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ORIGINAL ARTICLE

GEOELECTRIC INVESTIGATION OF GROUNDWATER POTENTIAL OF PART OF RAFIN-YASHI, MINNA, NORTH CENTRAL, NIGERIA

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ABSTRACT

Background: Potable water supply has become a real challenge in Rafin-Yashi, Minna, Nigeria due to the basement complex rocks underlying the area, the massive infrastructural development which has led to a corresponding population growth. Potable water supply has been grossly inadequate to meet the ever increasing demand for this essential resource by inhabitants of the area and this has led to the dependence on groundwater from hand-dug wells or boreholes by individuals as their main source of potable supply since public water supply from government has proven over the years to be grossly inadequate and for the most part, non-existent. **Objectives**: Consequently, this study employs the Geoelectric method to investigate the groundwater potential at part of Rafin-Yashi, Minna, North Central Nigeria to outline the suitable aquifers for groundwater development. **Methods:** The methods used for this study was Electrical Resistivity Profiling (ERP) and Vertical Electrical Sounding (VES) of the Electrical Resistivity (ER) method. A total of two hundred (200) Electrical Resistivity Profiling points along ten (10) profiles A-J with inter profile and inter grid separation distance of 50 m were investigated using the Werner array configuration at electrode spacing of 30 m. Twenty (20) of the promising points from the Electrical Resistivity Profiling contour map were selected and investigated using the Vertical Electrical Sounding (VES) technique employing the Schlumberger array configuration. The data acquired were analyzed using partial curve matching and computer iteration technique using WinResist software and the data were interpreted to disclose different geoelectric layers that constitute the area**. Results**: The results revealed about 95% H- type curve and 5% K- type curve with three distinct geoelectric layers namely: the top soil, weathered/fractured basement and the fresh basement. The apparent resistivity of the first layer ranged between 18.5 Ωm – 706.6 Ωm with a corresponding thickness of 1.1 m – 4.8 m, second layer has apparent resistivity values of 16.8 Ωm – 591.6 Ωm with corresponding thickness of 4.8 m – 15.3 m and the third layer has apparent resistivity values of 19.2 Ωm – 7299.1 Ωm with an infinite thickness. **Conclusions:** VES stations B6, B9, C6, C7, D6, E6, E7, F6, F9, G9, H8, H9, I9, J8 and J9 with relatively high overburden thicknesses of 11.4 m, 12.7 m, 14.7 m, 18.0 m, 11.8 m, 11.2 m, 10.1 m, 13.1 m, 17.2 m, 12.1 m, 10.0 m, 10.6 m, 10.8 m, 18.5 m, 11.2 m and 11.5 m respectively having a corresponding very low to low resistivity values ranging between 50 – 250 Ωm at depth 45 m have been established to have high groundwater potential and thus, have been chosen as priority locations suitable for groundwater development.
Keywords: *Geoelctric method, Electrical Resistivity profiling, Vertical Electrical Sounding, Wenner array, Schlumberger array, aquifer.*

1. INTRODUCTION

Rafin-Yashi is a suburb in Minna, the capital of Niger state, Nigeria, it has largely experienced massive infrastructural developments and thus, a resultant population growth. Potable water supply has been grossly inadequate to meet the ever increasing population and the demand for this essential resource by inhabitants of the area. Hence, this has led to the dependence on groundwater from hand-dug wells or boreholes by individuals as their main source of potable supply since public water supply from government has proven over the years to be grossly inadequate and for the most part, non-existent. The major effect of the situation is that some inhabitants who cannot afford alternative arrangements for potable water supply through hand-dug wells and boreholes resort to get water of unknown quality from water hawkers and also from surface water sources which include streams, rivers, oceans and lakes that are not particularly safe for direct consumption as a result of their exposure to pollutants and pathogenic organisms that make these surface water sources not as clean as the groundwater. Groundwater is the water that occurs beneath the ground surface, filling the pore spaces between grains in sediments and sedimentary rocks, and filling cracks and crevices in other types of rock known as aquifers. Groundwater is quite pure and largely confined from surface pollutants as a result of their depth of storage and natural filtration through different subsurface layers. Thus, there is a need to undertake an all-inclusive investigation of groundwater potential in the area to identify suitable locations for groundwater exploitation to alleviate the challenges of potable water supply in the area.

