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Application of Geoelectrical Resistivity Method in Locating the Aquifer within Rukuba Cantonment Bassa Local Government Area, Plateau State, Nigeria

Fagoyinbo VO[1], Olatunji SO[2], Dairo VA[3]

Dept of Geology and Mining, Crawford University, Faith City Igbesa, Nigeria

Abstract This paper evaluates the application of geoelectrical resistivity method in locating the aquifer within Rukuba Cantonment in Bassa Local Government Area of Plateau State.

Forty three geoelectric soundings were carried out in Rukuba Cantonment after map study and ground reconnaissance have been completed. 7 of the VES were carried out in areas covered by Rukuba biotite granite while thirty six of the forty three VES were carried out on areas covered by older basalt. The depth sounding field curves were first interpreted employing the partial curve matching technique followed by iterative computer programme. This was aimed at delineating aquiferous zones in the study area.

The older basalt were characterized by top lateritic layer with resistivity values between 90 and 1,500 Ωm and thickness ranging from 1m to 5m. The laterite layer is mostly underlain by sand layer or weathered Basalt with resistivity values mostly below 400Ωm. These layers are mostly aquiferous. The degree of the weathering of this basalt reduces with depth. In some cases, the fresh basalt is underlain by sub basalt alluvial deposits which are probably buried channels and they are highly aquiferous. The top soil here is underlain by thin lateritic layer and it grades into weathered granite which also grades into fractured granite. Under this, we have fresh granite.

This area is generally less aquiferous with the area of VES 32 having resistivity values of 1875 and 2061Ωm that makes it non aquiferous.

Keywords Soundings, Iterative, aquiferous, resistivity

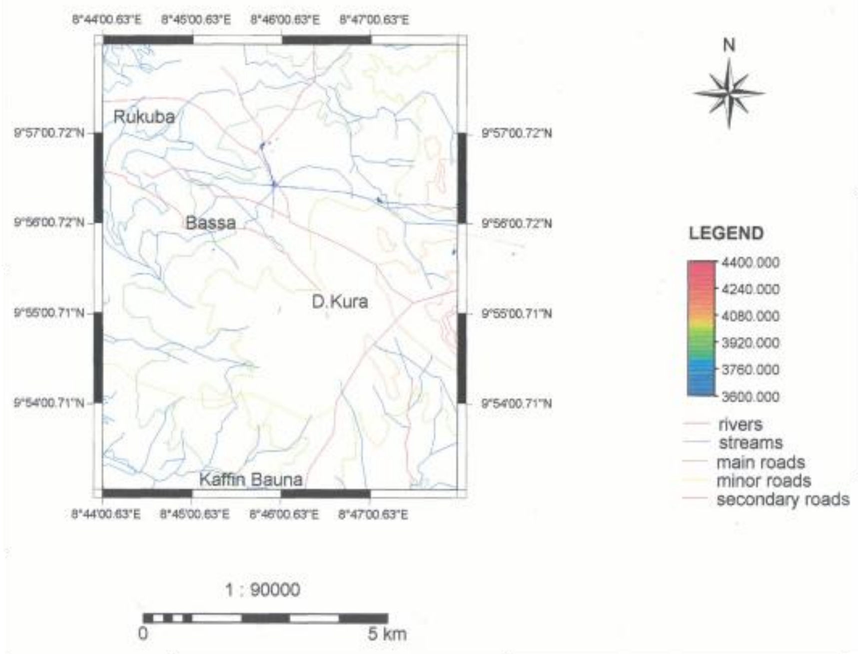
Introduction

Water is one of the basic needs of life. It is also essential in the sustenance of any organisation. The Army is not an exception. Most barracks in Nigeria are located in remote areas where there is no public water supply. It is therefore essential for the Nigerian Army (NA) to set up its own means of water provision for its personnel. Establishment of a data bank for water exploration for the NA is therefore essential. Location of the aquiferous area of the Rukuba cantonment will be a step in the right direction towards this goal. More so, when a barrack requires a central storage system from which water will flow under gravity to the consumers.

