ASSESSING THE GROUNDWATER POTENTIAL IN WUYE DISTRICT, FEDERAL CAPITAL TERRITORY, ABUJA, NIGERIA

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Abstract

The groundwater potential in Wuye District, Federal Capital Territory, Abuja, Nigeria has been investigated using integrated methods of structural analysis, geological mapping and geophysical survey. The aim of the study is to establish the type and nature of the subsurface lithology, rock types and fracture density of the area with the view of determining the groundwater potentials. The geological mapping revealed that the area is underlain by granites, granite-gneiss and gneiss. The structural analyses show a principal joint direction of NNE-SSW. The field data were obtained from the geophysical investigation was used to generate the depth to bedrock, geo-electric section, pseudo-section, isopach and isoresistivity maps. The geo-electric section, pseudo-section, isoresistivity and isopach maps obtained are true reflections of the lithology and fracture density of the area. The dominant curve types from the VES are KH, H and A. The layers comprise of topsoil, weathered layer, partly weathered or fractured basement and the fresh basement rocks. Groundwater exploration and exploitation in Wuye should concentrate on the southern and eastern portion of the area that is characterized by thick overburden and high fracture index. A combination geological, structural and geophysical investigation is more robust, reliable and rewarding for groundwater potential evaluation than any singular method. Based on the findings, the southern part of Wuye has high potential for groundwater development than the northern portion and a drill depth of between 35-95m is recommended.

Keywords: Assessment, Groundwater Potential, Wuye District, Abuja, Nigeria

1.0. Introduction

In many developed and developing countries, there is a great reliance on groundwater as a primary drinking supply as well as for both agricultural and industrial use. Due to the dependence on groundwater, it has become necessary that there are significant quantities of water and that the water meets the quality standards of its intended use (Amadi *et al*., 2012) Groundwater accounts for greater percentage of the world's fresh water and it is fairly distributed throughout the world. Surface water where available are sometimes seasonal and prone to contamination due to natural and anthropogenic factors. Other advantages of groundwater over surface water include its availability, though in varying quantities, in almost every geological formation. It accounts for over 70% of the domestic water supply of the country despite the minimal investment in its development when compared with the heavy water and the chemical and biological characteristics are fairly constant. Ground water requires minimal treatment, and in most cases readily potable (Offodile, 2002; Amadi *et al.*, 2015). The need to explore the groundwater resource qualitatively and quantitatively as a better alternative and to supplement the water supply from the water boards especially in the dry season within Wuye area of Abuja is very important in view of its numerous advantages as well as the acute water shortage encountered by the residence during the dry seasons. The water supplies from the Abuja water board have proven over the years to be grossly inadequate in meeting the water needs of the fastest growing capital in Africa and the present study is aimed at addressing this issue.

Many unsuccessful boreholes have been drilled in the area due to lack of detailed pre-drilling geophysical investigation and engagement of non-professionals in the drilling process. These factors make the study of groundwater potential of an area indispensible as it helps to save the cost of drilling abortive water-wells. The ability of man to provide the reliable supplies of portable water has been a critical factor in the match of civilization. The demand for groundwater has been increasing especially with upsurge in population growth. The occurrences of groundwater in recoverable quantity as well as its circulation are controlled by geological factors (Olorunfemi and Fasuyi, 1999; Amadi and Olasehinde, 2010). The occurrence of groundwater in this area which falls within the basement complex rocks is principally in fractures and weathered zones (Offodile, 2002; Annor and Olasehinde, 1996). In many cases the yields of the boreholes sunk into such zones is low (Olarewaju *et al.*, 1996; Olorunfemi *et al.*, 2002; Amadi *et al.*, 2015b). The study is aimed at evaluating the groundwater potential in the basement complex terrain of Wuye, Abuja, employing electrical resistivity techniques.

2.0. Materials and Methods

Study Area Description

Wuye District is one of the fourteen residential districts of Phase II in the Federal Capital Territory Abuja. The residential districts are divided into four sectors and Wuye District is grouped in sector B alongside Utako, Jabi and Dakibiyu Districts. The area falls within latitude 9°01 130 N to 9°04 1 15 N and longitudes 7°24 52 1 E to 7°27 55 E. The study area is bounded in the east by Ring Road 1 and Wuse district Phase I, in the north by Utako District, in the west by Dakibiyu District and south by the Kukwaba recreational park. The area is accessible through Nnamdi Azikiwe expressway and Jabi road.

Physiography of the Study Area

The study area falls within Gwagwa Plains of the FCT. The area is characterized by the gently undulating terrain interlaced by river valleys. The general altitude ranges from 430 meters to 530 meters above the sea level with a relative height of about 35 meter. The dominant feature within the study area is the flood plains and river valleys of River Jabi and Wuye that bounded the area and runs through the north-western boundary with its numerous tributaries and are structurally controlled. Other feature includes the gentle sloping plateau situated at the heart of the district, the conical shaped knoll rising to about 480 meters above sea level located at the north west of the study area. The Kukwaba Hill exerts much influence on the conditions within the district. These twin hills, located within the Kukwaba recreational park (Wonder Land) rise to about 570 meters above sea level.

