Hydrogeophysical Evaluation of Groundwater Potential in Federal Housing Estate Lugbe, Abuja, Nigeria using Electrical Resistivity Method

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Abstract

Inadequate potable water supply remains one of the challenges of residents of Federal Housing Estate, Lugbe, Abuja, Nigeria. The groundwater potential of the area was investigated using vertical electrical sounding (VES) method. A total number of 40 VES points were used for the investigation using Schlumberger array and the data obtained were analysed using curve matching and computer iteration techniques. The data revealed both a 3-layer (H-Curve) and 4-layer (HA-curve) for the area. In the 3-layer system, the apparent resistivity of the first layer ranged from 63 Ωm to 658 Ωm with a corresponding thickness of 0.8 to 2.1 m. The second layer has apparent resistivity varying from 29 to 726 Ωm with a corresponding thickness range of 3.0 to 21.7 m while the third layer has resistivity values ranging from 96 to 6769 Ωm to an infinite depth. For the four layered model curves, the first layers resistivity ranged from 37 to 1087 Ωm, with a corresponding thickness range of 0.5 to 2.4 m. The resistivity of the second layers ranged between 28 to 2453 Ωm with a corresponding thickness range of 1.4 m to 15.3 m. The resistivity of the third layer ranged from 25 to 2441 Ωm and a corresponding thickness range of 7.3 to 37.3 m respectively. The forth layer has a resistivity value ranging from 69 to 6820 Ωm and an infinite depth. An integration of the isopach and isoresistivity maps for both the 3 and 4 layer model curves indicates that the northern parts of the study area have low apparent resistivity values and thick overburden which implies good groundwater potential while the southern portion has higher resistivity values and shallow overburden, an indication of poor groundwater potential. Future boreholes in the area should reached an effective depth of 45 to 65 m and the borehole be supervised by a certified hydrogeologist for optimum groundwater yields. Pumping test should be carried out in order to ascertain the size and type of submersible pump to install.

Keywords: Assessment, Groundwater Potentials, Federal Housing Estate, Lugbe, Abuja, Nigeria

Introduction

The increase in groundwater demand for various human activities has placed great importance on water science and management practice world-wide (Amadi *et al.*, 2015a). The Federal Housing Estate, Lugbe, Abuja, Nigeria was designed originally for 100,000 inhabitants but currently has population of over 500,000 people and basic amenities are over-stretched. This population and the daily influx of people into Abuja, Nigerian's Capital in search of greener pastures have resulted in acute water shortage in the area and the inhabitants now rely on water vendors for their daily water needs. Groundwater accounts for greater percentage of the world's fresh water and it is fairly distributed throughout the world. It is the world's greatest essential factor for sustainable development. Surface water where available are sometimes seasonal and prone to contamination either as a result of urbanization or other human factors (Olasehinde *et al.*, 2015). The need to explore the groundwater quantitatively as a better alternative and to supplement the shortage in the daily water supply in estate, especially during the dry season cannot be overemphasised. The present study evaluates the groundwater potential in Federal Housing Estate Lugbe using electrical resistivity methods. This is necessary in order to ascertain the availability of the groundwater in the area for domestic, irrigational and industrial purposes.

Furthermore, pre-drilling geophysical survey using electrical resistivity method was employed in this study to determine the groundwater potentials in the area because it is efficient and cost-effective. In electrical resistivity method, artificially generated electric current are introduced into the ground and the resulting potential difference are measured at the surface. It is based on the measurement of the electrical resistivity of the ground which is dependent primarily on the porosity, fracturing, degree of saturation and the salinity of the pore water. Electrical resistivity method has been used successfully by many workers to evaluate groundwater potential in different parts of the basement complex rocks (Amadi, 2009; Olorunfemi and Fasuyi, 1993). Although the electrical resistivity method will never replace test drilling for quantifying aquifer yield, it has reduced the cost and time of drilling abortive boreholes. The basement complex terrain has many challenges as regards to groundwater potential evaluation and it explains why well yield in basement complex is lower than well yield in sedimentary terrain (Adesida and Omosuyi, 2005; Faleye and Omosuyi, 2011; Olasehinde and Bayewu, 2011). The application of this method enables us to determine the aquiferous units, aquifer thickness and depths to bedrock as well as identificaion of fluid migration pathways such as fractures, faults and joints (Amadi, 2010; Omeje *et al.*, 2013).

The search for better living conditions has made it very difficult to control the influx of both skilled and unskilled people in and out of Federal Housing Estate Lugbe, Abuja. This has exerted undue pressure on the water supply and drainage system in the area. The tap water no longer runs while the drainage system now serves as dumpsites for solid wastes. The determination and characterization of groundwater potential in Federal Housing Estate Lugbe, Abuja is important because it will unravel the nature of the subsurface geology and lithostratigraphy in the area. This information is useful in order to avoid drilling of abortive boreholes as currently experienced in the area, hence the need for the present study.

Materials and Methods

Study Area Description

Abuja, the Federal Capital Territory was created in 1978, following the decision to relocate the Nigerian Capital from Lagos in the southern coastal area to a more central location within Nigeria, devoid of dominant of any of the major ethnic groups (Igbo, Yoruba and Hausa). Lugbe lies in the north-eastern part of Abuja between longitude 7°19'45" E to 7°23'00" E and latitude 8°57'30" N to 9°00'15" N (Fig. 1). The study area falls within sheet 207, Kuje NE on a scale of 1:50,000. Lugbe is about 21km from the city centre and it is accessible through major and minor roads.