Rukuba is in Jos, Plateau State which is an area noted for being underlain by igneous and metamorphic rocks. Arbitrary digging of wells will amount to wasteful ventures. It is therefore essential to carry out all necessary geological and geophysical investigations before drilling for water. It is a common fact that groundwater can only be found in reasonable quantity in an area underlain by basement complex when such areas have been weathered. Other factors include the parent rock, which determines the permeability of the weathered rock and availability of recharge source.

Rukuba cantonment lies within longitude 8° 45’E and 8° 48’E and latitude 9° 54’N and 9° 57’N covering an area of about 30 square kilometres. It has a climate typical to Jos Plateau which is greatly influenced by the altitude of the high plateau [1] and its position across the path of seasonal migration of the Inter-Tropical Convergence Zone (ITCZ). It has wet and dry season which determine the rainfall, temperature, relative humidity and wind [2]. However, the deviation of the average parameters from that of ITCZ resulted from its altitude, which is similar to those of Obudu and Mambilla Plateaux. Also, the rainfall is generally high as a result of its high altitude [3]. The altitude of the study area is generally more than 3900m above sea level.

FIG.1 MAP OF STUDY AREA



Alford and Tuley, 1974 [1] described Jos vegetation as woodland savannah with woody vegetation and few trees of economic importance. Mining activities and farming has affected the vegetation. However, the study area being a military zone did not experience much mining compared with Jos general area. The study area is located towards the south west area of Jos Plateau. It is generally plain with few high grounds. It is drained from the centre towards the periphery of the area. The geomorphology must have been considered before choosing the area as a military barracks as it does not have pronounced hill features like the Jos Plateau. The peculiarity of the study area, as reflected in the location, elevation, climate and especially being a military location, which most people will not have access to, necessitates the need to have a data bank. The scope will cover the geology of the area, the hydrology and hydrogeology of the area, geo-electrical study and its interpretation.

Geology of the Study Area

The younger granites cover the northern to eastern area of the Rukuba hills except the NW and NE corners where the basement complex is exposed. The basalts dominate the South Western position while the older granite dominates the Eastern fringe. However, there are intrusions of the older basalts within the younger granites.

The younger granites are discordant, high level intrusions which transgress all units of the Basement Complex. They have been preceded by extensive acid volcanism and emplaced by ring faulting and block subsidence. Macleod and Turner, 1965, [4] classified the major types of minerals as: Hornblende-Pyroxene-Fayalites Granites, Biotite Granite and Riebeckite Granites. According to them, the major structural features are ring faulting, cauldron subsidence, cone sheets and ring dykes.

The older basalts in the area are generally small, eroded and partly decomposed remnants. They lack well defined volcanic focus [5]. He classified the Rukuba basalts with larger flows which do not possess a clear focus as older basalts. These older basalts pass upwards into laterite. He claimed that the older basalts are characterised by absence of volcanic cones. The older granites form part of the Basement Complex of Nigeria. There are two main types of the older granites namely: Biotite-Granite Group III (Ray Field type) to the eastern fringe and Biotite-Granite Group II (Ngell type) to the southern fringe. The Ray Field type range from granite-gneiss to Migmatite-Granite-Gneiss and Aplo-Pegmatitic-Granite-Gneiss [4].

He grouped the Ngell type as fine and medium grained Biotite and Biotite-Muscovite Granite. They are classified largely based on general textural and mineralogical characteristics. This classification was preferred because of the frequent uncertainty of the age relationship. Wright (1965) claimed that the period of formation of the complex series of Migmatite Granites is referred to as Older Granite Orogenic Cycle.

It was assigned that the older granites of the Jos Plateau the same age with more Western parts of Nigeria Basement and Dahomey Basement. They were assigned late Cambrian and Ordovician Orogeny [6].

