (AB/2; Fig. 3) range of 1 – 100 m was used to generate maximum information about the subsurface lithology and overburden thickness. Five VES were conducted in the Utako Police Barrack (Fig. 4). The profiles were chosen based on the existing wells in the area. The Dei Dei Police Barrack had four teams which include: Teams E, F, A and C (Fig. 5). Four, two, six and three VES points were conducted at teams E, F, A and C respectively. The Kuje junction Police Barrack was investigated at thirteen VES points (Fig. 6) while Wuse 2 Barrack was investigated at four VES points (Fig. 7). Apparent resistivity (ℓa) for the Schlumberger array was computed from the equation (1) below (Sharma, 1997):

$$\ell_a = \frac{\pi L^2}{I} \frac{\Delta v}{2l} \qquad (1)$$

where (L) is half the distance between the current electrodes (AB), (l) is half the distance between the potential electrodes (MN), $\frac{\Delta v}{2l}$ is the surface gradient of potential at the midpoint between M and N, and I is the input current.

The current from a battery was sent into the ground through the outer electrodes. The potential difference generated by this current was measured using a voltmeter. The apparent resistivity value for the electrode spacing was calculated by multiplying the resistance obtained at the point with the geometric factor. The field data were quantitatively interpreted by partial curve matching (William, 2007) and computer iteration techniques (Sharma, 1997). The partial curve matching involved segments by segment matching of the field curves with two layer model curves and their corresponding auxiliary curves. The VES data presented as depth sounding curves were inverted with the Computer aided iteration curve matching techniques using WinResist Version 1.0 (Vander Velpen, 1988). Typical sounding curves are shown in Figs. 8 – 14. The geoelectric layers for the sounding curves vary from three to five in the study locations.