Several research works have been carried out on the use of resistivity methods in investigating groundwater potential within Minna metropolis and Niger State at large. Alhassan et al. (2017) carried out Vertical electrical sounding (VES) in northern part of Paiko, North Central Nigeria to determine the subsurface layer parameters (resistivities, depths and thickness) employed in delineating the groundwater potential of the area and established three to four discrete geoelectric layers, namely, the top layer, the weathered layer, the fractured/fresh layer, and the fresh basement layer [1]. Eight VES stations were delineated as ground water potentials of the area, with third and fourth layer resistivities ranging from 191 to 398 Ωm. Depths range from 13.60 to 36.60 m and thickness varies from 9.23 to 30.51 m [1]. Akande et al. (2016) investigated the groundwater potential of Chanchaga area, Minna, North-central Nigeria with a view to delineating the suitable aquifer for groundwater development. The technique employed for this study was Vertical Electrical Sounding (VES) of the Electrical Resistivity (ER) method. It concluded that the central and northern parts of the study area have meagre to marginal groundwater potential, and this is supported by the occurrences and concentration of fractures which can constitute weathered/fractured aquifers around these regions [2]. Ejepu and Olasehinde (2014) used the Vertical Electrical Sounding (VES) to give information about the subsurface lithology and structures of the Gidan kwano Campus, Federal University of Technology Minna, with the aim of evaluating its groundwater potential [3]. Out of the 48 VES made, 8 VES stations have been selected as priority locations for the development of groundwater resources. The study area has been found to have a very high potential for groundwater development [3]. Amadi et al. (2011) studied the groundwater potential of Pompo Village in the neighbourhood of Gidan Kwano campus of Federal University of Technology, Minna, using Vertical Electrical Resistivity Sounding. Out of the 12 VES carried out, 5 VES stations have been chosen as the most viable locations for the development of groundwater resources. Two types of aquifers, which are the weathered basement and fractured basement aquifer, have been delineated in this study [4]. These aquifer units may have significant groundwater potential [4].

Mohammed et al. (2007) employed the Vertical Electrical Resistivity (VES) to investigate the land mass covering Minna and its environ in Nigeria aimed at assessing the lithology underneath the area, delineate the aquiferous formations and its depths and thicknesses [5]. The weathered/fractured layers along the transitional zones form the aquiferous formations in the area with a maximum thickness of about 45 m [5]. Udensi et al. (2005) employed vertical electrical resistivity (VES) method to carry out hydro geological and geophysical surveys for groundwater at designated locations of the Gidan Kwano main campus of the Federal University of Technology, Minna and reported that the thickness of the weathered zone appears to be too thin to sustain a productive borehole by itself [6]. They concluded that, the prospect of exclusively exploiting the aquifer of the weathered zone is not realistic and opined that there was no other alternative than to consider the fracture aquifer system [6]. The use and application of Electrical Resistivity Profiling (Wenner array) and Vertical Electrical Sounding (VES) (Schlumberger array) survey methods of groundwater investigation in hard rock terrain had proved to be a potent tool in delineating subsurface fractures and aquifer potentials. From reviewed literatures and reports of works carried out around the study area, none employed the combination of Electrical Resistivity Profiling (ERP) and Vertical Electrical Sounding (VES) survey methods of groundwater investigation. Hence, the adoption of both Electrical Resistivity Profiling (ERP) and Vertical Electrical Sounding (VES) survey methods for this study to have a detailed survey of the area for groundwater potentials.

1.1 Location of the study area

The study area is located adjacent Upper Niger River Basin Authority, Rafin-Yashi, Minna, Nigeria. It lies between latitudes 09°40' 27.0'' to 09°40'43.0''N and longitudes 06°30'24.0'' to 06°30'38.1''E. The area lies within the south western part of Minna metropolis and is accessible through Minna - Zungeru road. The research work covers an area of 1000m by 500m or 1km by 0.5km. The area coverage was gridded into 10 profiles, each consisting of 20 grid points with an inter grid and inter profile separation distance of 50m respectively. This separation distance was maintained throughout for data collection. The area has a typical Guinea Savannah climate with distinct wet and dry seasons. The dry season usually lasts from December to March and the rainy season which lasts from April to October. The area is characterized by shrubs, scattered trees and grass across the area. This vegetation is dependent on the annual rainfall and the nature of the soil.

1.2 Geology of the study area

The Nigerian Basement Complex is part of the ancient African shield, bounded to the west by West African Cratonic Plate and underlies about 60% of Nigeria’s land mass. The Basement complex has been described as a heterogeneous assemblage, which include migmatites, para-gneisses, ortho gneisses, quartzites, paraschists and a series of basic to ultrabasic metamorphic rocks [7]. Pan African Granites and other minor intrusions such as pegmatite and aplite dykes and veins, quartz veins and extrusive diorites and dolerites have intruded these rocks.