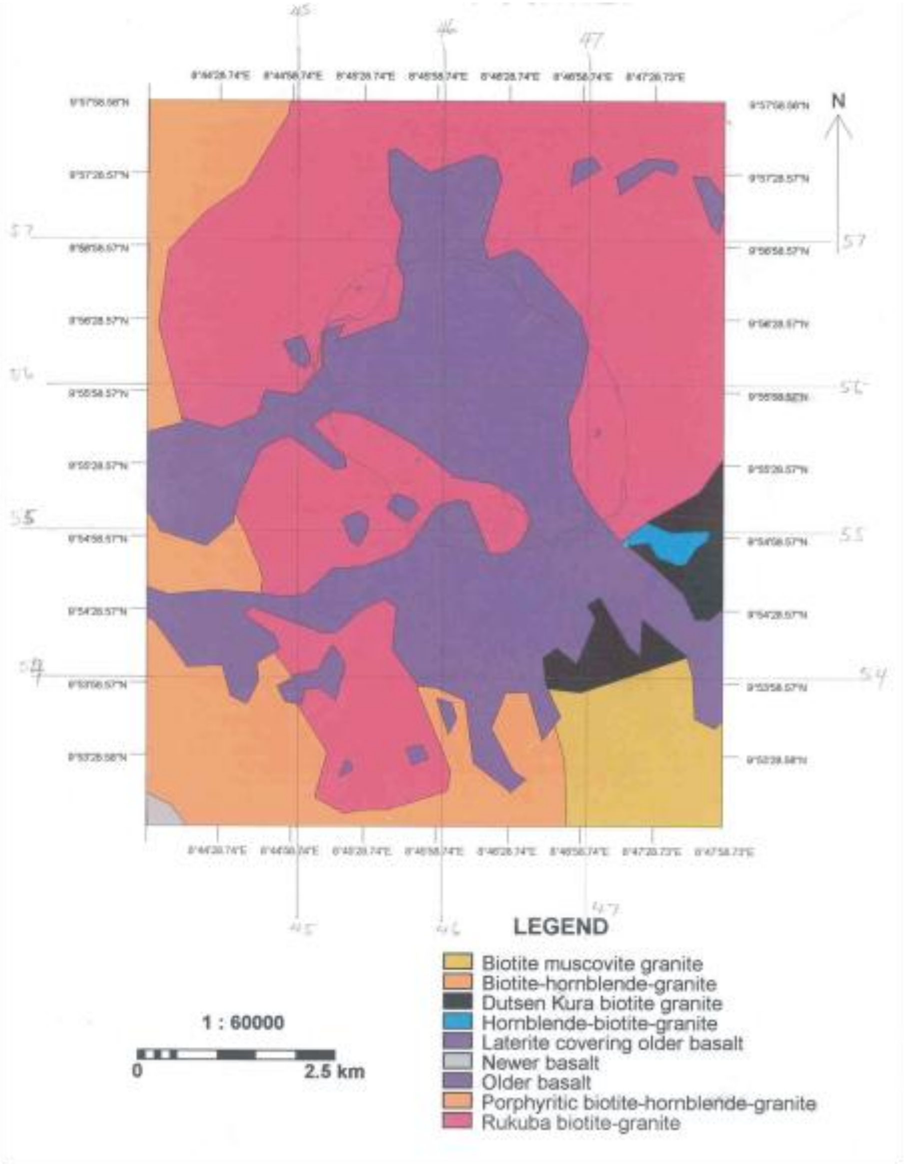


Figure 2: Geological Map of the Study

Methodology

A study of the topographical map of Rukuba area was carried out on NARAGUTA NE sheet 168 NE 1:50,000 published in 1965. This was followed by ground reconnaissance carried out systematically together with geo-electrical soundings using the ABEM Terrameta SAS 300C. The soundings were conducted perpendicularly to the general strike direction of the rocks. A total of 43 geo-electrical soundings were carried out. However, this perpendicularity was not strictly adhered to due to the presence of some permanent structures. The depth sounding field curves were first interpreted employing partial curve matching technique. This was followed by an iterative computer programme. The geo-electrical data interpretations were carried out at the Plateau State Rural Water Development and Sanitation Agency.

Hydrogeology of the Jos Plateau

Three types of aquifers were characterised on the Jos Plateau [1]. These are:

- Lower or fractured crystalline aquifer: This aquifer contains water in fractures and joints of the crystalline rocks. The water can be tapped by drilled wells provided that the boreholes are located within the tectonically fractured zone.
- The middle or soft overburden aquifer: The thickness of the overburden in this zone is between 30m to 50m. Open wells here are usually very productive.
- The upper or volcanic aquifer: This is formed by jointed blasts and volcanic ashes. If the thickness of the volcanic series is sufficient, very good yields can be obtained from open wells. The volcanic aquifer is found in the north-west part of the Plateau. The Rukuba Cantonment lies in this area.