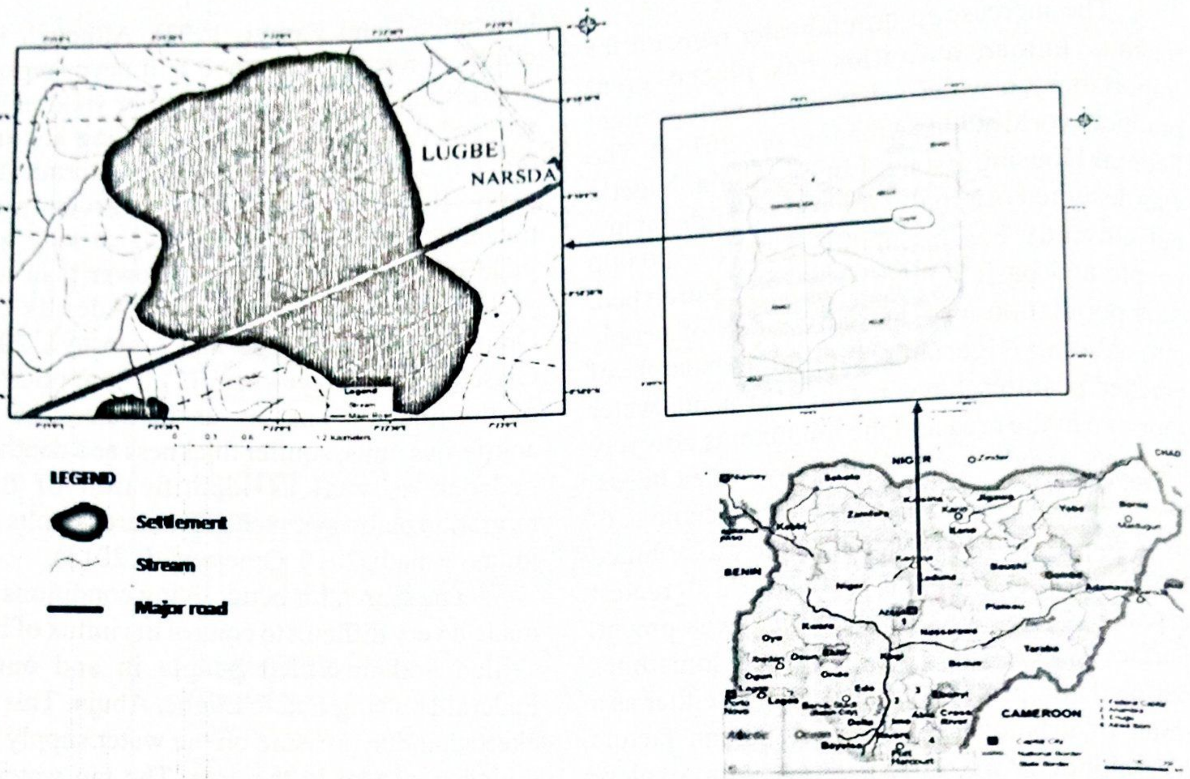

Fig. 1: Location Map of Lugbe, Abuja

Physiography of the Area

Hills occur as clusters and long ranges all over the Federal Capital Territory. The topography of the study area is varied with the highest elevations found in the northeast where the plain is at elevation of about 460m above sea level. The lowest part of the area is the southern part (Sabon-Lugbe) where the elevation is about 350m above sea level. The study area records its highest temperature (37°C) during the dry season months (November-March) while the lowest temperature of about 27°C occurs during the rainy season The annual total rainfall is in the range of 1100 mm to 1600 mm (Eduvie *et al.*, 2003; Dan-Hassan,2013; Ofodile, 2002).

Geology of the Study Area

The geology of Abuja (Fig. 2) has been described by many workers, including Ajibade (1976), Grant (1978), McCurry (1985) and Ajibade and Woakes (1983). It is underlain by Precambrian rocks of the Nigerian Basement Complex which cover about 85 % of the land mass while the cretaceous sedimentary rocks belonging to the Bida Basin covers the remaining 15 % (Fig. 2). The geological mapping carried out in Federal Housing Estate Lugbe revealed two main lithologic units: migmatite-gneiss and course grained to porphyritic biotite-hornblende granite. The migmatite gneiss dominates the eastern part of the study area while the porphyritic biotite-hornblende granite occupied the western portion of the study area (Fig. 3).

Pre-drilling Geophysical Investigation

A total spread of 165 m was covered with maximum current electrode separation (AB/2) of 82.5 m. An *ABEM SAS 1000 Terrameter* was used for the electrical resistivity survey. Schlumberger electrode configuration was used for the pre-drilling geophysical survey. The array consists of 2 current (C_1 and C_2) and 2 potential (P_1 and P_2) electrodes (Fig 4). It works under the principles of the wider the current electrodes, the deeper the current penetration (Olasehinde and Awojobi, 2004). The interpretation of the field data using *WinResist and Ipl2win Computer softwares* as well as curve matching method were used to obtain the apparent resistivity values (Annor *et al.*, 1990; Edet and Okereke, 1997 Amadi, 2008; Akintorinwa and Adeusi, 2009).