Minna is underlain by rocks belonging to the Basement Complex system of Nigeria, these comprises the migmatite-gneiss complex, the Older Granite and schist belt. The migmatite-gneiss complex is composed of migmatites of various structures and composition but predominantly with tonalitic or amphibolitic paleosome and granitic, pegmatitic or aplitic leucosme [8]. The Older Granite comprises rocks whose texture varies from medium-grained to coarsely-porphyritic; and composition varies from granite to tonalite [8], they form rugged topography and inselbergs. Grant (1978) identified four generations of structures for Kushaka and Birnin-Gwari Schist Formation and the Zungeru Mylonite [9]. The field relation shows that the schist belts are intruded and separated by the rocks of migmatite-gneiss complex and granitic rocks [10]. Rafin-Yashi the study area consists mainly of granitic rocks (Fig. 1.2)

2. MATERIALS AND METHODS

Electrical resistivity profiling is usually carried out when variation in apparent resistivity in horizontal direction is to be determined [11]. However, the length of the electrode configuration or electrode spacing is very important because it determines the depth of penetration. For each position of the electrode, an apparent resistivity is obtained and the resulting data is contoured that is joining area of equal apparent resistivity with a line. The method is particularly applicable to location of high and low resistivity surface materials. This technique can be used for fractures, topographic peaks, ore bodies, gravel deposits and water. For this study, Wenner spread was adopted for the Electrical Resistivity profiling survey along a grid in the area by keeping both the current electrode spacing and the potential electrode separation at 30m expected to probe to a depth of about 45 m. A total of 200 Electrical Resistivity Profiling (ERP) points were probed along 10 profiles using the GeoSensor DDR1 model resistivity meter as shown in Figure 2. Electrical current was passed into the ground through the two outer current electrodes and the resulting potential difference was measured across the two inner potential electrodes that were arranged in a straight line, equally spaced about a centre point.

Electrical resistivity sounding is used when an investigation of resistivity variation with depth is being carried out. This method helps in determining apparent variation in resistivity with depth that is, vertical changes in apparent resistivity in the earth when the subsurface of different geo-electrical layers are detected horizontally. It may be different vertically. Apparent resistivity method present details on the vertical succession of the conducting zones and the individual thickness and true resistivities. The technique is based upon the fact that the fraction of the electric current put into the ground, penetrating below any particular depth, increase with increased penetration of the current. The electrode configuration commonly used for vertical electrical sounding (VES) is the Schlumberger array. A total number of twenty (20) Vertical Electrical Sounding (VES) most promising points were selected from the 200 Electrical Resistivity Profiling points and probed along a grid in the area using the GeoSensor DDR1 model resistivity meter.

The apparent resistivity values in (Ωm) obtained from the Vertical Electrical Sounding (VES) presented as depth sounding curves by plotting the apparent resistivity along the ordinate axis and the half current electrode spacing (AB/2) along the abscissa. The plot was made on log-log graph paper. The resistivity depth sounding curves was classified based on layer resistivity, the number of layers in the subsurface and the thickness of each layer.