Groundwater in Rukuba Cantonment

Water table in Rukuba Cantonment varies from month to month. Most homes depend on open wells as their main source of water. The wells have moderate yields but most dry up between January and March. Some boreholes were already in existence but data was available on only 2 of them as follows;

- Borehole 1: The altitude is 1230m above sea level. The sequence of the layers are 0 to 3m thick laterite as the top layer, followed by a thickness of 3m to 6m range for the weathered biotite granite layer and 6m to 12m range for the weathered basalt layer. The hard, partially weathered basalt zone, range in thickness between 12m and 25m.
- Borehole 2: The altitude is 1273m above sea level. The sequence and thickness of the layers are 0m to 1m laterite layer as the capping, followed by 1m to 6m alluvial sand layer range and 6m to 49m weathered fractured biotite granite. The partially weathered, fractured biotite granite, range between 49m and 54m thickness range. They were both of moderate yields.

Table 1: Result of Geo-Physical Investigation of the Study Area

VES	Rock Type	Curve Type	Depth Range(M)	Resistivity Values(Ω-m)	Soil Type	Remarks
P1	Older Basalt	P1<p2>p3>p4>p5	4,13,28,28+	5.7,293,162,171	Lat SC, Sand M, W Bas	
P2	Older Basalt	P1<p2>p3>p4>p5	4,10,21,31,31+	421,309,549,443,231	Lat, W.Bas, F.Bas, W.Bas, S,M	Transition Alluvium
P3	Older Basalt	P1<p2>p3<p4<p5	4,10,21,31,31+	546,309,243,468	S.Lat, W.Bas, F.Bas, F.Bas	
P4	Older Basalt	P1>p2>p3<p4<p5	5,24,35,35+	250,79,90,546	S.Lat, W.Bas, F.Bas, F.Bas	
P5	Older Basalt	P1<p2>p3<p4<p5	2,5,10,10+	200,43,217,748	Lat, Sand.G,C, W.Bas, F.Bas	
P6	Older Basalt	P1>p2<p3<p4	3,6,6+	57,196,598	S.Lat, W.Bas, F.Bas	
P7	Rukuba Bio Granite	P1>p2>p3<p4<p5	2,5,15,21+	120,24,85,159	Lat, S.Lat, W.Gran, F.Gran	
P8	Older Basalt	P1<p2<p3<p4>p5	3,10,21,21+	507,789,828,519	Lat, Fr.Bas, Bas, Bas	
P9	Older Basalt	P1>p2<p3>p4<p5	4,8,24,24+	432,502,336,728	Lat, W.Bas, W.Bas(wet), F.Bas	
P10	Older Basalt	P1>p2<p3<p4	1,5,10,10+	302,185,307,529	Lat, W.Bas, F.Bas	