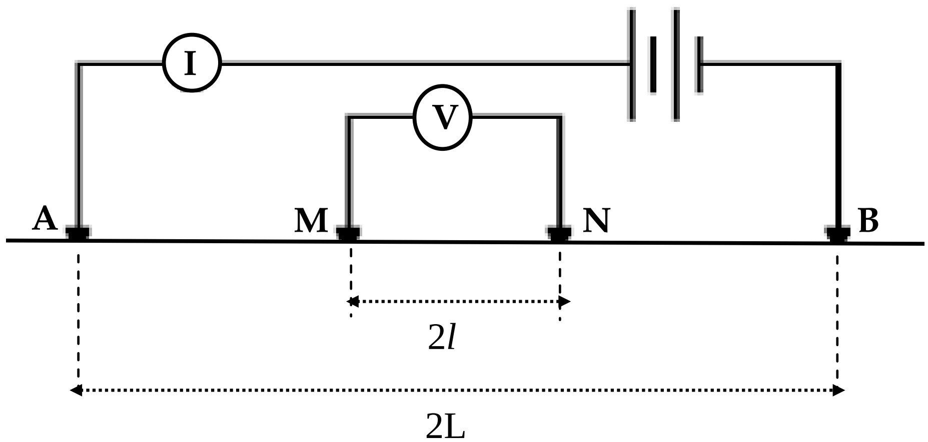

Fig. 3. Diagram of VES Schlumberger Configuration

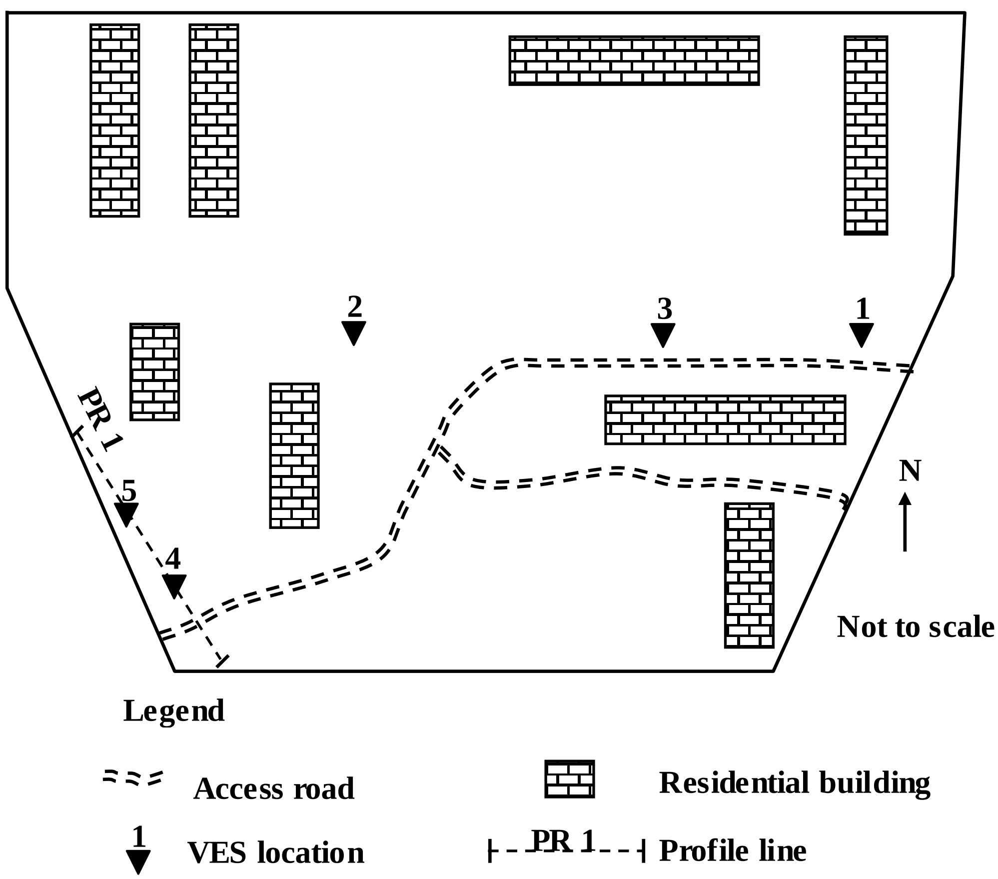

Fig. 4. A Sketch Map of Utako Police Barrack Showing the VES Sites

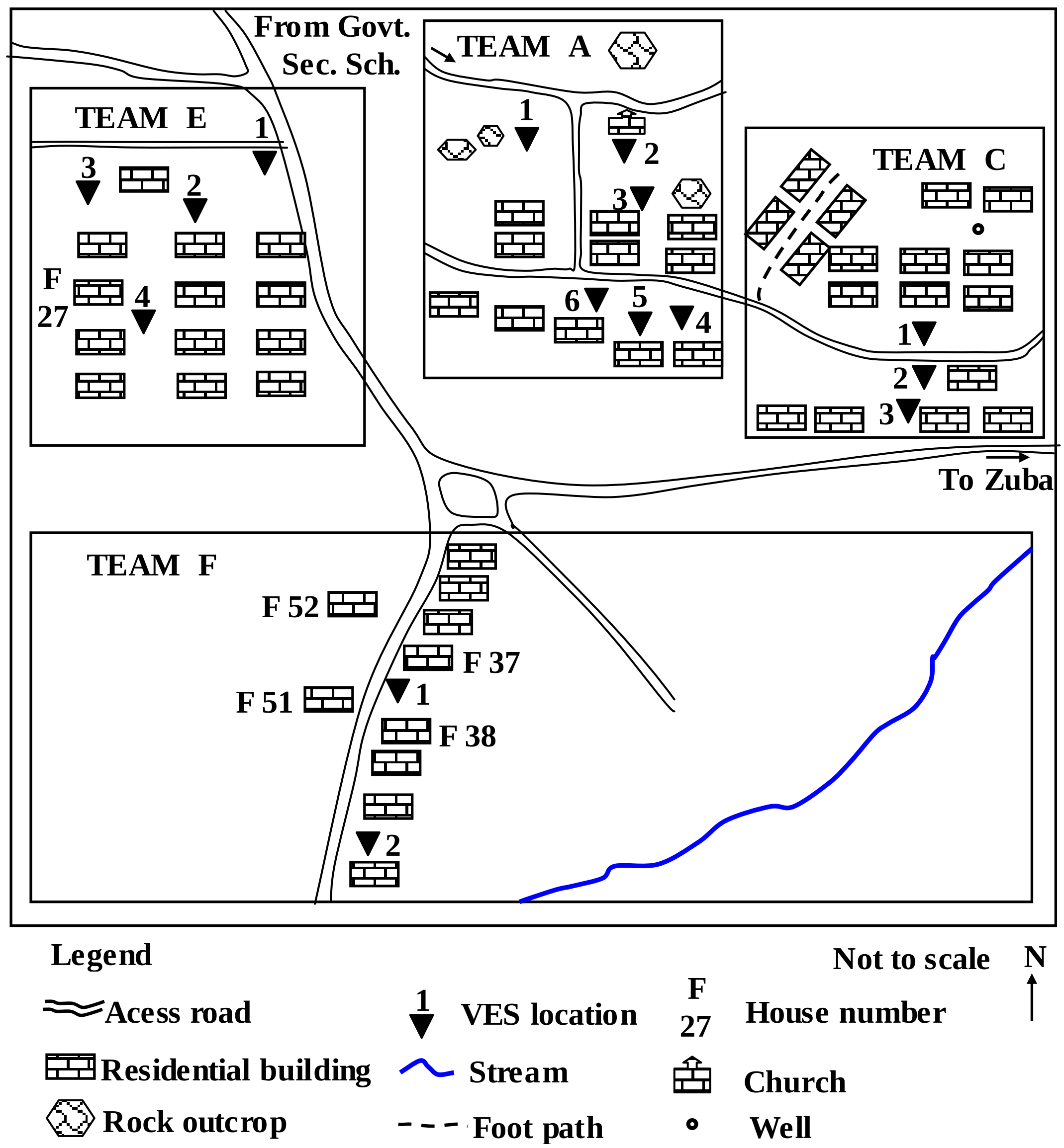

Fig. 5. A Sketch Map of Dei Dei Police Barrack Showing the VES Sites.