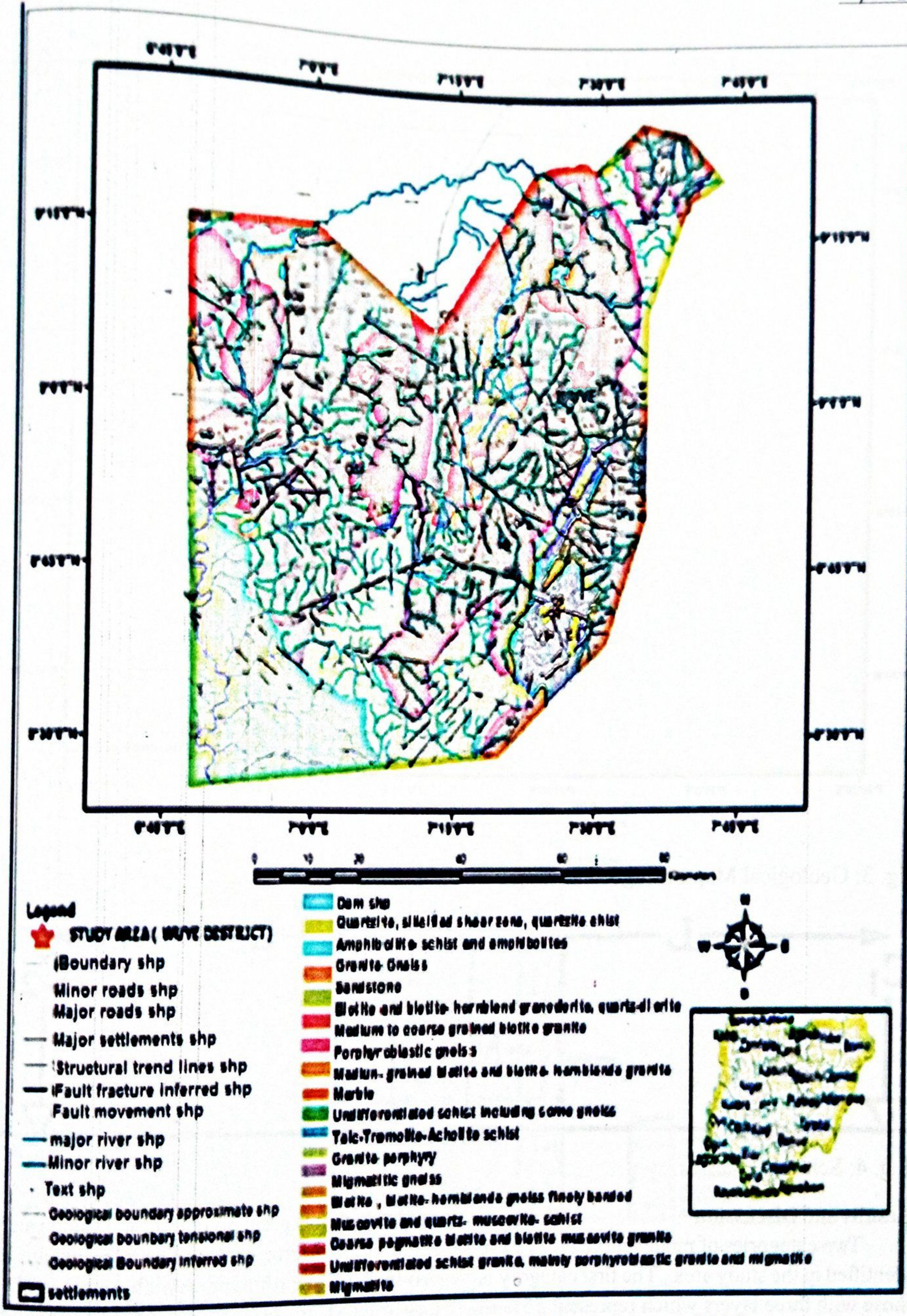

Fig. 2: Geological Map of Abuja (Nigerian Geological Survey Agency, 2004)