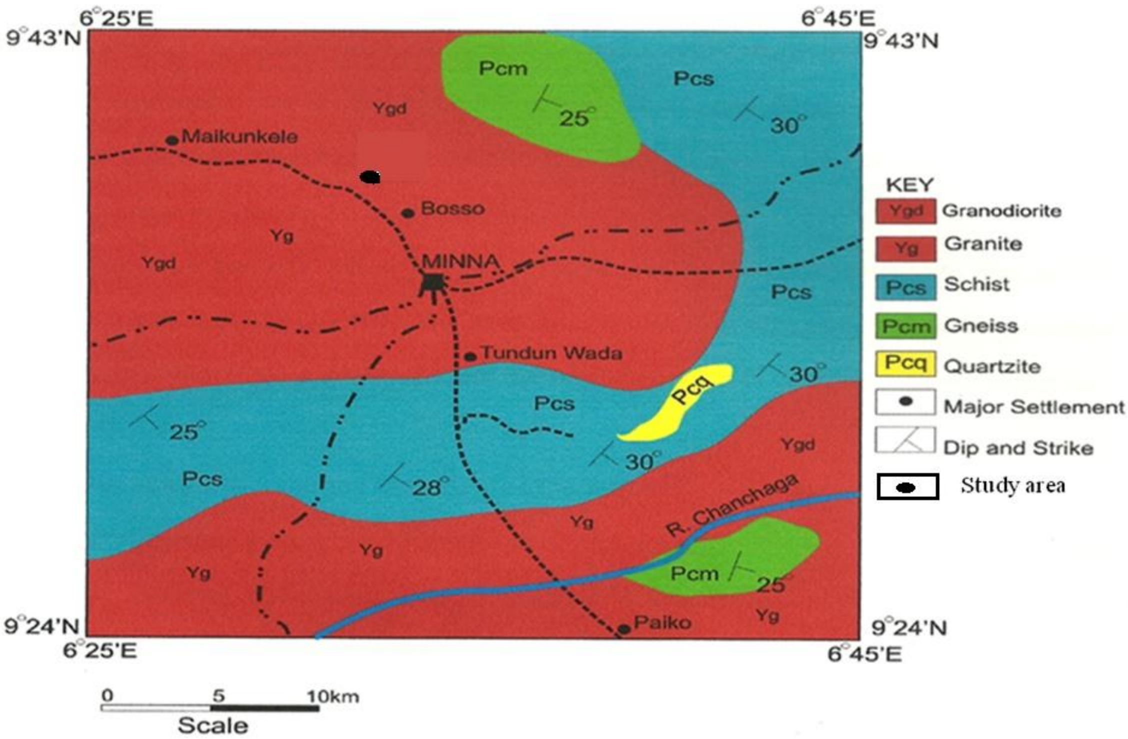

Figure 1: The figure presents the geological map of Minna showing the study area [12].