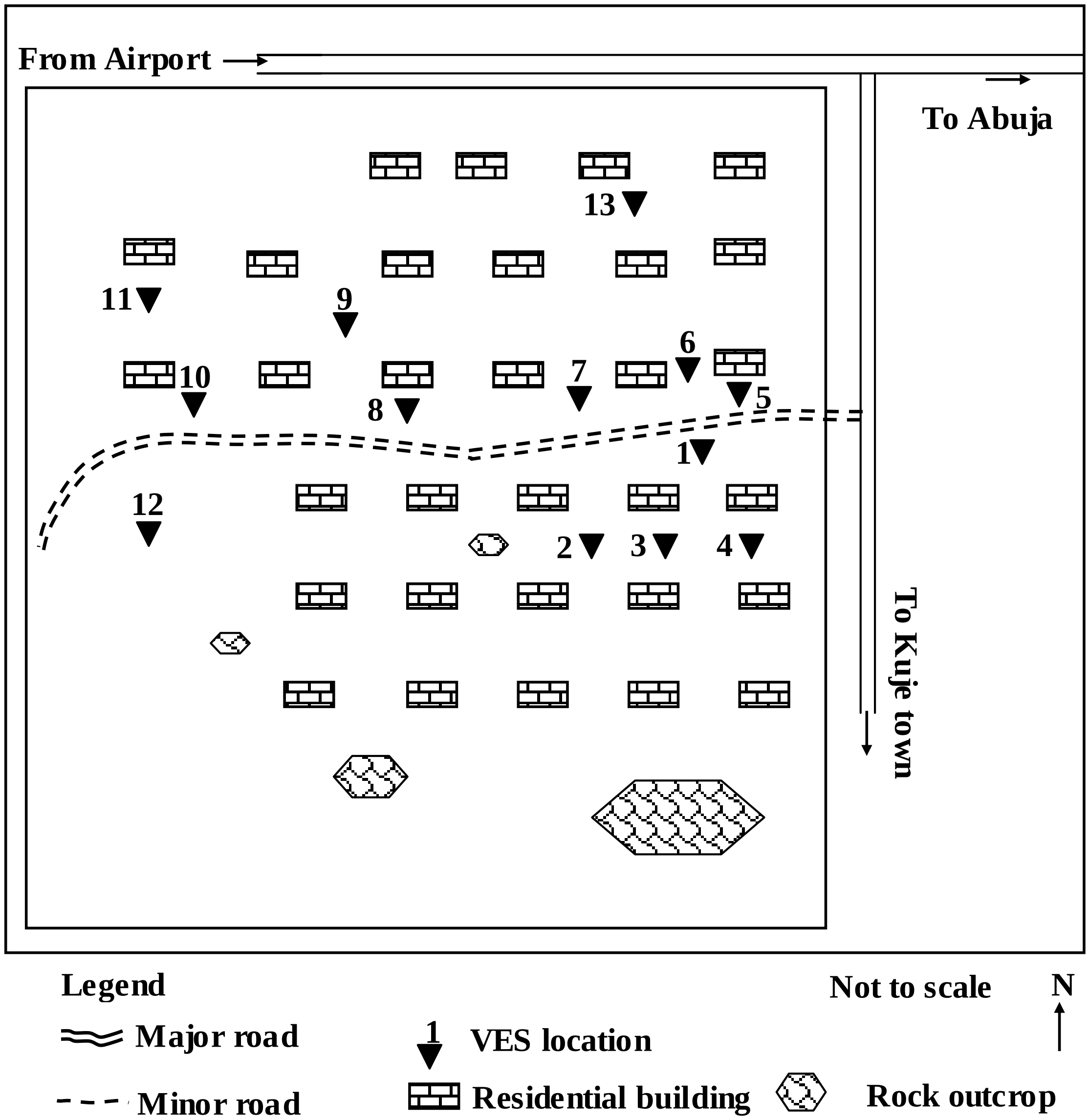

Fig. 6. A Sketch Map of Kuje Barrack Showing the VES Sites.

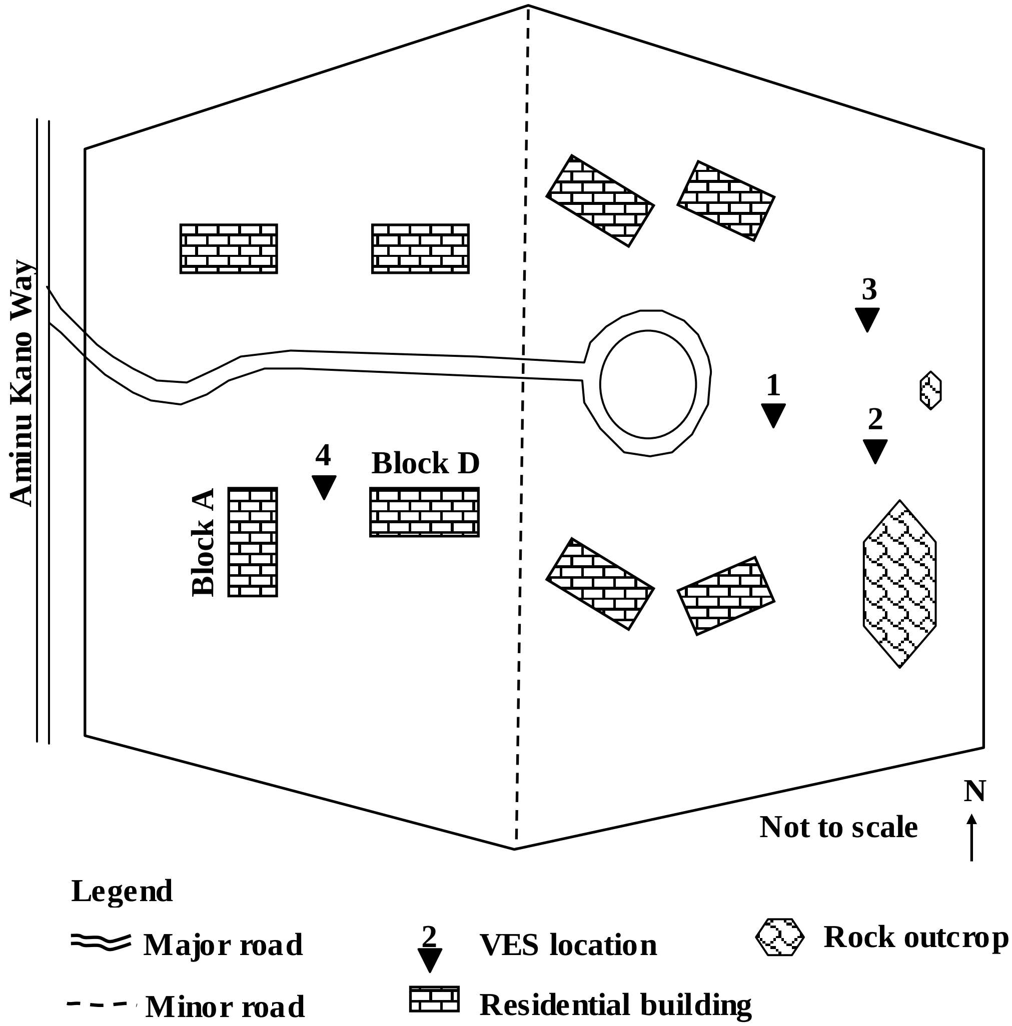

Fig. 7. A Sketch Map of Wuse 2 Barrack Showing the VES Sites.