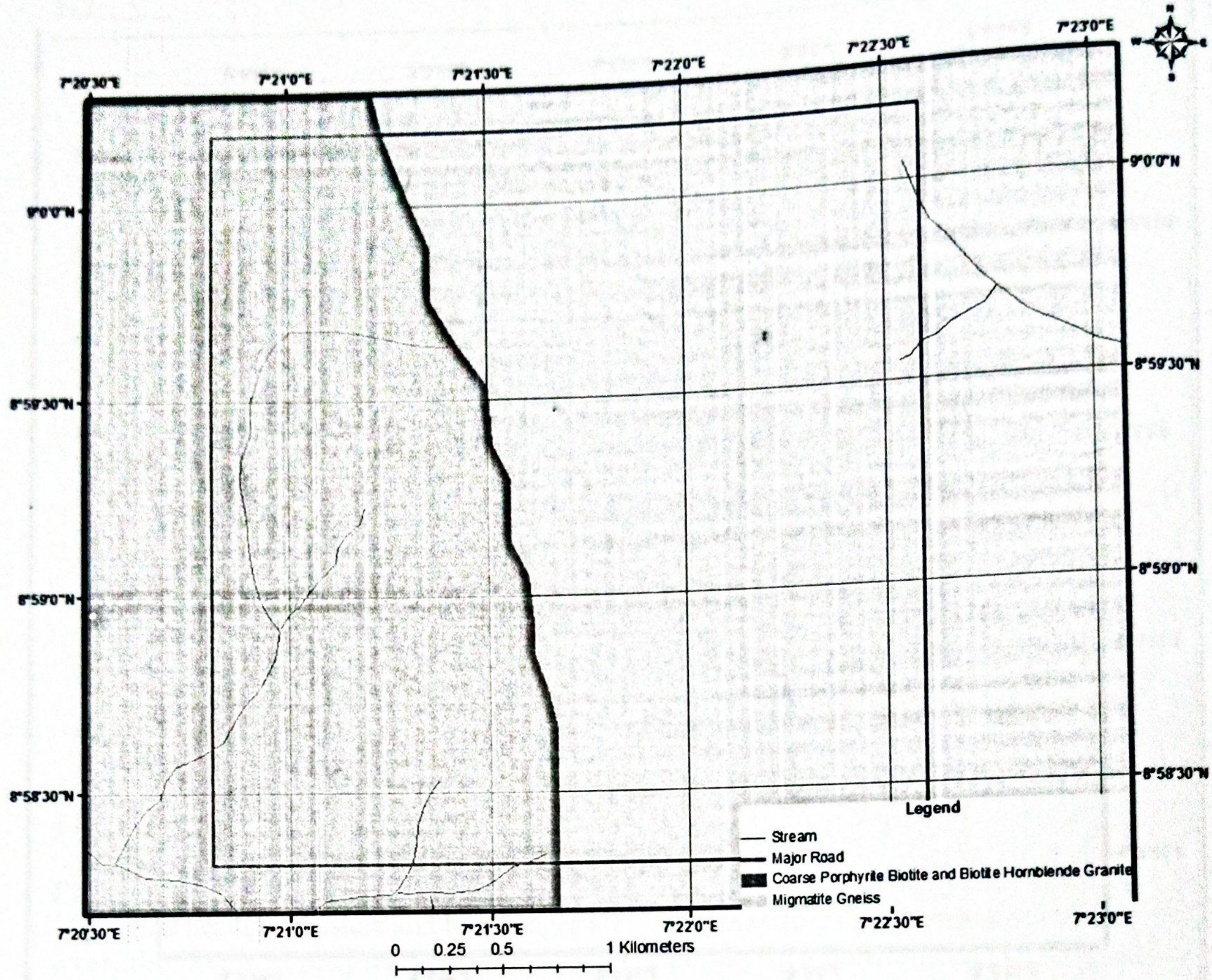

Fig. 3: Geological Map of Lugbe Housing Estate, Abuja

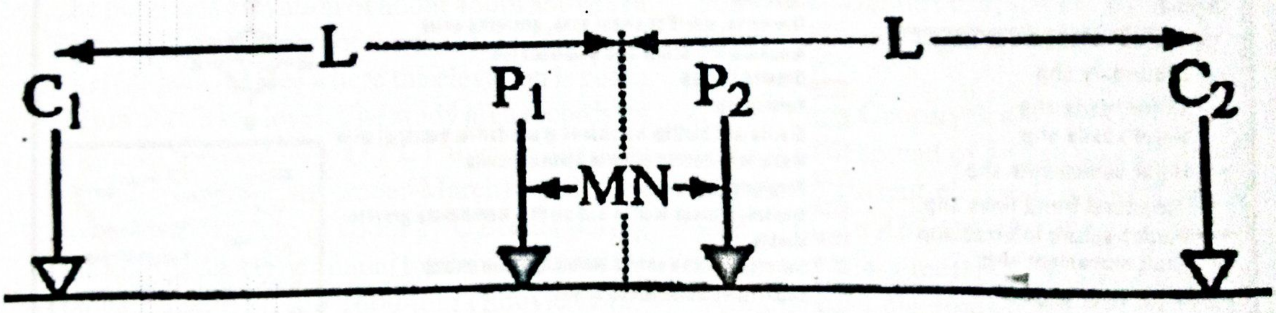

Fig. 4: Schlumberger Array

Results and Discussion

Two categories of model curve types were identified in the study area. The first category is those with three layers which represent 55% of VES curves (Fig. 5) while the second category consists of four layers, representing 45% of the sounded points within the study area (Fig. 6). The geoelectric sections of the study area show that the subsurface lithology of the area is not uniformly distributed. Area with thick regolith materials shows great potential for groundwater exploitation (Ako, 1996). The regolith are a product of weathering which induces the geological materials to be porous and permeable, which qualifies them as aquifers, since they can store and transmit groundwater in economic quantity (Amadi *et al.*, 2012; Momoh *et al.*, 2012).