Geology and Hydrogeology of the Area

The study area falls within the Basement Complex rocks of North-Central Nigeria with the main rock units as granites, granite-gneiss and gneiss (Figure 1). The rocks are generally weathered into reddish sandy clay-to-clay materials with high content of mica flakes, capped by laterite. Basement complex rocks do not inherently make good aquifers, but their hydrogeologic characteristics can only be enhanced when the rocks are fractured and/or when they are weathered (Omeje *et al.*, 2013). This is the case of the basement rocks in the study area as the outcome of the vertical electrical sounding that was conducted showed that the area is deeply weathered with high fracture index which implies good potentials for groundwater exploitation. Studies have shown that fracturing and weathering of basement rocks forms the pathway through which groundwater migrates in basement complex terrains

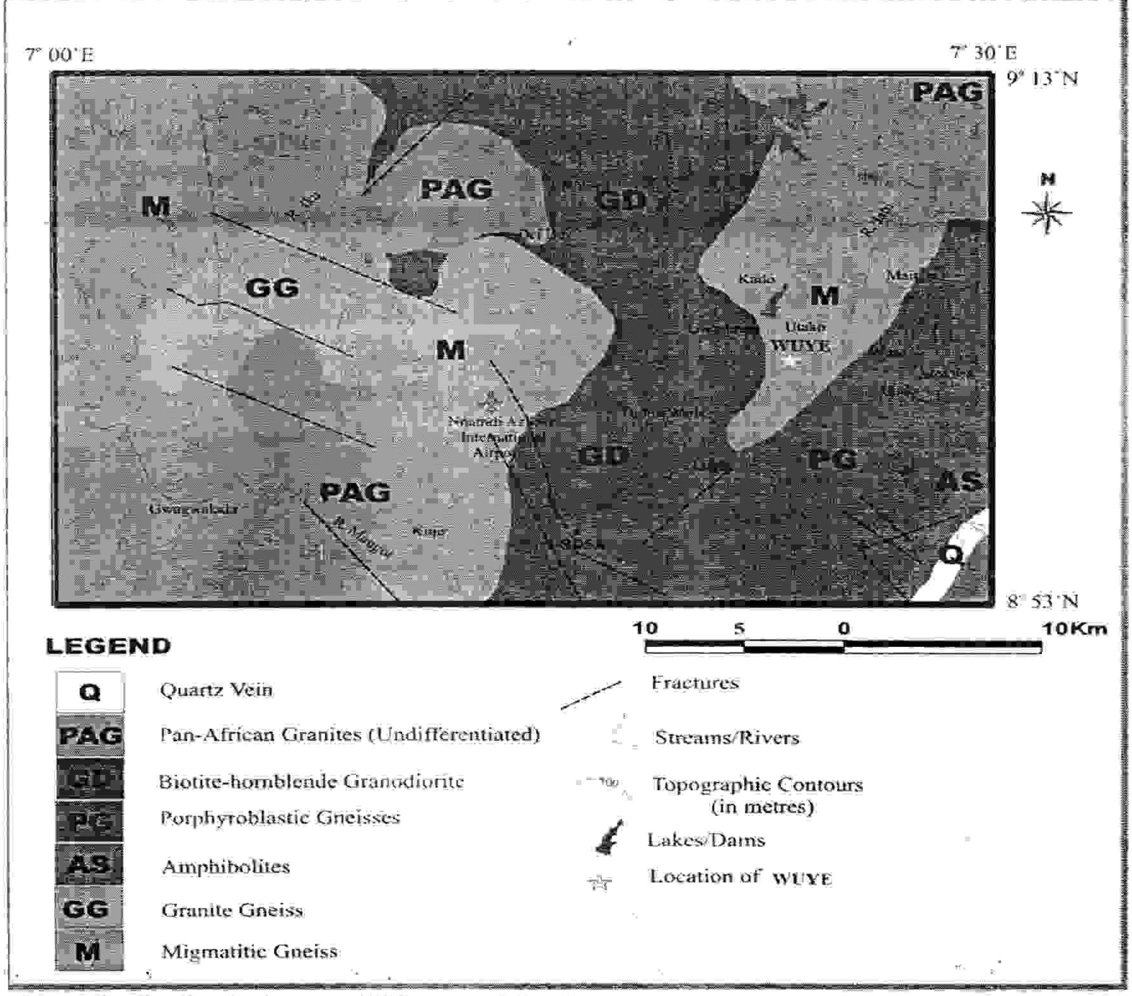

Figure 1: Geological map of Wuye and Environs

Groundwater potentials of the study area were determined by geophysical means, through which the thickness of the overburden and the network of fractures in the basement rocks were ascertained. Geophysical investigations are important tool in groundwater exploration in basement terrains in view of the discontinuous (localized) nature of basement aquifers (Olorunfemi and Okankune, 1992; Olasehinde, 1999; Amadi, 2010). The use of the vertical electrical sounding (VES) method in this study to evaluate the groundwater potentials in Wuye and environs is due to its efficiency and economy (Olorunfemi and Fasuyi, 1993; Nur and Ayuni, 2004; Olasehinde *et al.*, 1998; Amadi *et al.*, 2010).

Theory and Principle of Electrical Resistivity Method

Electrical resistivity techniques are based on the response of the earth to the flow of electric current. With an electrical current passed into the ground and two potential electrodes to record the resultant potential difference between them, we can obtain a direct measure of electrical impedance of the subsurface material. The resistivity of the subsurface material observed is a function of the magnitude of the current, the recorded potential difference and the geometry of the electrode array used. Measurement of resistivity is, in general, a measure of water saturation and pore space connectivity. Resistivity measurements are associated with varying depths relative to the distance between the current and potential electrodes in the survey, and can be interpreted qualitatively and quantitatively in terms of a lithologic as well as the geohydrologic model of the subsurface (Amadi, 2010). Electrical resistivity method involves the supply of direct current or low-frequency alternating current into the ground through a pair of current electrodes and the measurement of the resulting potential through another pair of electrode called potential electrodes. Rock resistivity depends on a number of factors such as the amount of water present in fractures and features, porosity and the degree of saturation. The VES stations were taken along three profiles, AB, CD and EF, taken in southwest-northeast, northeast-southeast and southeast-northwest directions (Figure 2).