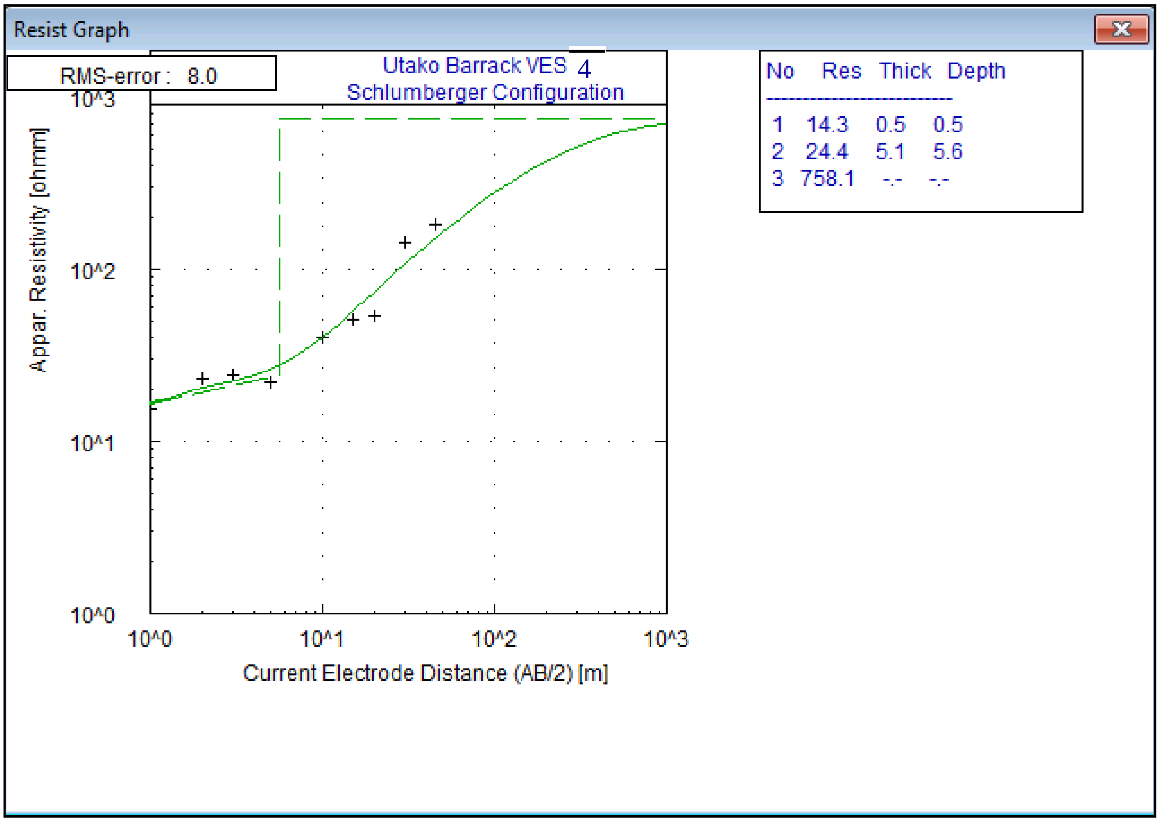

Fig. 8. Typical VES Curves Obtained at Utako Barrack Study Area.

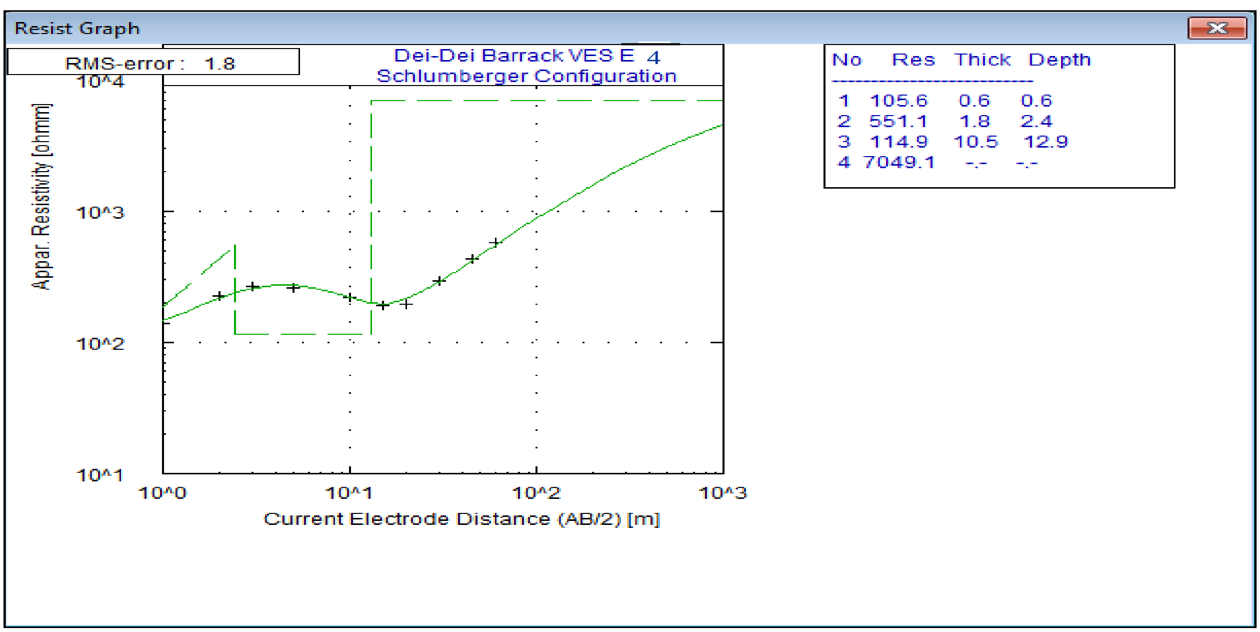

Fig. 9. Typical VES Curves Obtained at Dei-Dei Barrack Team E Study Area.