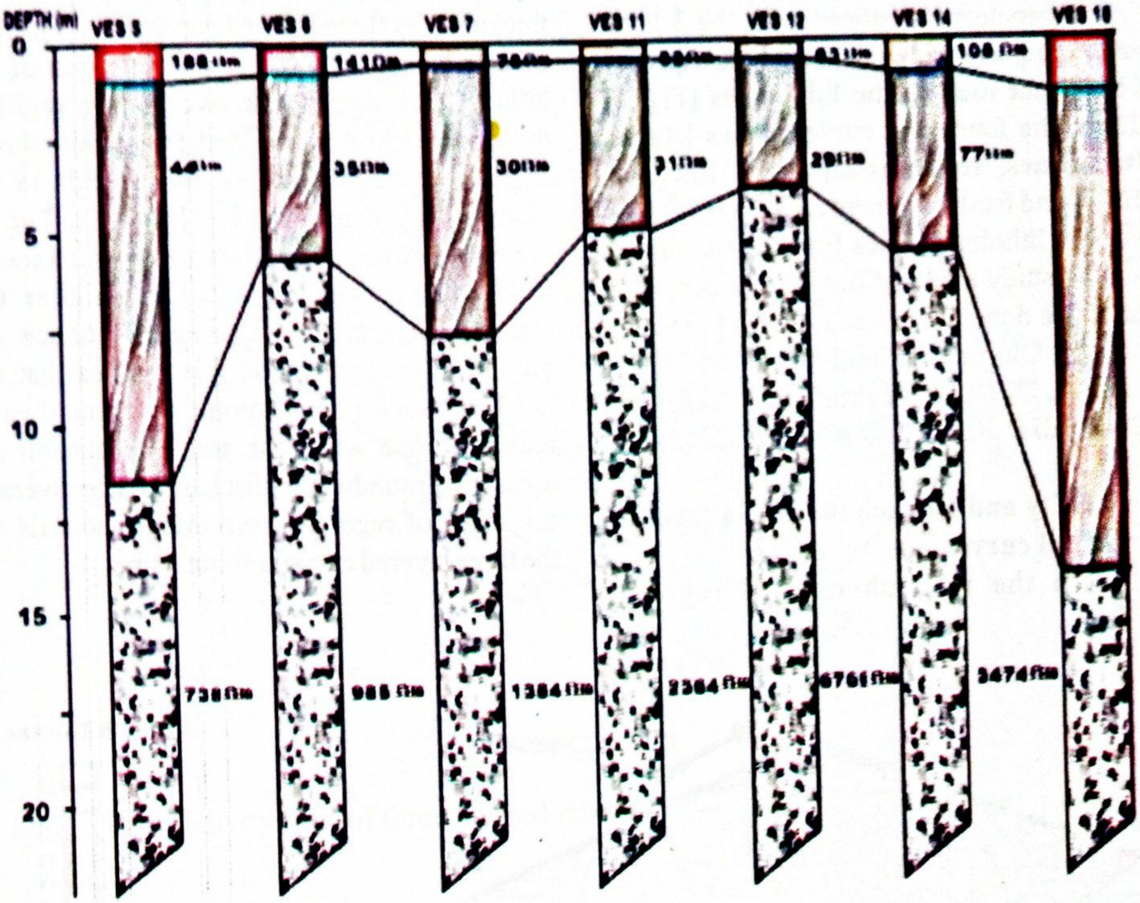

Fig 5: Geoelectric Sections for 3 Layer System

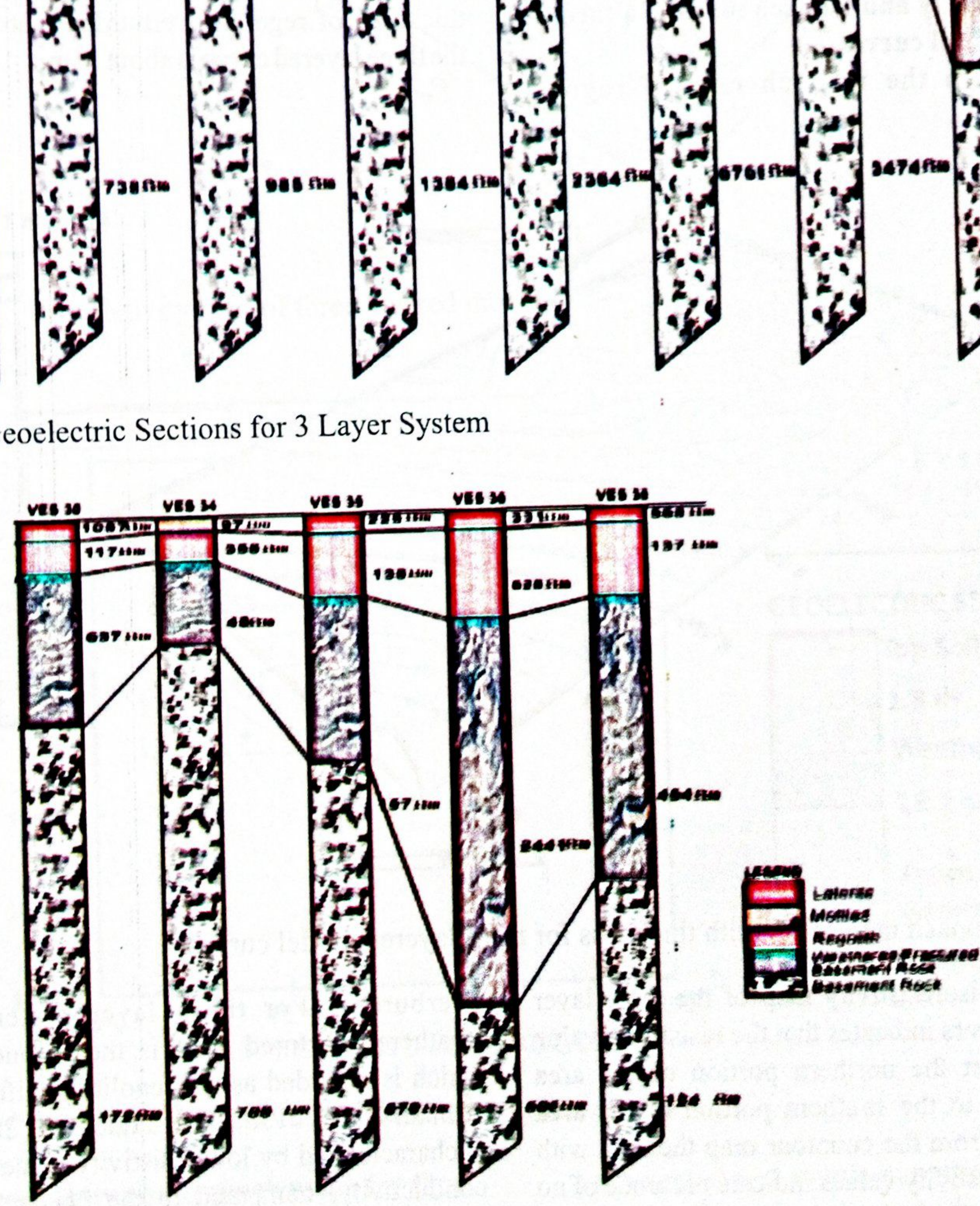

Fig. 6: Geoelectric System for 4 Layer System

The geoelectric sections with the 3 layer show laterite, mottled zone, regoliths/saprolith and basement rock as the lithologies (Fig. 5) while the the four layer curves shows laterite, molted zones, regoliths/saprolith, fractured basement and fresh basement rocks (Fig. 6). The subsurface lithology varies from place to place within the study area and the finding conforms to the work done other researchers (Mbonu *et al*., 1991; Olorunfemi and Okakune, 1992; Ikpokonte, 2010; Aiyegbusi and Akujieze, 2010; Amadi *et al*., 2013, Omeji *et al*., 2013).

Isoresistivity and Isopach maps of a three layer model curves

From the isopach map of regolith thickness for three layered curves (Fig. 7), it can be established that the northern portion of the area shows deep/thick overburden/regolith thickness, while south-western portion shows shallow overburden. This corresponds to the isoresistivity map, as the shallow overburden materials are seen around the ridge which