P11	Older Basalt	P1>p2>p3<p4<p5	1,3,10,22,22+	113,71,294,603	Lat, .Lat,S, Grav,S W.Bas, F.Bas	Aquiferous
P12	Older Basalt	P1<p2>p3<p4<p5	1,3,5,22,22+	180,118,92,193	Lat, W.Lat, Sand.G,C. W.Bas	Aquiferous
P13	Older Basalt	P1>p2>p3<p4>p5	1,1,6,20,20+	347,220,334,195	Lat, Lat,C W.Bas, Sand.M (allu)	Aquiferous
P14	Older Basalt	P1>p2>p3>p4<p5	1,2,10,15,15+	214,135,106,306	Lat,S Sand.G, W.Bas, Fr.Bas	Aquiferous
P15	Older Basalt	P1>p2<p3>p4	1,10,15,32	243,363,158	Lat, W.Bas, Fr.Bas	Aquiferous
P16	Older Basalt	P1>p2>p3<p4>p5	1,3,6,20,20	517,142,350,94	H.Lat, Lat,S W.Bas, Sand.G	Aquiferous
P17	Older Basalt	P1>p2<p3<p4	1,3,5,35	36,58,51	Lat,S,C, Sand.M,C W.Bas(sandy)	Aquiferous
P18	Older Basalt	P1>p2>p3<p4	1,2,10,32	546,309,243	Lat, Sand,M. W.Bas	Aquiferous
P19	Older Basalt	P1>p2<p3>p4	1,2,3,15	180,345,127	Lat,(Sat), Lat S,C, Lat, W.Bas	Aquiferous
P20	Older Basalt	P1<p2>p3	1,20,20+	285,243	Lat, W.Bas	Aquiferous
P21	Older Basalt	P1<p2<p3>p4>p5	1,1,6,9,28	386,631,198,78	Lat, Bas, Bas/Allu dep trans, Sand C,G	Transition Alluvium
P22	Older Basalt	P1<p2<p3	1,5,35	24,149	Sand,G,C. W.Bas S	Aquiferous
P23	Older Basalt	P1<p2>p3<p4	1,2,6,28	85,42,61	Lat,(Sat), Sand S,G, Sand,S,G	Aquiferous
P24	Older Basalt	P1<p2>p3>p4	1,2,7,32	217,64,20	Lat, Sand,G,S. Sand, M,G	Aquiferous
P25	Older Basalt	P1>p2>p3	1,5,10	546,309	H.Lat, W.Bas	Aquiferous
P26	Older Basalt	P1>p2>p3>p4	1,3,10,32	338,77,43	Lat, Sand,G,C, W.Bas	Aquiferous
P27	Older Basalt	P1<p2>p3>p4	1,3,7,32	630,250,97	H. lat, Sand G.C, W.Bas	Aquiferous
P28	Older Basalt	P1>p2>p3>p4	2,5,16,35	870,289,49	H. Lat, Lat, Sand G.C, W.Bas	Aquiferous
P29	Older	P1>p2>p3	1,4,35	551,50	Lat, Sand G.C	Aquiferous

	Basalt					
P30	Older Basalt	P1>p2>p3	1,5,35	194,94,15	Sand G.S, W.Bas	Aquiferous
P31	Older Basalt	P1<p2>p3>p4	1,5,15,15+	244,41,31	Lat, Sand G.S, W.Bas	Aquiferous
P32	Rukuba Biotite Granite	P1>p2	1,23	1875,2061	H. Lat, Gran	
P33	Rukuba Biotite Granite	P1<p2	2,26	273	Fr Gran	Aquiferous
P34	Rukuba Biotite Granite	P1<p2<p3	1,2,2+	287,422	W.Gran, Fr.Gran	Aquiferous
P35	Older Basalt	P1>p2<p3>p4	1,1,13,13+	96,214,115	Sand G.C, W.Bas, Fr.Bas	Aquiferous
P36	Older Basalt	P1<p2>p3<p4<p5	1,3,7,22,22+	1100,553,156,253	H.Lat, Sand S.C, Sand G.S, W.Bas	Aquiferous
P37	Older Basalt	P1<p2<p3<p4	1,3,13,29	52,79,232	Sand G,S, W.Bas, Fr.Bas	Aquiferous
P38	Older Basalt	P1<p2>p3<p4	1,5,15,32	303,144,496	Lat, Sand G.S, W.Bas	Aquiferous
P39	Older Basalt	P1<p2>p3<p4	1,6,20,20+	178,141,219	Lat,(Sat), Sand G.C, W.Bas	Aquiferous
P40	Older Basalt	P1>p2>p3	2,8,35	1098,385,65	H.Lat, Lat, Sand G.C	Aquiferous
P41	Rukuba Biotite Granite	P1>p2	7,32	1669,294	H.Lat, Sand G.S	Aquiferous
P42	Rukuba Bio Granite	P1>p2>p3	2,10,32	821,284,146	H.Lat, Sand G.S, W.Gran	Aquiferous
43	Rukuba Biotite Granite	P1>p2>p3	3,7,32	602,237,100	H.Lat, Sand G.S, W.Granite	Aquiferous

Key

Lat. -Laterite.

Bas -Basalt

F. Bas-Fresh Basalt

W. Bas-Weathered Basalt

G -Gravelly

28+ -From the depth of 28m

W. Gran-Weathered Granite

S -Sandy

Fr. Bas-Fractured Basalt

C -Clayey

M -Silty

Discussion of Results

The Older Basalt

Thirty six of the 43 VES were carried out on areas covered by Older Basalt. The older basalt is characterised by a top laterite layer with thickness ranging from 1m to 5m but over 75% of these are about 1m in thickness. Coincidentally, the lateritic layer of around 1m fall within the aquiferous zone. In most cases, the laterite layer is overlain by top soil. The resistivity value of the lateritic layer ranges from 90 to 1,500 Ω-m depending on the degree of hardness, thickness and dryness. However, most of them fall below 300Ω-m. The laterite layer is underlain in most cases by a sand layer or weathered basalt as reflected in the resistivity values which fall mostly below 400Ω-m. These layers are mostly aquiferous and they are the sources where most hand dug wells derive their water.