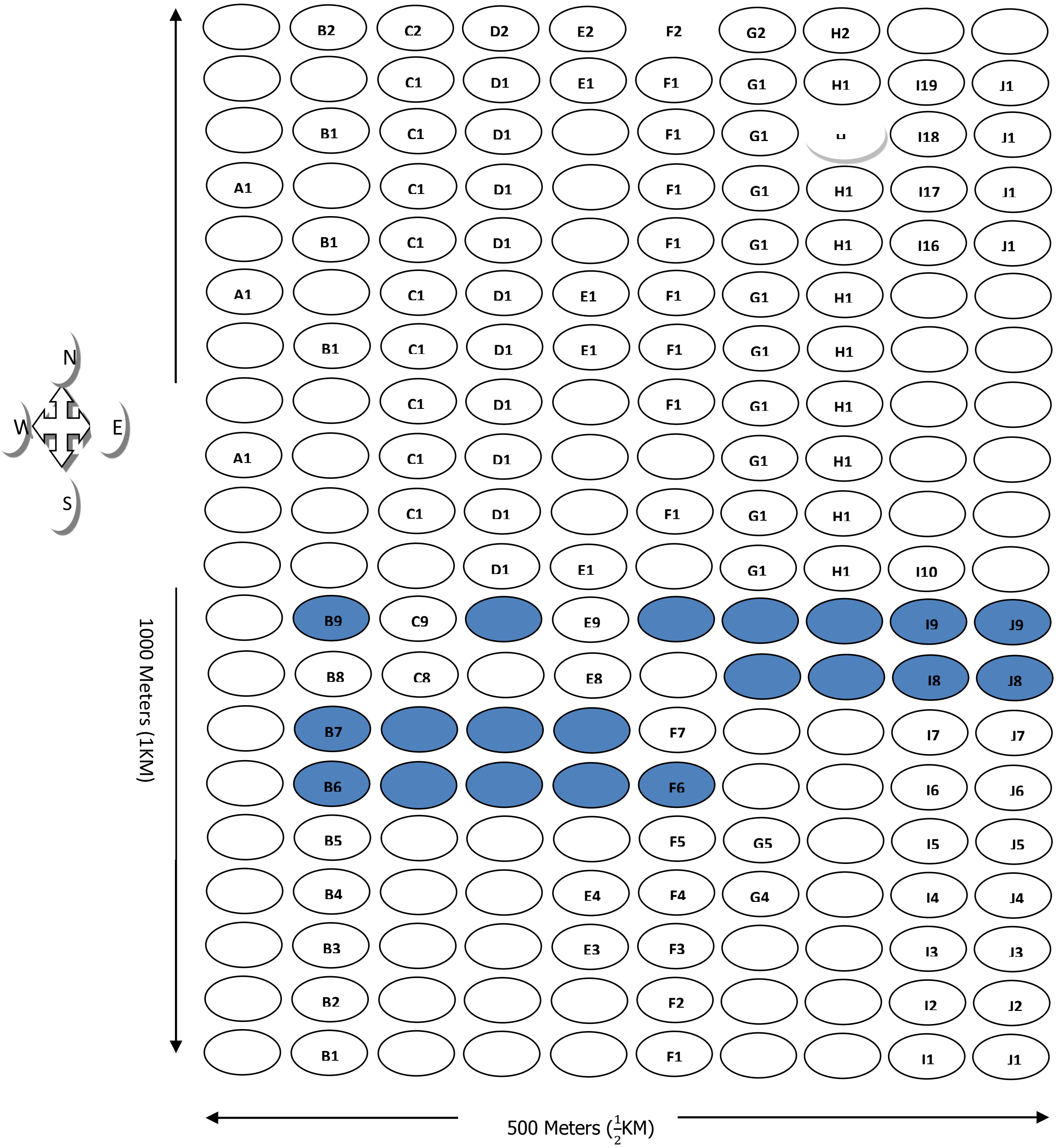

Figure 2: The figure presents the study area layout showing the 200 ERP points and 20 selected VES points.

3. RESULTS

The Electrical Resistivity Profiling contour of the entire study area is represented in Figure 3. The general summary of results of the selected twenty (20) Vertical Electrical Sounding (VES) points analysis and the interpretations of representative curves of the VES points in the study area showing the VES points, curve types, number of layers, thicknesses, resistivity and depths are shown in (Table 1). Figure 4 and figure 5 shows the depth to basement map (Isopach map) and aquifer thickness map respectively.

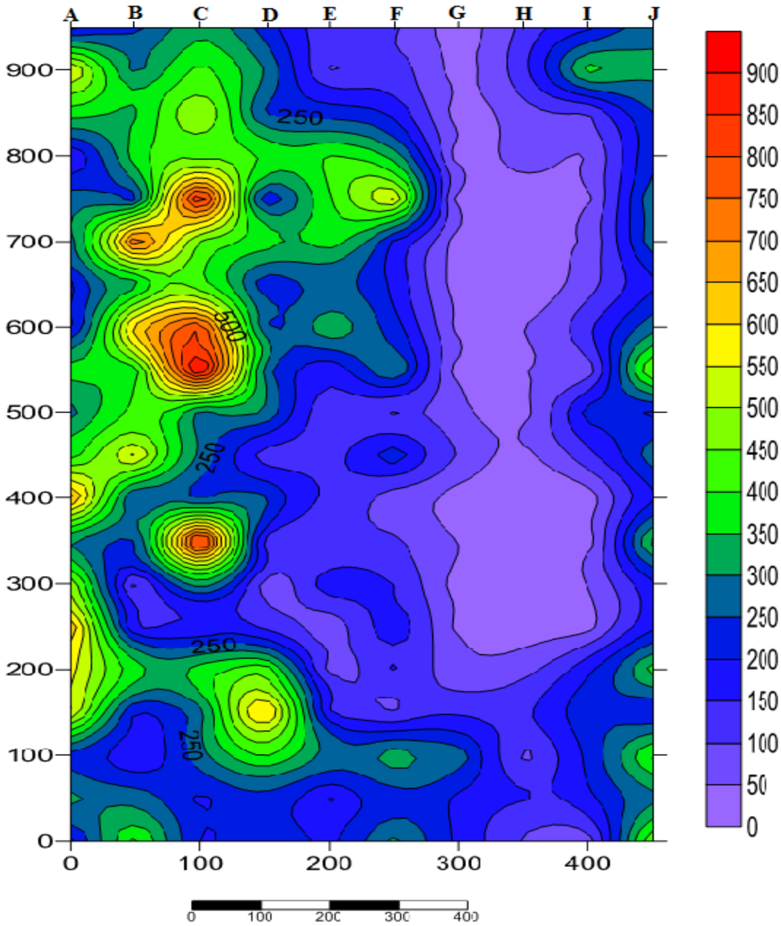

Figure 3: This figure presents the contour map of the 200 Electrical Resistivity Profiling point.