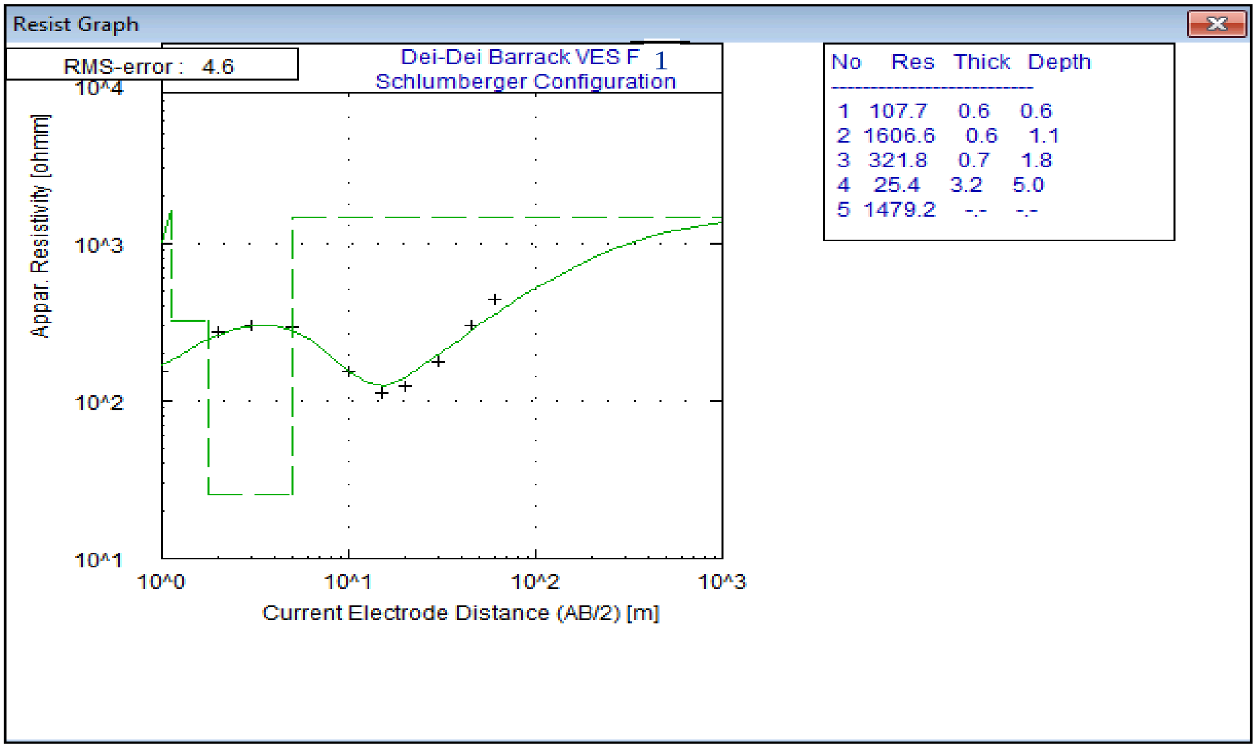

Fig. 10. Typical VES Curves Obtained at Dei-Dei Barrack Team F Study Area.

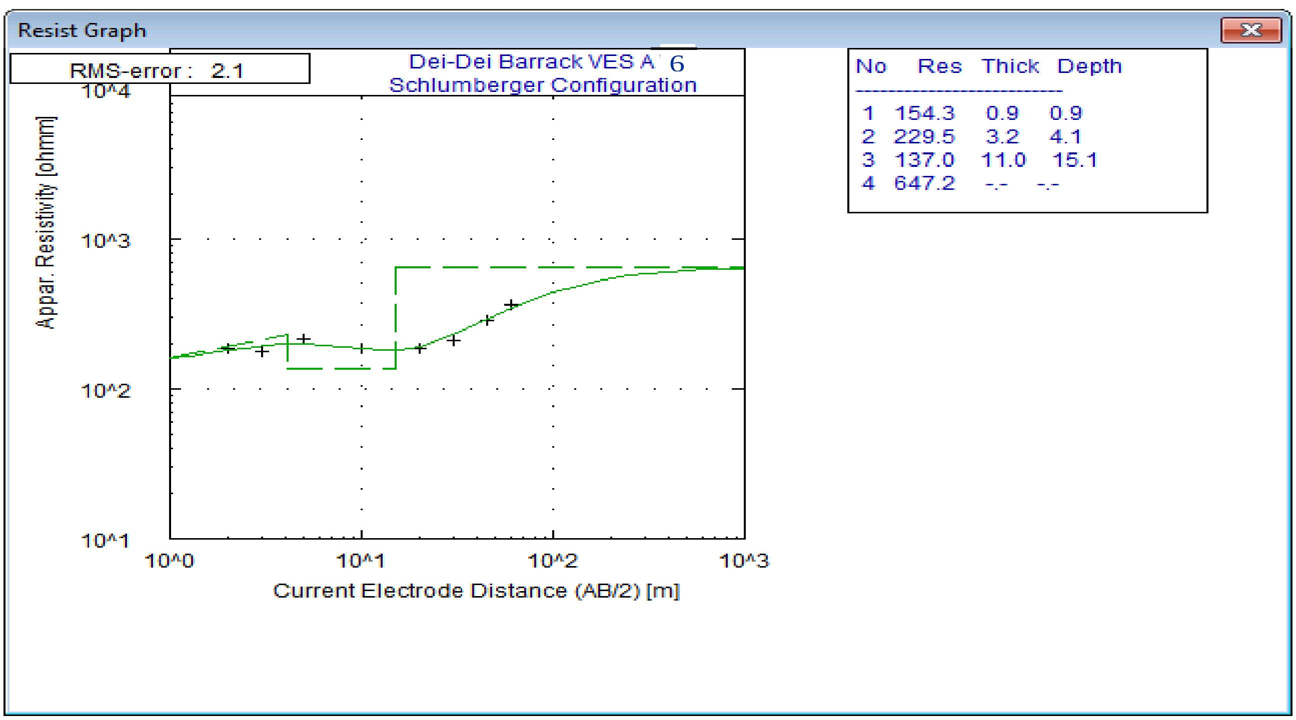

Fig. 11. Typical VES Curves Obtained at Dei-Dei Barrack Team A Study Area.