shows lower resistivity values. The thicker the overburden materials the better chance for groundwater storage and this implies that the northern sector correspond to groundwater recharge zone while the southern portion are areas of groundwater discharge. The average thickness of regolith/overburden materials for the three layered curve is about 11m.

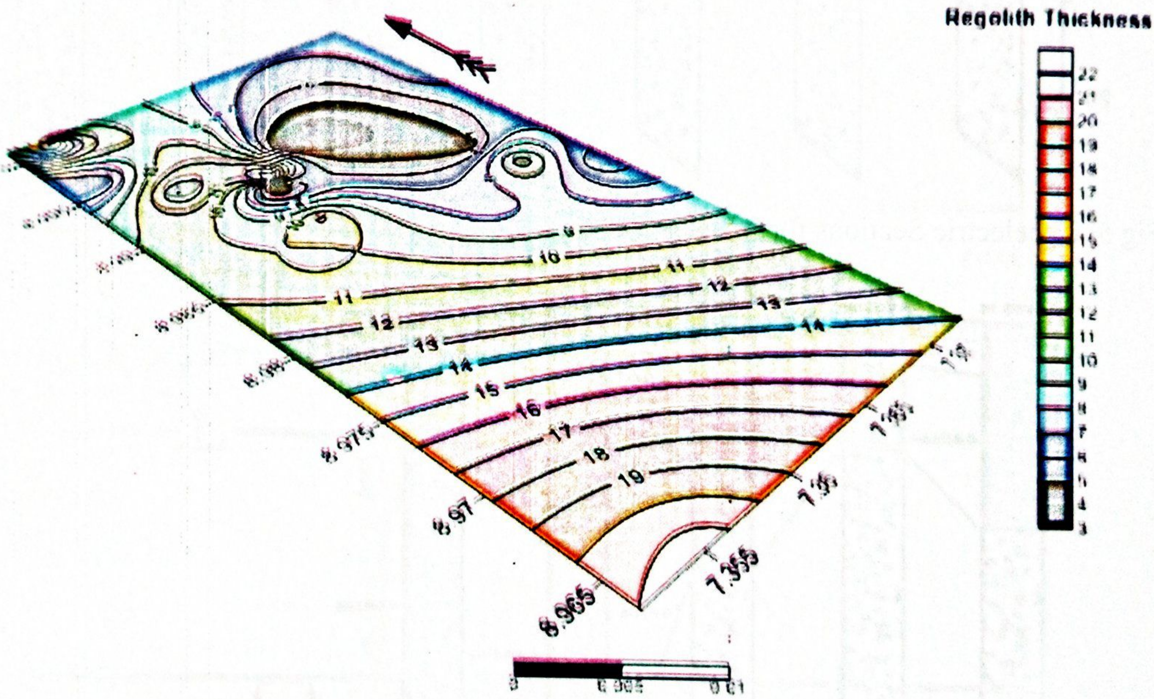

Fig. 7: Isopach map of regolith thickness for three layered model curves

The isoresistivity map of the three layer model curves indicates that the resistivity value is lower at the northern portion of the area compared to the southern portion of the area (Fig. 8). From the countour map the area with higher resistivity values indicate presence of no water or conducting materials while lower resistivity values are indicative of a thick overburden. For the 3 layer system, the weathered/fractured zone is the second layer which is regarded as the regolith aquifer zone (Amadi *et al*., 2015b; Olasehinde *et al*., 2016). It is characterized by low resistivity values (high conductivity) compared to the first and third layers as illustrated in Figure 9.