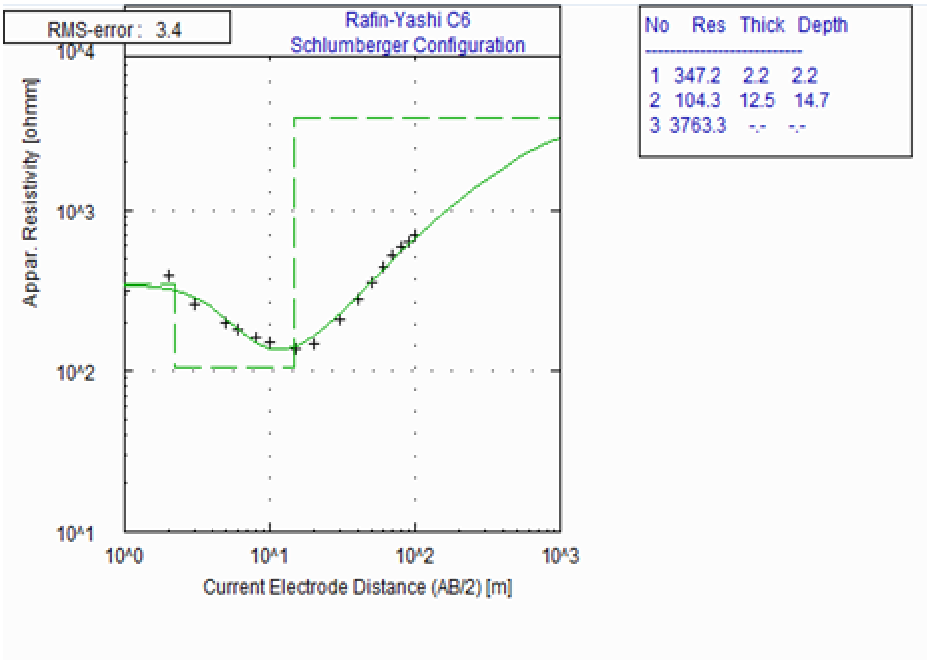

Figure 4: The figure presents the apparent resistivity curve for Vertical Electrical Sounding point C6.

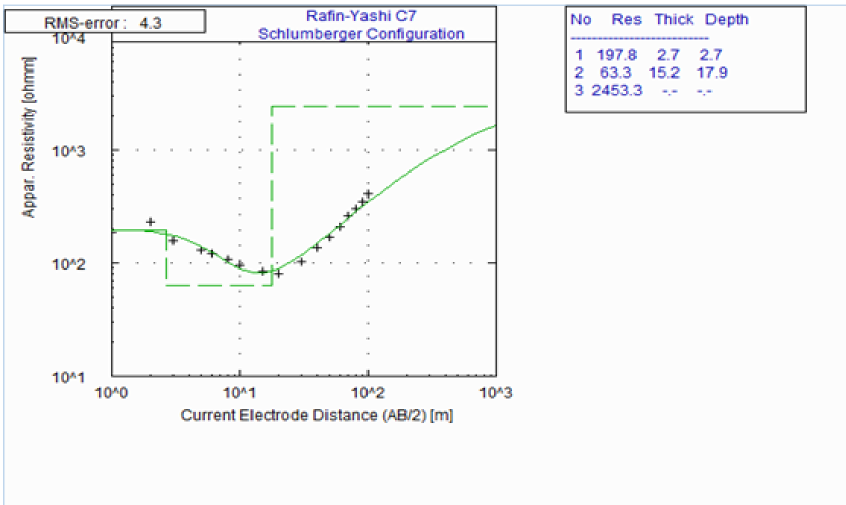

Figure 5: The figure presents the apparent resistivity curve for Vertical Electrical Sounding point C7.

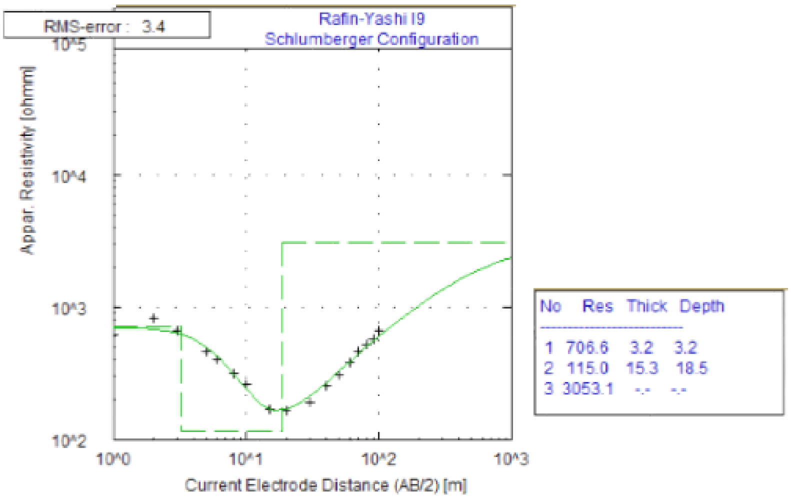

Figure 6: The figure presents the apparent resistivity curve for Vertical Electrical Sounding point I9.