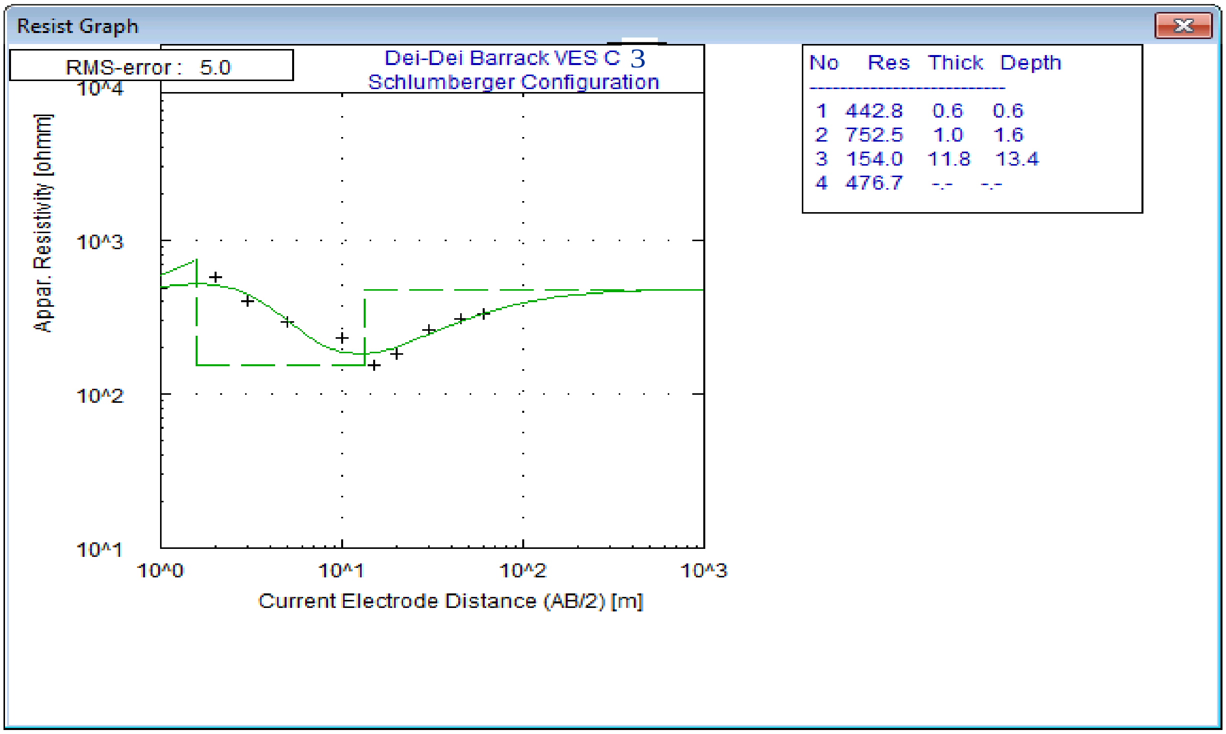

Fig. 12. Typical VES Curves Obtained at Dei-Dei Barrack Team C Study Area

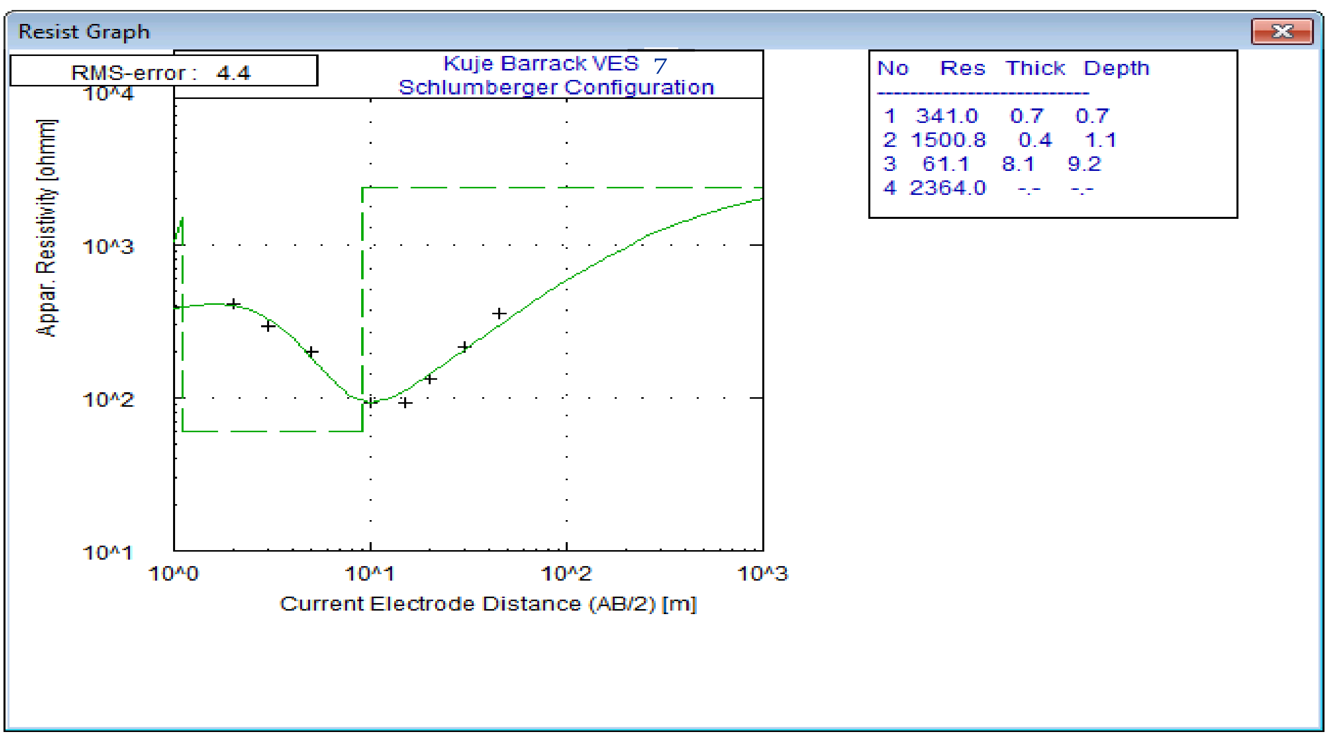

Fig. 13. Typical VES Curves Obtained at Kuje Barrack Study Area

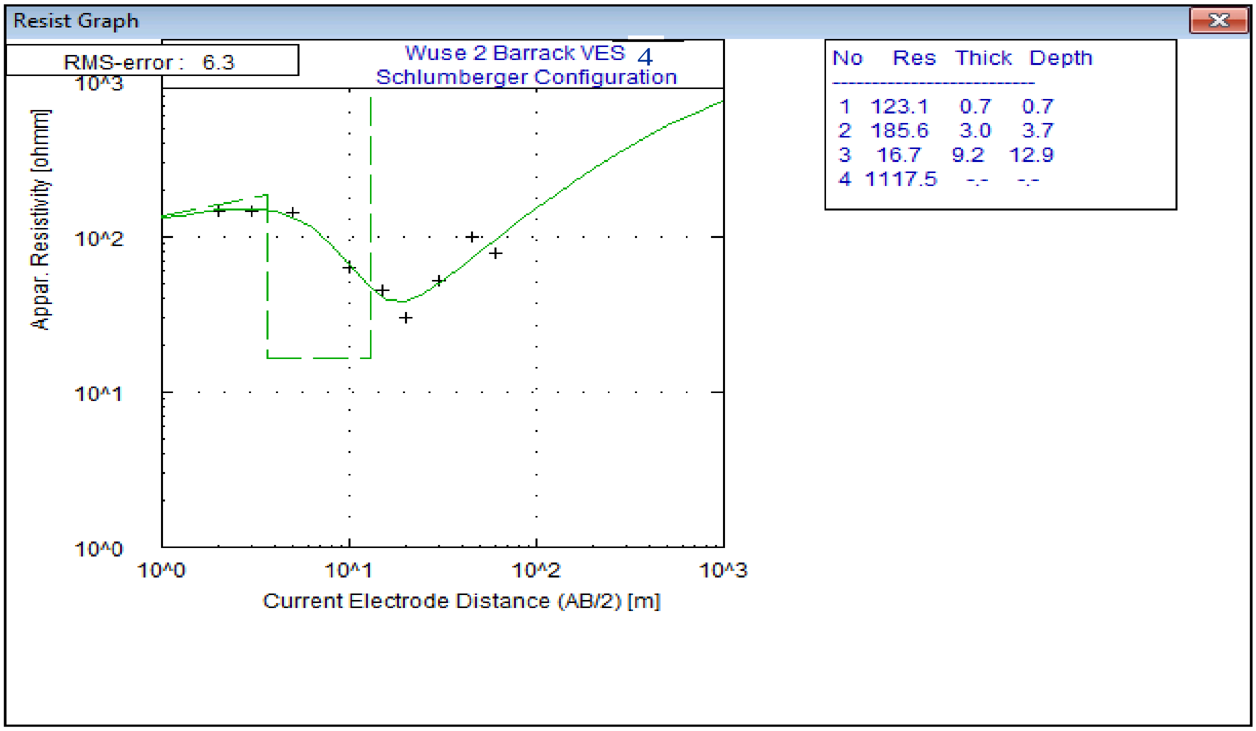

Fig. 14. Typical VES Curves Obtained at Wuse 2 Barrack Study Area

3. RESULTS AND DISCUSSION

3.1 The VES Curves

The typical VES curves are displayed in figures 8 - 14. The summary result from the interpretations of VES data is presented in Table 1. From the interpretation of the VES curves, 3 to 5 subsurface layers were identified within the study area. The curve types range from A at Utako VES 4, KQH at Dei-Dei VES F1, to KH in every other station investigated. The KH type is the most predominant as it accounts for more than 70 % of the curve types. The VES interpretation results at Utako Barrack VES 4 and 5 indicated three major geologic units: the top soil, the partly weathered/fractured basement and the resistive bedrock. The topsoil is composed of silt, clayey sand and sand with resistivities of 14.3 and 31.6 Ω-m and thicknesses of 0.5 and 0.9 m respectively; the fractured basement resistivities of 24.4 and 25.3 Ω-m and thicknesses of 5.1 and 2.9 m respectively while the fresh basement or bedrock had resistivities of 758.1 and 1093.5 Ω-m respectively. The fractured basement constitute the main aquifer unit and the groundwater potential at VES 4 which was chosen for the Utako Barrack is very high.

The Dei Dei Police Barrack had four team sites which include: Team sites E, F, A and C (Fig. 5). Four, two, six and three VES points were investigated at team sites E, F, A and C respectively. The VES interpretation result at team site E, location VES 4 indicated four major geologic units: the top soil, the weathered basement, the fractured basement and the highly resistive bedrock. The topsoil is composed of clayey sand and sand with resistivity 105 Ω-m and thickness of 0.6 m; the weathered basement is made up of sandy clay/clayey sand with resistivity

551.1 Ω-m and thickness of 1.8 m; the fractured basement has resistivity 114.9 Ω-m and thickness of 10.5 m while the fresh basement or bedrock had resistivity of 7049.1 Ω-m. The weathered and the fractured basement constitute the main aquifer units there.