3.0. Results and Discussion

The outcome of the geological mapping revealed two main rock units in the study area: granite, grnite-gneiss and gneiss (Plate 1). Physical examination of the rocks indicates high level weathering and fracturing, which are criteria for high groundwater potential in any basement terrain. The rose diagram plotted from the joint directions collected shows a major NNE-SSW trending direction and it conforms to the regional principal joint direction of the area. Statistically, 57% of the VES curves display KH type (Figure 3), 29% show H type (Figure 4) while the remaining 14% indicate A type (Figure 5). The HK curve type is a combination of the merits of both K and H curve types. The H type curve explains the apparent resistivity curve for a three-layer subsurface structure in which the intermediate layer has the minimum resistivity. The middle layer is typically the groundwater saturated weathered/fractured zone sandwiched between the highly resistive top soil and the highly resistive dry, non-fractured crystalline rocks.

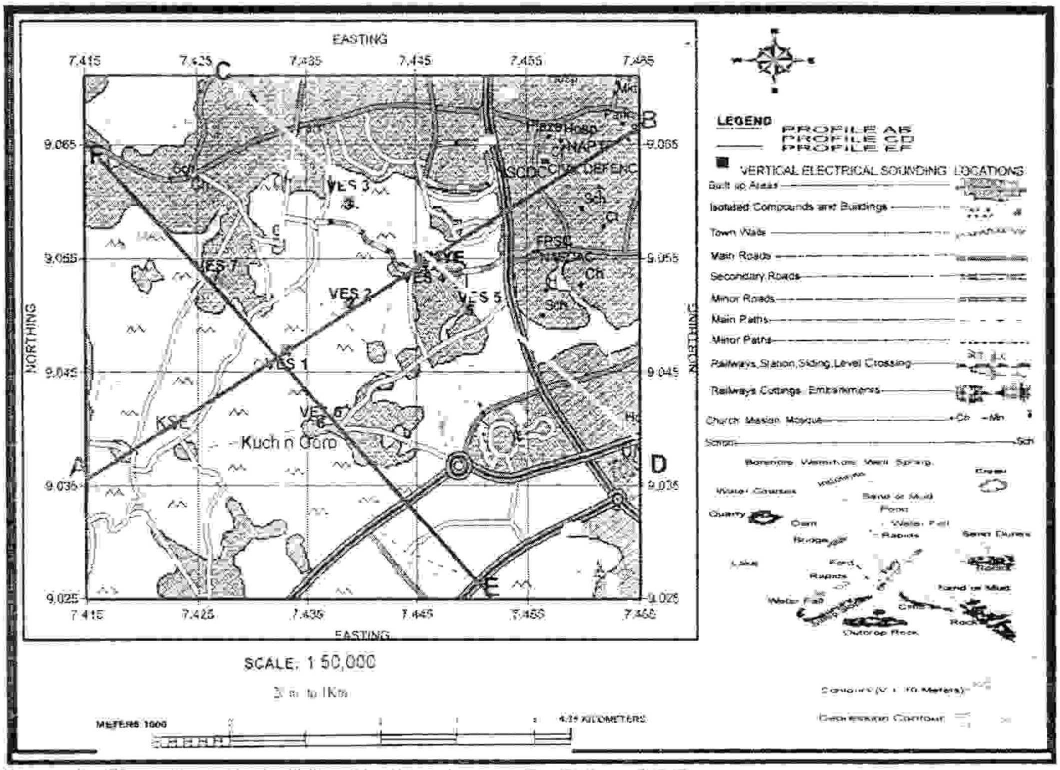

Figure 2: Electrical Resistivity Profile along AB, CD and EF
Figure 2: Electrical Resistivity Profile along AB, CD and EF

Plate 1: Folding in some of the gneiss outcrop in Wuye and Environs

It is a common curve type in the basement terrain where the basement rocks are weathered or fractured and the intermediate layer is of great hydrogeological importance. The A curve type describes a subsurface structure in which resistivity continuously increases with depth irrespective of whether it is a three layer or four layer subsurface. The H and HK curve types are indicators of high groundwater potentials in crystalline rocks. The different curve types in the area were represented in pie charts (Figure 6).