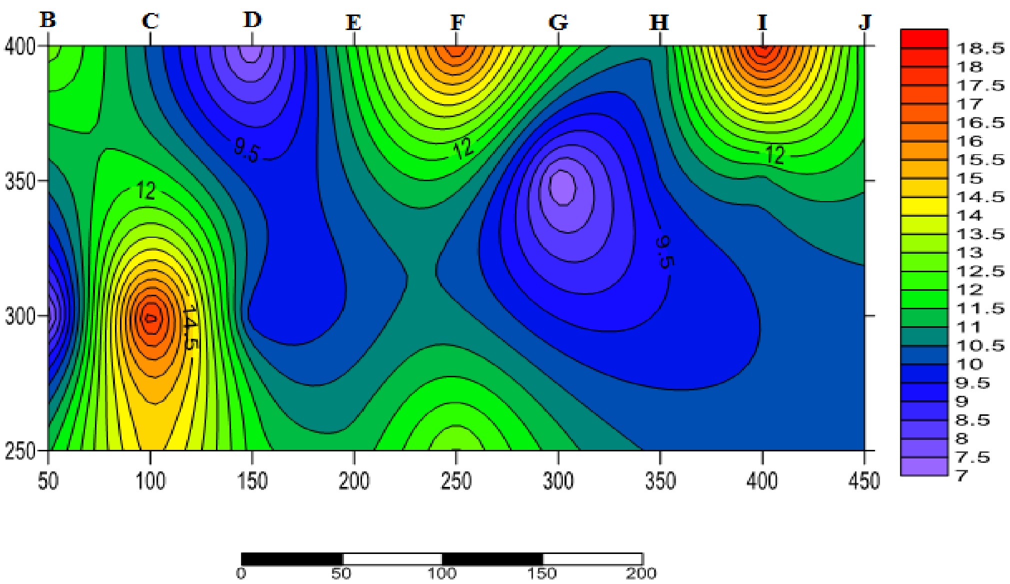

Figure 7: The figure presents the depth to basement map (Isopach map).

Table 1: The table presents the summary of VES points, curve types, number of layers, thicknesses, resistivity and depths

VES Points	Curve Type	No. of Layers	Thickness (m)	Depth (m)	Resistivity (Ωm)
B6	H	1	3.1	3.1	290.6
		2	8.3	11.4	65.7
		3	∞	∞	1479.1
B7	H	1	2.3	2.3	72.9
		2	4.8	7.1	48.7
		3	∞	∞	1239.4
B9	H	1	4.1	4.1	875.8
		2	8.6	12.7	109.5
		3	∞	∞	3916.7
C6	H	1	2.2	2.2	347.4
		2	12.5	14.7	104.5
		3	∞	∞	3752.8
C7	H	1	2.7	2.7	198.1
		2	15.3	18.0	63.6
		3	∞	∞	2473.4
D6	H	1	1.8	1.8	298.9
		2	10.0	11.8	84.9
		3	∞	∞	1384.6
D7	H	1	2.0	2.0	229.4
		2	7.6	9.6	60.2
		3	∞	∞	1217.4
E6	H	1	2.8	2.8	200.6
		2	8.5	11.2	59.7
		3	∞	∞	1766.2
E7	H	1	3.1	3.1	229.9
		2	7.0	10.1	63.8
		3	∞	∞	7299.1
F6	K	1	1.8	1.8	18.5
		2	11.3	13.1	591.6
		3	∞	∞	19.2
F9	H	1	4.8	4.8	307.7
		2	12.3	17.2	50.9
		3	∞	∞	1302.8
G8	H	1	2.0	2.0	141.3
		2	5.1	7.1	34.0
		3	∞	∞	5886.7
G9	H	1	3.2	3.2	486.2
		2	8.9	12.1	91.5
		3	∞	∞	5769.6
H8	H	1	2.5	2.5	478.8
		2	7.5	10.0	55.8
		3	∞	∞	4758.4
H9	H	1	2.8	2.8	442.0
		2	7.8	10.6	67.5
		3	∞	∞	6171.2
I8	H	1	3.5	3.5	65.2
		2	7.3	10.8	16.8
		3	∞	∞	1599.8
I9	H	1	3.2	3.2	706.6
		2	15.3	18.5	115.0
		3	∞	∞	3053.1
J8	H	1	3.2	3.2	240.8
		2	8.0	11.2	48.0
		3	∞	∞	3228.8
J9	H	1	3.9	3.9	39.4
		2	7.5	11.	17.4
		3	∞		1893.6