The VES interpretation result at team site F, location VES 1 indicated five major geologic units: the top soil, the lateritic layer, the weathered basement, the fractured basement and the highly resistive bedrock. The topsoil is composed of clayey sand and sand with resistivity 107.7 Ω-m and thickness of 0.6 m; the lateritic layer had resistivity 1606.6 Ω-m and thickness of 0.6 m; the weathered basement is made up of sandy clay/clayey sand with resistivity 321.8 Ω-m and thickness of 0.7 m; the fractured basement has resistivity 25.4 Ω-m and thickness of 3.2 m while the fresh basement or bedrock had resistivity of 1479.2 Ω-m. The weathered and the fractured basement constitute the main aquifer units there.

The VES interpretation result at team site A, location VES 6 indicated four major geologic units: the top soil, the weathered basement, the fractured basement and the highly resistive bedrock. The topsoil is composed of clayey sand and sand with resistivity 154.3 Ω-m and thickness of 0.9 m; the weathered basement is made up of sandy clay/clayey sand with resistivity 229.5 Ω-m and thickness of 3.2 m; the fractured basement has resistivity 137.0 Ω-m and thickness of 11.0 m while the fresh basement or bedrock had resistivity of 647.2 Ω-m. The weathered and the fractured basement constitute the main aquifer units there.

The VES interpretation result at team site C, location VES 3 indicated four major geologic units: the top soil, the weathered basement, the fractured basement and the highly resistive bedrock. The topsoil has resistivity of 442.8 Ω-m and thickness of 0.6 m; the weathered basement has resistivity of 752.5 Ω-m and thickness of 1.0 m; the fractured basement has resistivity of 154.0 Ω-m and thickness of 11.8 m while the fresh basement or bedrock has resistivity of 476.7 Ω-m. The weathered and the fractured basement constitute the main aquifer units there.

The VES interpretation result at Kuje Junction Barrack, location VES 7 indicated four major geologic units: the top soil, the weathered basement, the fractured basement and the highly resistive bedrock. The topsoil had resistivity of 341.0 Ω-m and thickness of 0.7 m; the weathered basement had resistivity of 1500.8 Ω-m and thickness of 0.4 m; the fractured basement had resistivity of 61.1 Ω-m and thickness of 8.1 m while the fresh basement or bedrock had resistivity of 2364.0 Ω-m. The fractured basement constitute the main aquifer units there.

The VES interpretation result at Wuse 2 Barrack, location VES 4 indicated four major geologic units: the top soil, the weathered basement, the fractured basement and the highly resistive bedrock. The topsoil has resistivity of 123.1 Ω-m and thickness of 0.7 m; the weathered basement has resistivity of 185.6 Ω-m and thickness of 3.0 m; the fractured basement has resistivity of 16.7 Ω-m and thickness of 9.2 m while the fresh basement or bedrock has resistivity of 1117.5 Ω-m. The weathered and the fractured basement constitute the main aquifer units there.

4. CONCLUSIONS

Geophysical investigation for groundwater potential of the subsurface layers in some parts of the Basement Complex terrain of Abuja, the Capital of Nigeria has revealed five major lithologic units. These include: the topsoil, the

Table 1: Summary of Results from the Interpretation of the VES Data.

VES Station	Layer Resistivity	Thickness	Depth	Remark
1. Utako Barrack (i) VES 4	14.3 24.4 758.1	0.5 5.1 infinity	0.5 5.6 infinity	Top Soil Fractured Basement Fresh Bedrock
(ii) VES 5	31.6 25.3 1093.5	0.9 2.9 infinity	0.9 3.8 infinity	Top Soil Fractured Basement Fresh Bedrock
2. Dei-Dei Barrack (i) Team E VES 4	105.6 551.1 114.9 7049.1	0.6 1.8 10.5 infinity	0.6 2.4 12.9 infinity	Top Soil Weathered Basement Fractured Basement Fresh Bedrock
(ii) Team F VES 1	107.7 1606.6 321.8 25.4 1479.2	0.6 0.6 0.7 3.2 infinity	0.6 1.2 1.9 5.1 infinity	Top Soil Lateritic layer Weathered Basement Fractured Basement Fresh Bedrock
(iii) Team A VES 6	154.3 229.5 137.0 647.2	0.9 3.2 11.0 infinity	0.9 4.1 15.1 infinity	Top Soil Weathered Basement Fractured Basement Fresh Bedrock
(iv) Team C VES 3	442.8 752.5 154.0 476.7	0.6 1.0 11.8 infinity	0.6 1.6 13.4 infinity	Top Soil Weathered Basement Fractured Basement Fresh Bedrock
3. Kuje Junction Barrack VES 7	341.0 1500.8 61.1 2364.0	0.7 0.4 8.1 infinity	0.7 1.1 9.2 infinity	Top Soil Weathered Basement Fractured Basement Fresh Bedrock
4. Wuse 2 Barrack VES 4	123.1 185.6 16.7 1117.5	0.7 3.0 9.2 infinity	0.7 3.7 12.9 infinity	Top Soil Weathered Basement Fractured Basement Fresh Bedrock

lateritic layer, the weathered layer, fractured basement and the fresh bedrock. The weathered and the fractured basement constitute the main aquifer units. The depths to bedrock at the investigated VES locations vary from 3.8 to 15.1 m in the study area. Apart from the good fracture network reported within the Basement and the presence of regolith (having variable thicknesses) from decayed/decaying rock fragments, the Lower Usmanu (near Bwari town) and Jabi dams serve as additional recharge sources to the water that accumulates in the basement storage sites (Abam and Ngah, 2013).

The geoelectric interpretations of the electrical resistivity data obtained in the study areas have elicited areas of low resistivity which constitute the prospective zones for water exploration. The range of resistivity values for the weathered and fractured zones as well as their thicknesses (Table 1) coupled with the additional recharge sources from dams, rivers and rain water show that, the groundwater yield (especially for the chosen VES locations) in the study area is high. This work has shown that the VES method is very useful for subsurface water investigation in the Basement Complex terrain, especially when groundwater becomes a very viable alternative for water supply and when majority of the land is of the Crystalline Basement type where aquifers occur in localized or a discontinuous manner like that of FCT, Abuja in Nigeria.

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