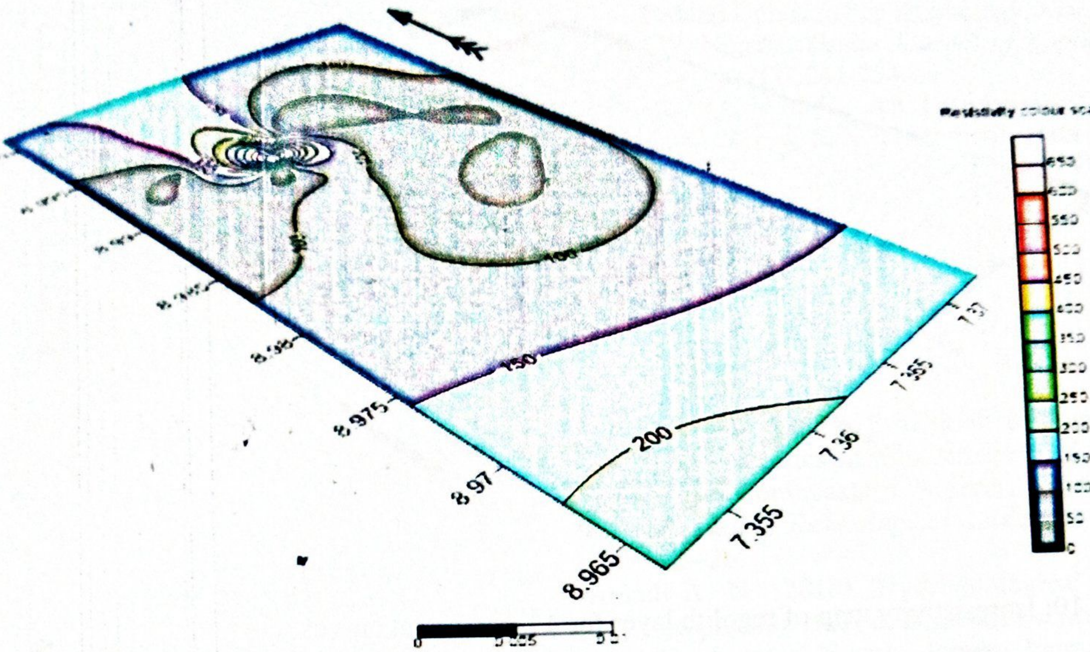

Fig. 8: Isoresistivity map of three layered model curves

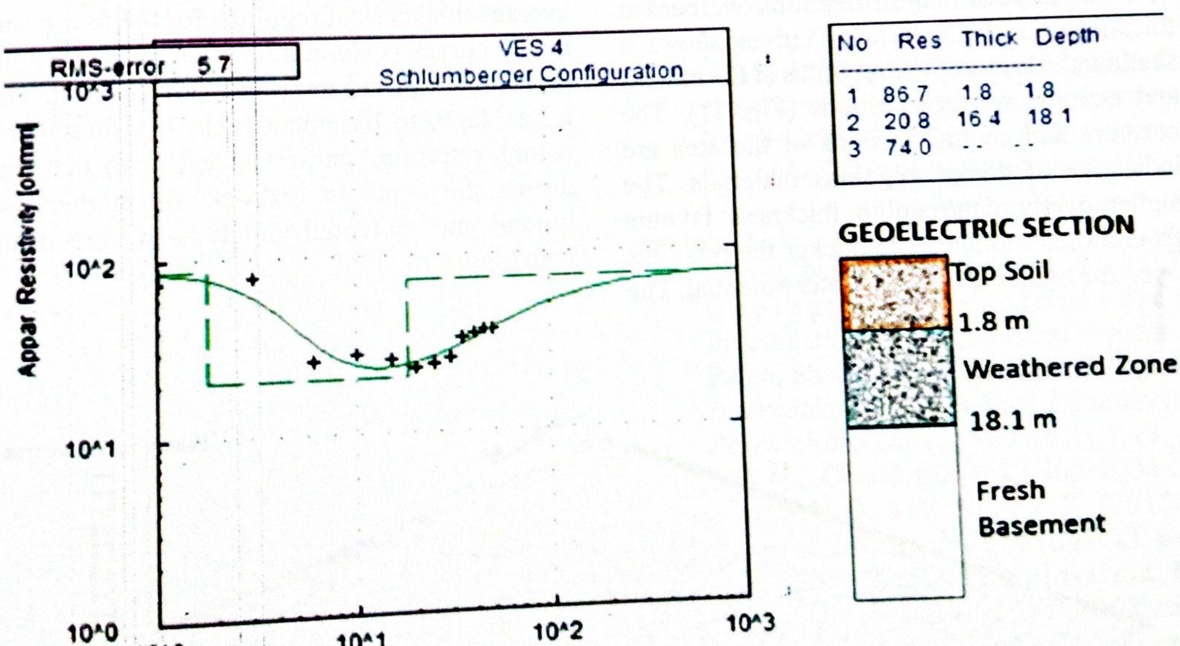

Fig. 9: A typical VES curve for 3 layer system in the area

Isoresistivity and Isopach maps for four layer model curves

For the four layer model curves, the regolith/overburden layer is represented in the third layer. The isoresistivity map of the four layer curves shows low resistivity of the regolith/overburden layer at the eastern and western part of the study area (Fig. 10). The north-central and sourthern portion of the area are indicative of moderate to high resistivity values. These implies that the eastern and wester parts of the area holds greater potential for groundwater storage than the north-central and southern portions. The result agrees with the isoresistivity map of three layer curves (Fig. 9).