4. DISCUSSION

Electrical Resistivity Profiling (ERP) was carried out for 200 Electrical Resistivity Profiling (ERP) stations using Werner spread at electrode spacing of 30 m expected to probe to a depth of about 45 m. The Electrical Resistivity Profiling (ERP) contour map as presented in Figure 3 was produced from the traversed apparent resistivity measurement of the 200 Electrical

Resistivity Profiling (ERP) stations. Two major anomalous zones were observed on this map; the low and high resistivity zones. The low resistivity zones were found along profiles G, H, I and J with apparent resistivity range of 50 to 250 Ωm with few points having apparent resistivity values ranging between 350 to 450 Ωm. The high resistivity zones were found along profiles A, B, C, D, E and F with apparent resistivity values ranging from 350 to 900Ωm with pockets of points within the area having apparent resistivity values ranging between 100 to 200Ωm. Based on the apparent resistivity values from the ERP, twenty (20) most promising points based on their low resistivity values were selected for the Vertical Electrical Sounding (VES). The Vertical Electrical Sounding results revealed about 95% H- type curve and 5% K- type curve with three distinct geoelectric layers namely: the top soil, weathered/fractured basement and the fresh basement. The apparent resistivity of the first layer ranged between 18.5 Ωm – 706.6 Ωm with a corresponding thickness of 1.1 m – 4.8 m, second layer has apparent resistivity values of 16.8 Ωm – 591.6 Ωm with corresponding thickness of 4.8 m – 15.3 m and the third layer has apparent resistivity values of 19.2 Ωm – 7299.1 Ωm with an infinite thickness.

The depth of overburden contour map, as presented in Figure 7, shows the disparity of depths to top of bedrock across the residual area of the 20 selected VES stations within the study area. The VES points B6, B9, C6, C7, D6, E6, E7, F6, F9, G9, H8, H9, I9, J8 and J9 have relatively high overburden thicknesses of 11.4 m, 12.7 m, 14.7 m, 18.0 m, 11.8 m, 11.2 m, 10.1 m, 13.1 m, 17.2 m, 12.1 m, 10.0 m, 10.6 m, 10.8 m, 18.5 m, 11.2 m and 11.5 m respectively. The average thickness of the overburden in the area is thus, about 11.7 m, which is much less, than the average value of about 24 m established by Mohammed et al. (2007) and 30 m established by Adeniyi (1985) for Minna and its surrounding area [5-13].

The Electrical Resistivity Profiling (ERP) contour map as presented in Figure 3 which probed to a depth of 45 m disclosed that the eastern parts of the study area have very low to low resistivity values ranging between 50 – 250 Ωm and zones with low resistivity values at depths of about 45 m in the basement complex terrain are known to have high groundwater potential [14,15].

Olorunniwo and Olorunfemi (1987) established that low resistivity values with the combination of thick overburden are conditions for high groundwater yield in the basement complex environment **[13]**. Therefore, combining the information of the depth to basement contour map and the Electrical Resistivity Profiling contour map at depth 45 m, it can then be inferred that VES stations B6, B9, C6, C7, D6, E6, E7, F6, F9, G9, H8, H9, I9, J8 and J9 have relatively high overburden thicknesses and very low to low resistivity values and thus, may be more promising for groundwater prospection.

5. CONCLUSION

The Geoelectric investigation of groundwater potential at part of Rafin-Yashi, Minna, North Central Nigeria established that the VES curve types are 95% H- type curve and 5% K- type curve with three distinct geoelectric layers namely: the top soil, weathered/fractured basement and the fresh basement.

VES stations B6, B9, C6, C7, D6, E6, E7, F6, F9, G9, H8, H9, I9, J8 and J9 with relatively high overburden thicknesses of 11.4 m, 12.7 m, 14.7 m, 18.0 m, 11.8 m, 11.2 m, 10.1 m, 13.1 m, 17.2 m, 12.1 m, 10.0 m, 10.6 m, 10.8 m, 18.5 m, 11.2 m and 11.5 m respectively having a corresponding very low to low resistivity values ranging between 50 – 250 Ωm at depth 45 m have been established to have high groundwater potential and thus, have been chosen as priority locations suitable for groundwater development.

It is recommended that boreholes should be drilled to a depth of about 45 to 50 m for optimum yield.

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