The degree of weathering of this basalt reduces with depth until it gets to the fresh basalt as indicated by the resistivity values. In some cases, the fresh basalt is underlain by sub basalt alluvial deposits which are probably buried channels. These alluvial deposits are mostly aquiferous. The alluvial deposits must have been there before the larva flow overlies them.

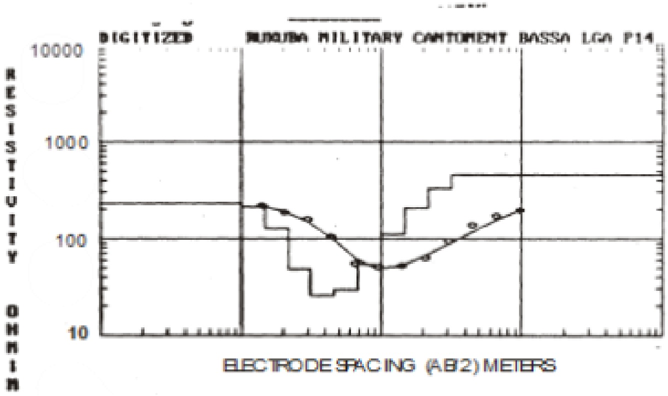


Figure 3: Vertical Electrical Sounding P 14 (Older Basalt)

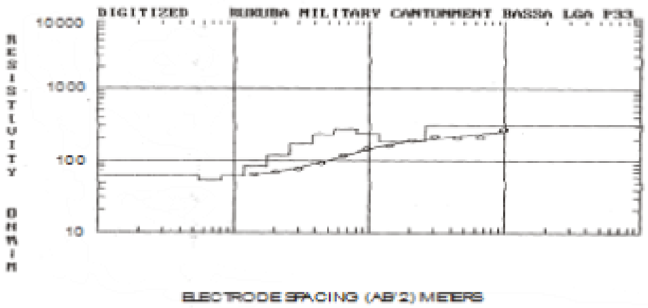


Figure 4: Vertical Electrical Sounding P 33 (Biotite Granite)

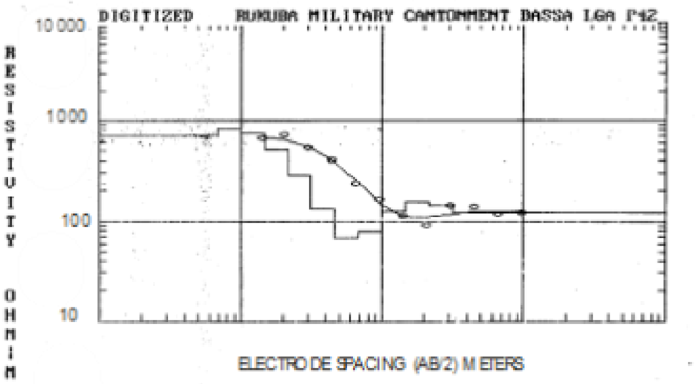


Figure 5: Vertical Electrical Sounding P 42 (Biotite Granite)

Rukuba Biotite Granite

The Rukuba Biotite Granite covers less than 25% of the study area. Only 7 of the Vertical Electric Sounding (VES) were carried out on the area covered by it. This rock type is generally characterised by a thin layer of top soil which is usually less than 2m. The top is either underlain by a thin lateritic layer or graded into weathered granite which also grades into fractured granite that is moderately aquiferous depending on the degree of fractures. Beneath the fractured granite is the fresh granite which is not water bearing (aquitard). Of particular interest is the VES P32 which was carried out on the slope of a hill. The resistivity values were very high indicating that it had no water as it is composed of hardened laterite over massive granite. The resistivity values of 1875 and 2061 Ω-m were distinctively higher than that of their surrounding areas. This must have been caused by the slopy terrain which does not encourage water percolation thereby greatly impairing weathering.