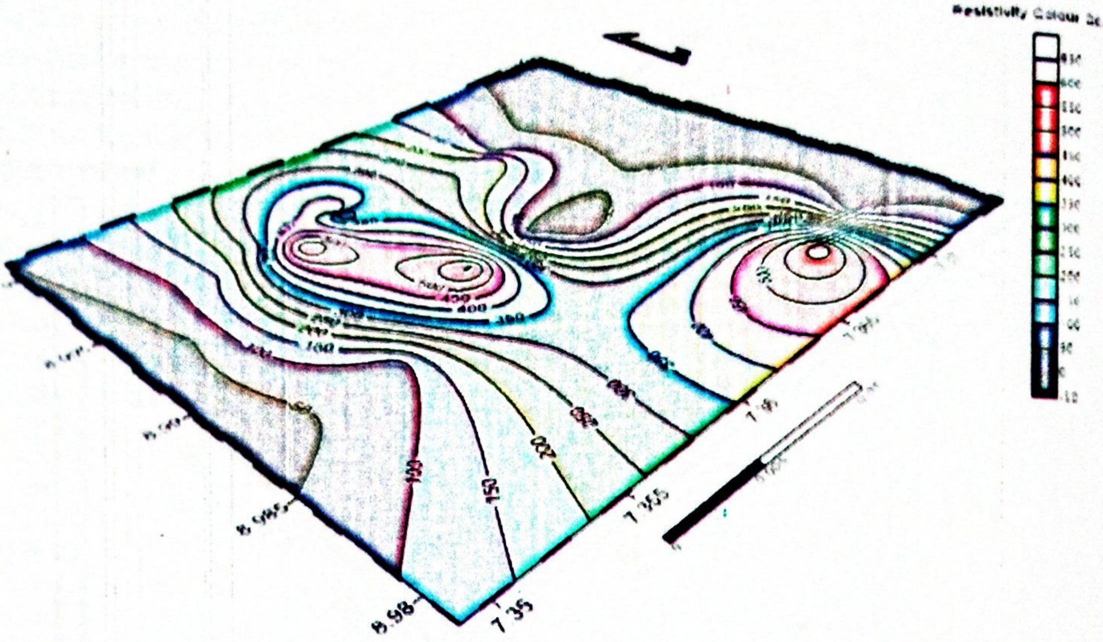

Fig.10: Isoresistivity map of regolith layer for 4 layer model curves

The isopach map of regoliths/overburden thickness for the four layer curves shows a shallow thickness of the regoliths at the eastern and extreme western portions (Fig. 11). The northern and central portions of the area are indicative of thicker regoliths materials. The higher overburden/regolith thickness favours groundwater storage. The thicker the regoliths layer, the higher the groundwater potential. The average thickness of regoliths for the four layer model curves is about 22m. Generally the four layer model curves from the study area indicate a fair depth to basement rock. In a basement complex terrain, studies have shown that the deeper the depth to bedrock, the higher the groundwater potential and it is in agreement with Figure 10.

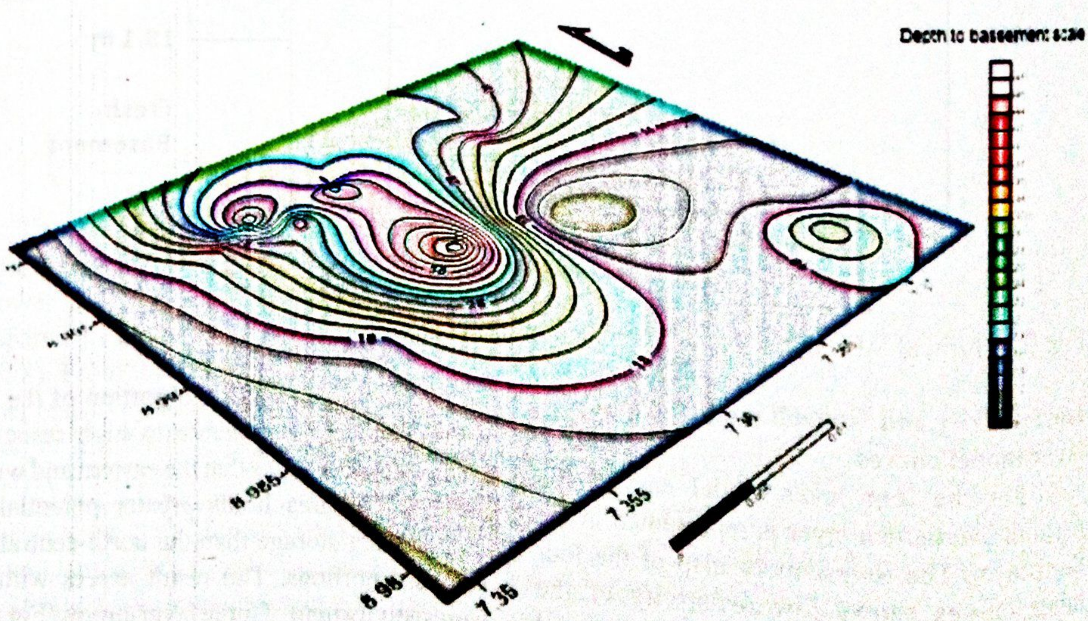

Fig. 11: Isopach map of regolith thickness of 4 layer model curves

Conclusion

The present study investigates the groundwater potential of Federal Housing Estate, Lugbe, Abuja, Nigeria using Vertical Electrical Sounding of the Electrical Resistivity method. The study became necessary due to the increase in population of the area and the incessant water scarcity experienced by the occupants of the estate. A total number of 40 VES points were conducted and the data obtained were analysed through curve matching and computer softwares. The area comprises of both 3 layer and 4 layer system. The 3 layers were predominantly H-type curve while the 4 layer system was mainly HA-curve type and are typical of the basement complex terrain. The field data, geoelectric section, isopach and isoresistivity maps of both the 3 and 4 layer model curves show that the northern parts of the study area correspond to recharge zone while the southern portion correspond to discharge zone. A total drill depth of 45 to 65 m was recommended for optimum groundwater yields in the area.

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