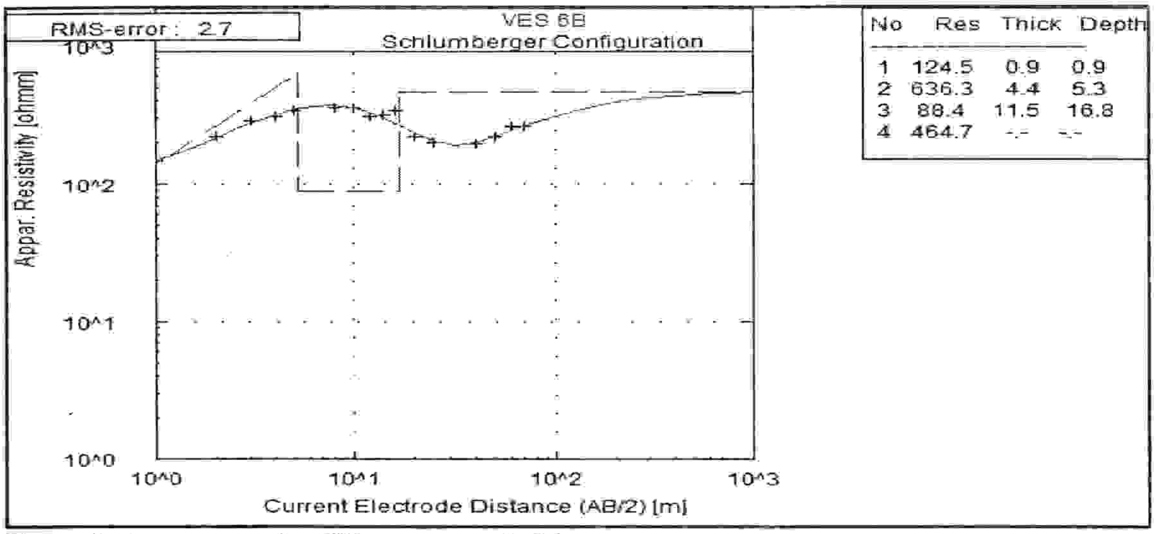

Figure 3: A representative KH curve type in Wuye

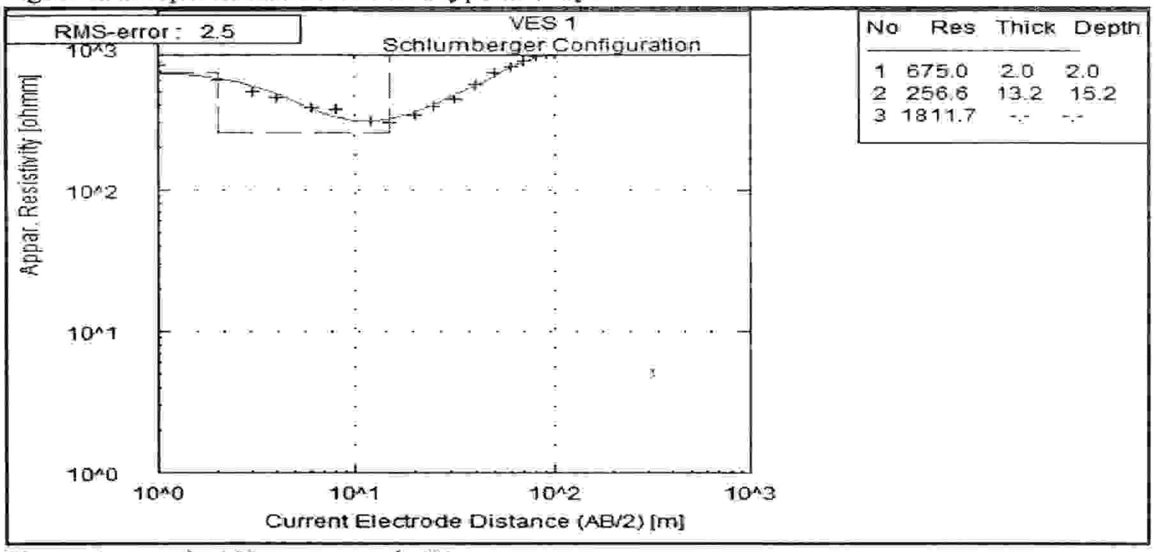

Figure 4: A typical H curve type in Wuye

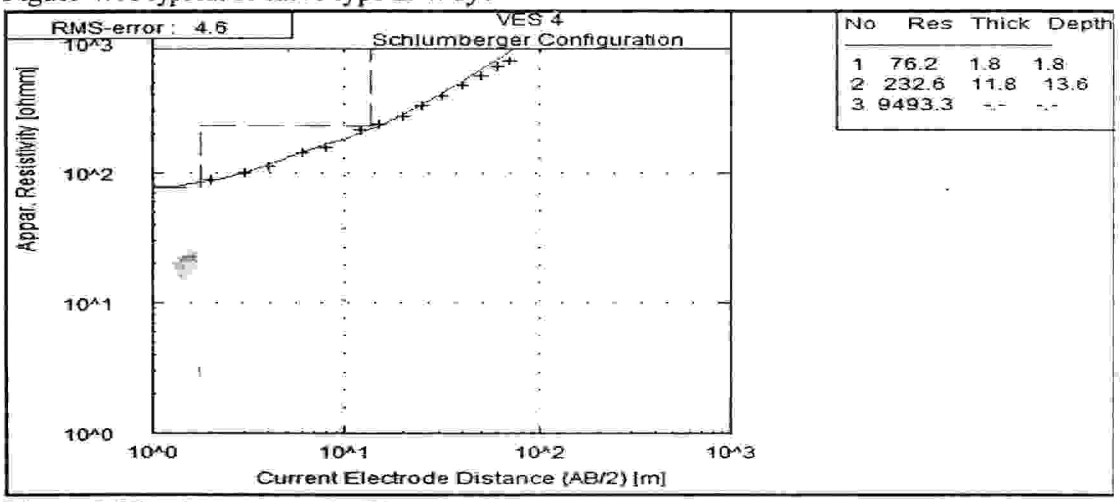

Figure 5: The A curve type in Wuye

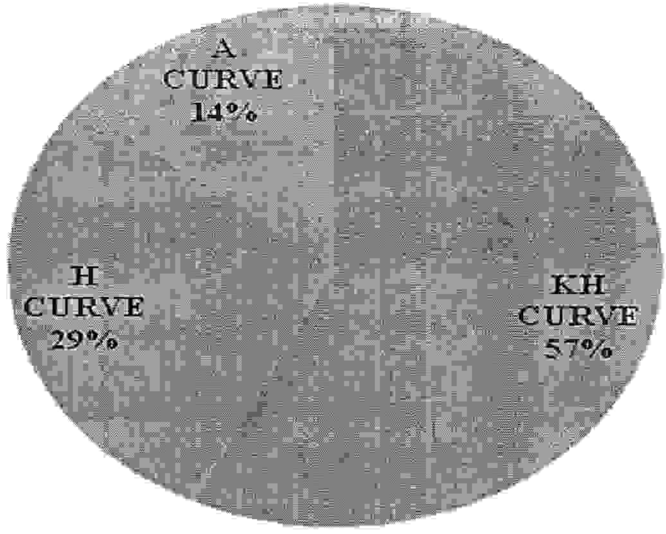

Figure 5: Resistivity Curve Distributions in Wuye

The resistivity pseudo-sections (Figures 6, 7 and 8) agree with the local geology of the area and the geo-electric sections (Figures 9 and 10). It shows that the interconnection of the resistivity properties of the subsurface along a profile and useful in identifying areas of thick overburden and high fracture index (Olasehinde and Bayewu, 2011). The layers comprises of topsoil, weathered layer/fractured basement and the fresh basement rock. The topsoil composes of clayey sand, silty sand and lateritic soil with resistivity value ranging from 76.2 to 675 Ωm and thickness of 0.8 to 2 meters. The topsoil resistivity values in VES 1 and VES 3, is more than 250 ohm-m which is a typical resistivity value of sandy and lateritic soil. The other VES stations have resistivity values less than 250 Ωm, which is clay, sandy clay or saturated material. The other VES points have a second layer in between the topsoil and weathered layer, which is suspected to be a pure clayey sand layer with a resistivity values from 566.7 to 946.8 Ωm and thickness from 2.3 to 5.9 meters, thereby making them a four layer system (KH type) instead of the normal three layer components (H and A types). The weathered layer has resistivity's value that ranges from 88.4 to 297 Ωm and thickness of 8.7 to 13.3 meters. The resistivity value of the partly fractured or fresh basement layer varies from 202 to 9493.3 up to infinity. According to Reynolds (1997), the resistivity in the range of 1-100 Ωm suggests clays while those in the range of 50 – 150 Ωm suggest lateritic clay.

Furthermore, isopach maps of depth to weathered basement (Figure 11) and fresh basement (Figure 12) were produced. The shallowest part is located within the centre and the northeastern part of the area while the deepest portion is located in the southern part of the study area. The finding is in agreement with the geo-electric sections, geological and structural mapping. The iso-resistivity map shows a strong correlation with the geology of the area (Figure 13). Resistivity value high than 150 Ωm that dominates the entire place is a clear indication that the area is underlain by gneiss. The north western region of the study area has resistivity value higher than 250 Ωm and as such are underlain by competent geologic materials like clayey sand and laterite, while the south easthern part consist of resistivity value less than 250 Ωm which suggests clay and sandy clay material or saturated material as the case maybe.

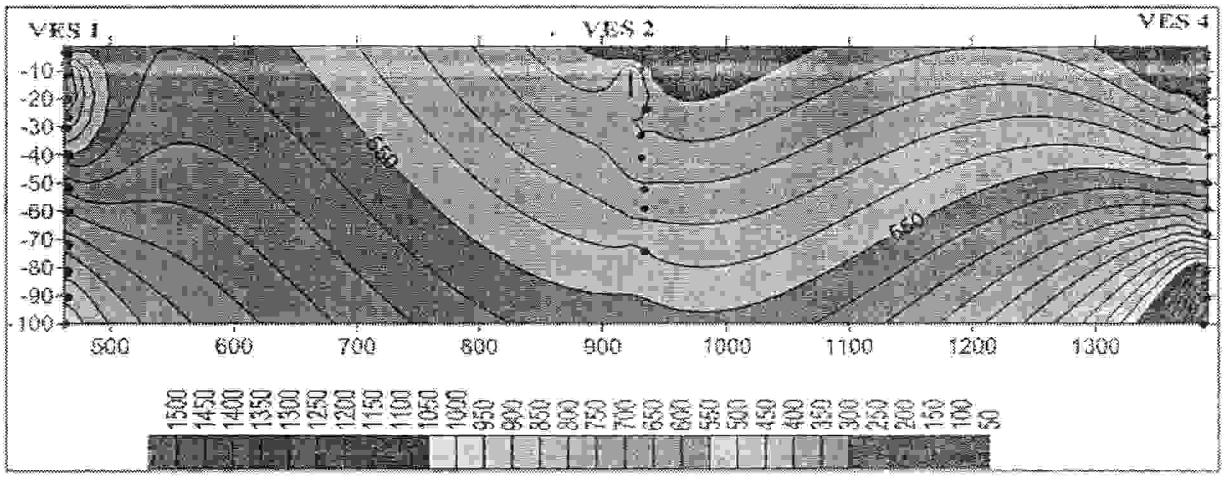

Figure 6: Resistivity Pseudo-section along Profile AB

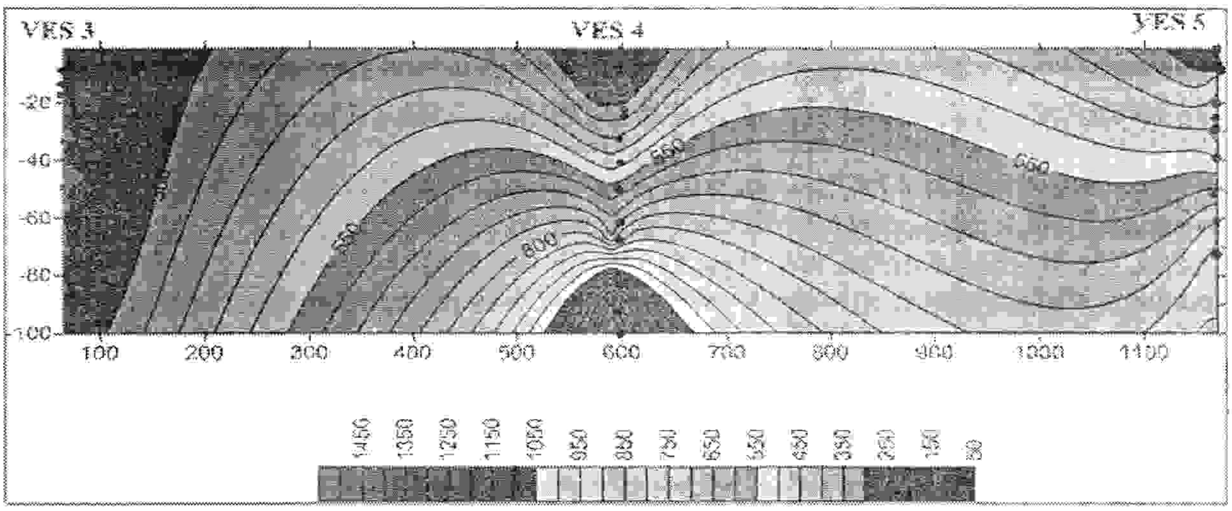

Figure 7: Resistivity Pseudo-section along Profile CD

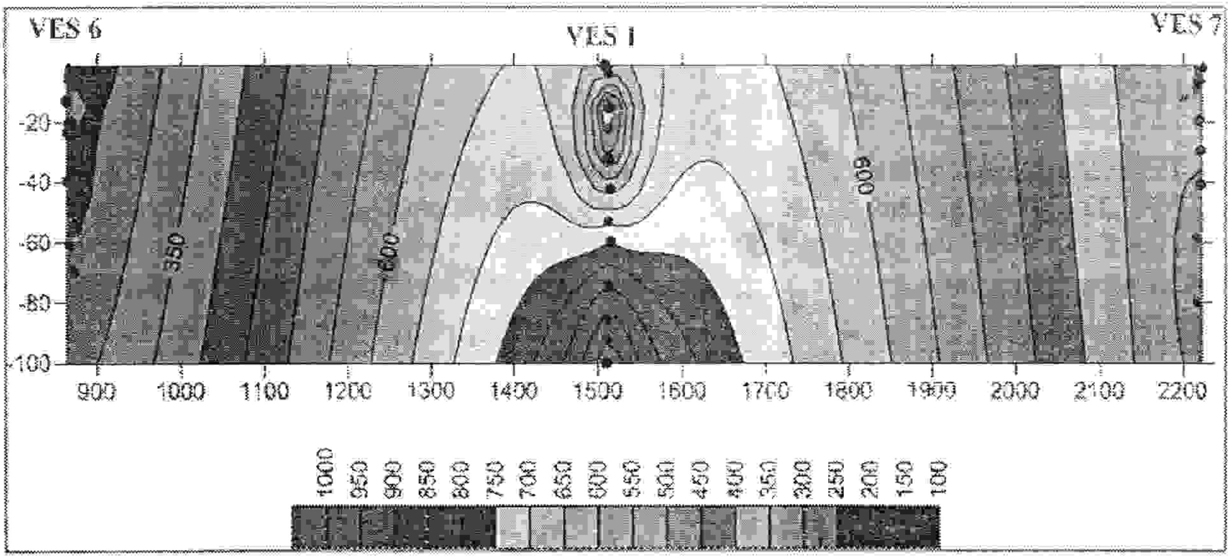

Figure 8: Resistivity Pseudo-section along Profile EF

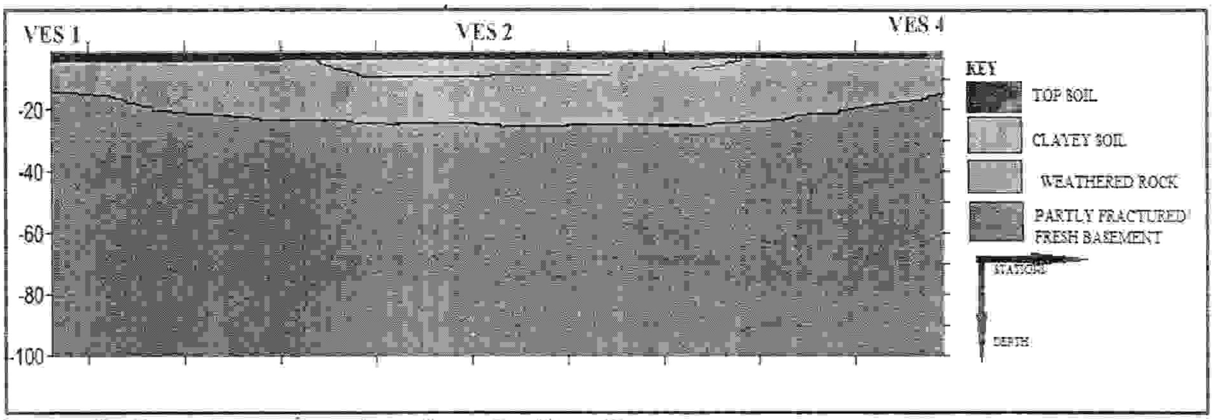

Figure 9: Geo-electrical section along Profile AB

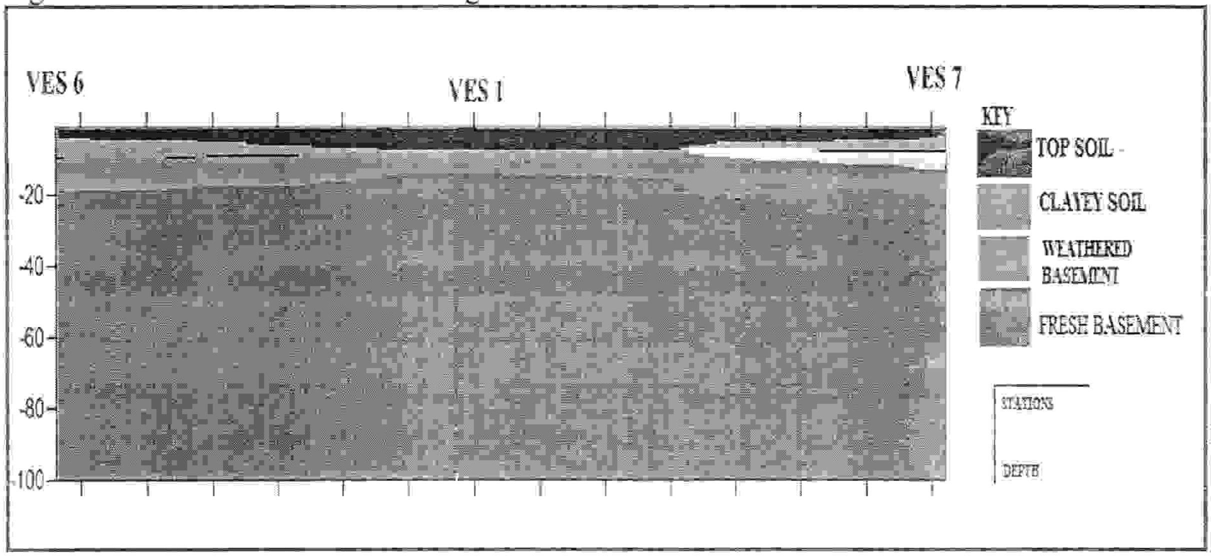

Figure 10: Geo-electrical section along Profile EF

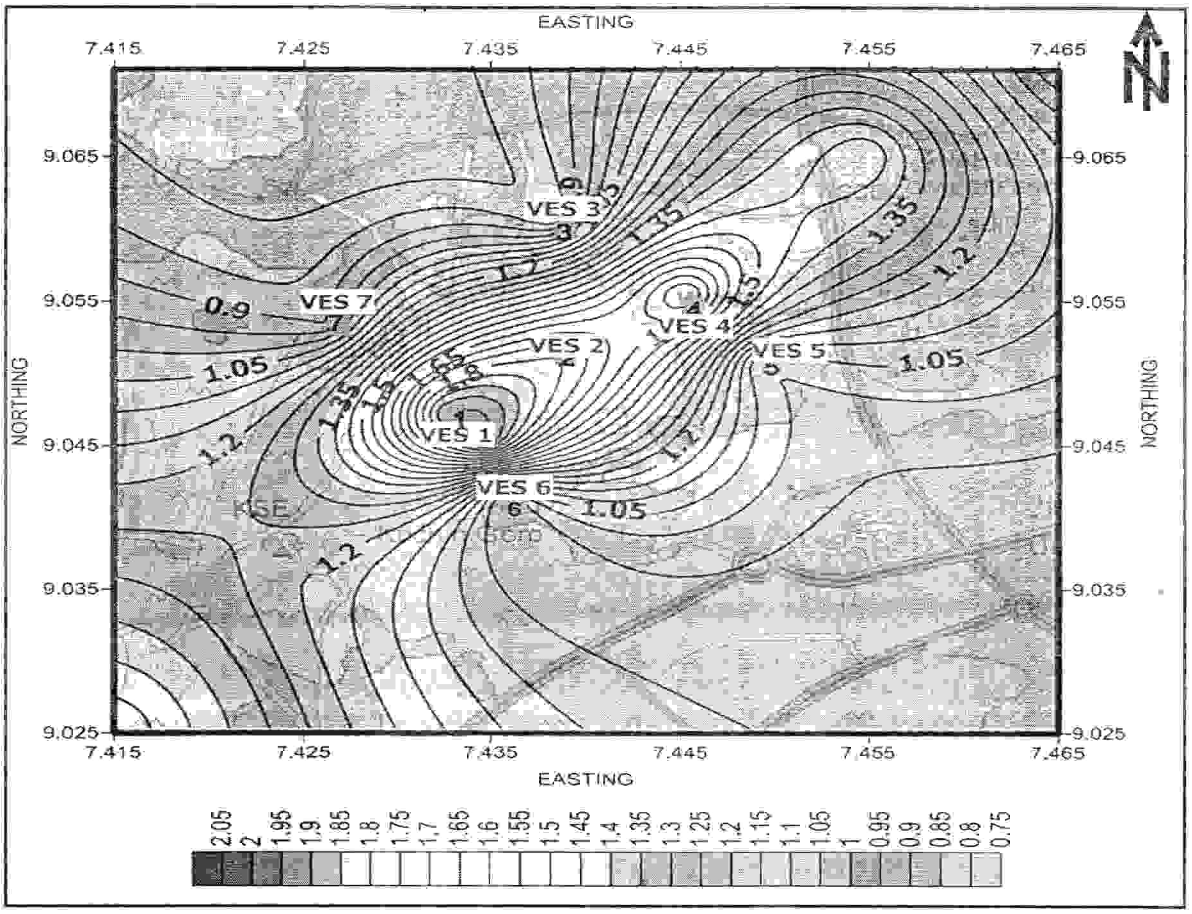

Figure 11: Isopach map of depth to weathered basement in Wuye

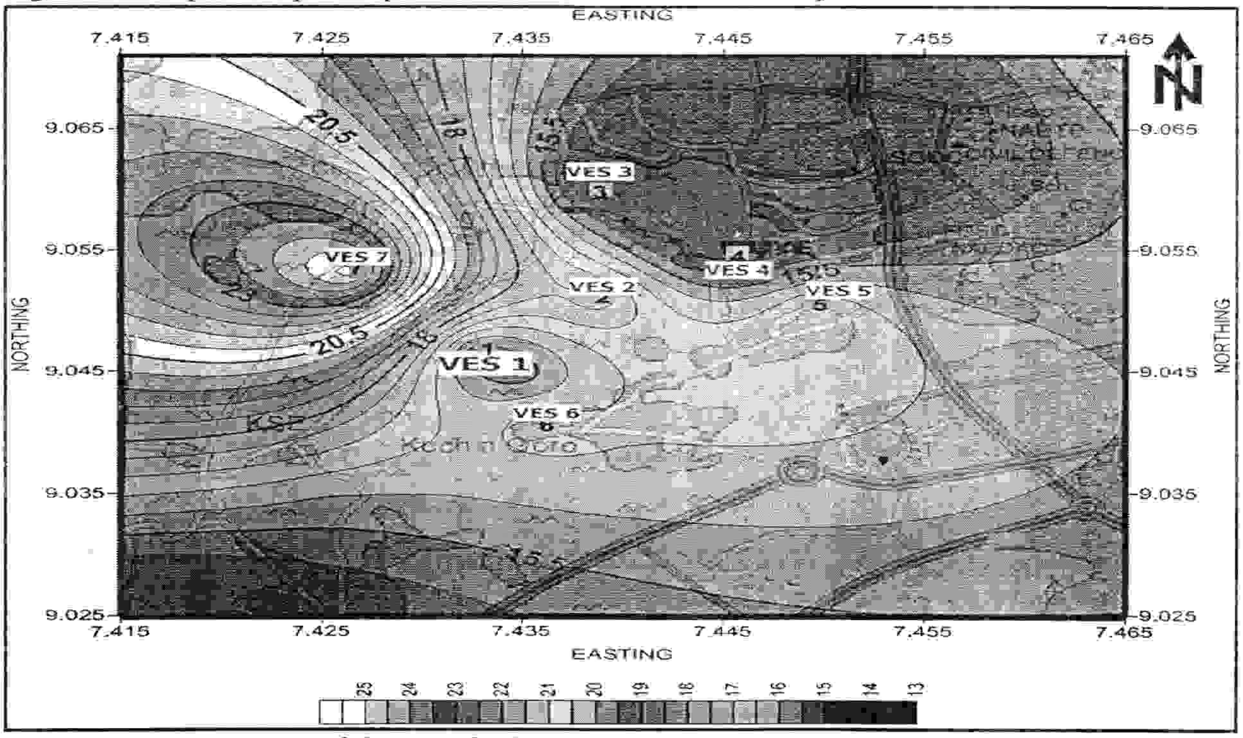

Figure 12: Isopach map of depth to fresh basement in Wuye

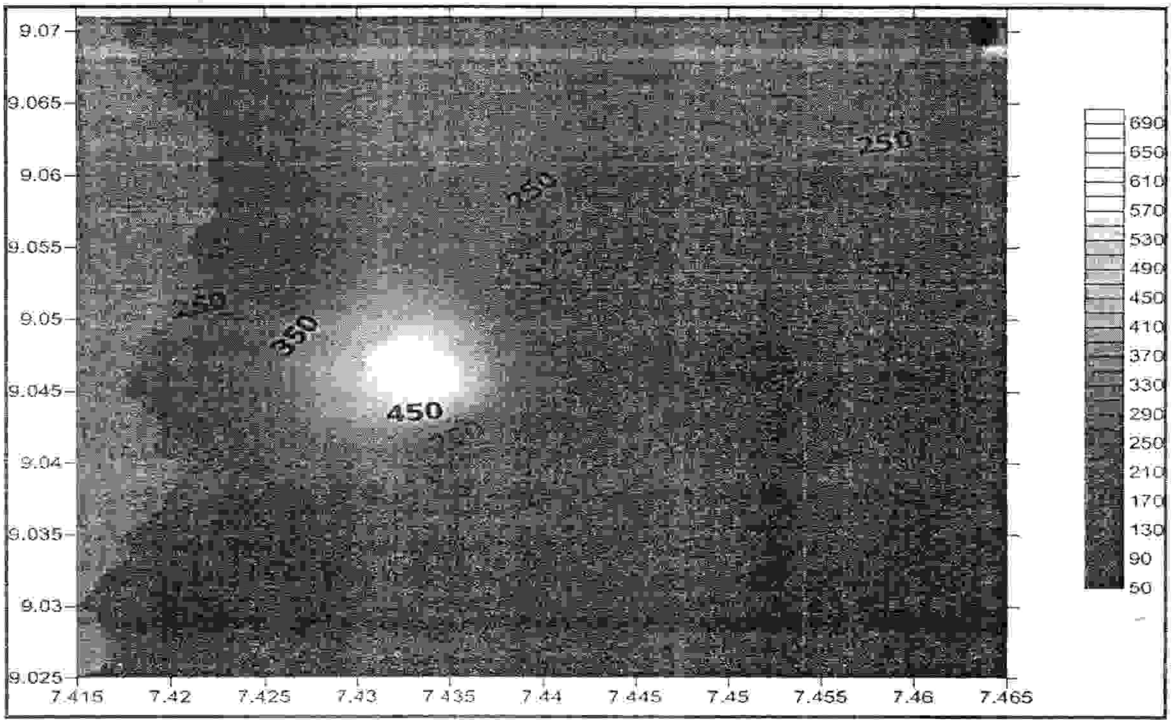

Figure 13: Iso-resistivity map of the topsoil in Wuye District

4.0. Conclusions

Groundwater is a primary source of drinking water as well as water for agricultural and industrial uses. Due to the advantages of groundwater over surface water, it has become necessary to determine the groundwater potentials of Wuye in view of the increasing population in the area and the inadequacy of water supply by the Abuja water board. Three profiles were established and the VES results were qualitatively interpreted using partial curve matching and computer softwares. The interpretation revealed, three to four distinctive geologic layers which includes, topsoil, weathered rock, weathered/fractured basement rocks, and fresh basement. The result of the geophysical investigation revealed that the shallowest part is located within the central portion as well as the northeastern part of the area while the deepest portion is located in the southern part of the study area. The finding is in agreement with the geo-electric sections, geological and structural mapping. Groundwater exploration and exploitation should concentrate on the southern portion of the area which is characterized by thick overburden and high fracture index. Integration geological, structural and geophysical techniques for groundwater exploration in the basement complex terrain should be embraced due to their complementary roles in fracture delineation. A drill depth ranging from 35m to 95m is recommended for the area.

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