Fig 6 shows the isopach resistivity contour map of the study area. The top soil in the northern portion of the area has high resistivity. This area is underlain by Rukuba biotite-granite. The top soil in VES 28 and VES 32 have the highest resistivity. The top soil resistivities at the central and southern portions are generally low.

Fig. 7 shows the thickness of the weathered layer of the study area. The weathered layer are thicker in the Eastern periphery of the area extending westwards towards the northern portion. They have generally low thickness. These implied that the eastern portion will be more water bearing. From this figure, the middle portion of the northern area has the highest thickness of weathered layer.

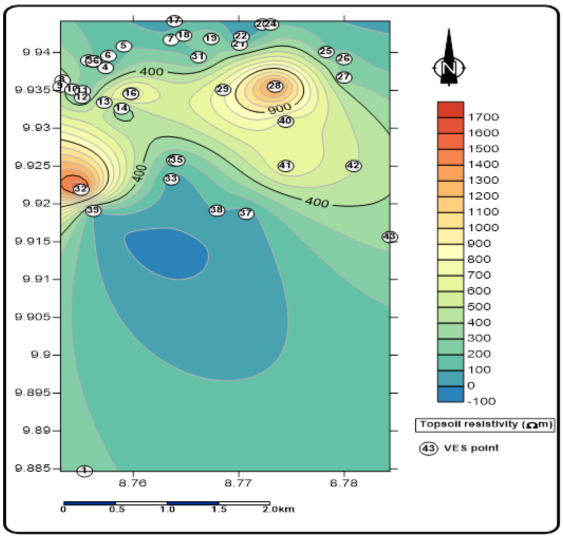


Figure 6: Topsoil resistivity contour map of the study area

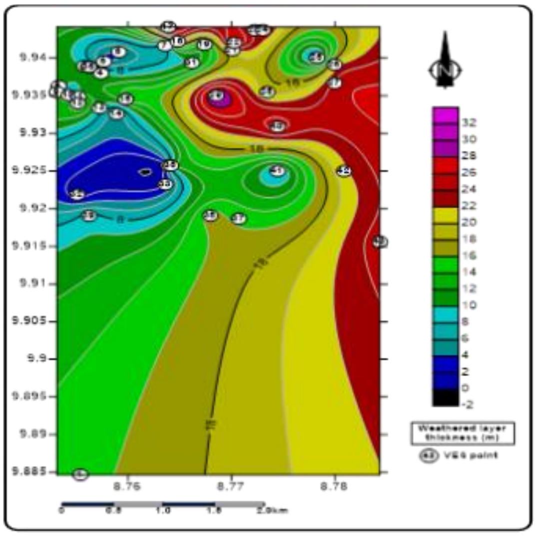


Figure 7: Thickness weathered layer contour map of the study area

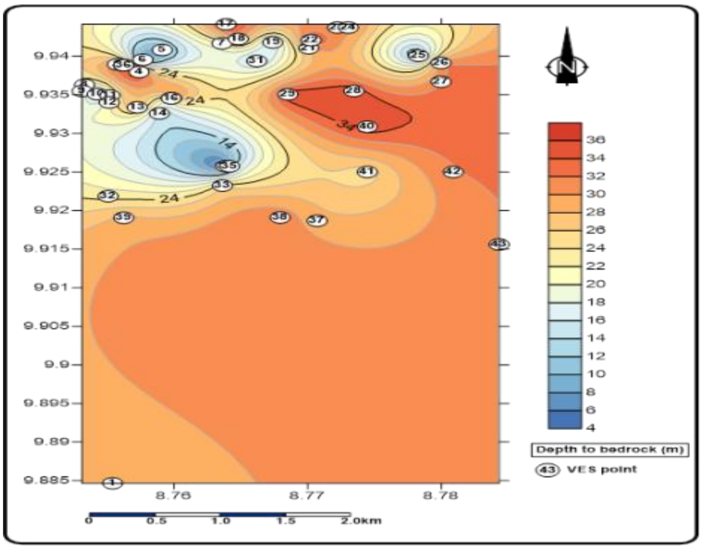


Figure 8: Depth to bedrock contour map of the study area

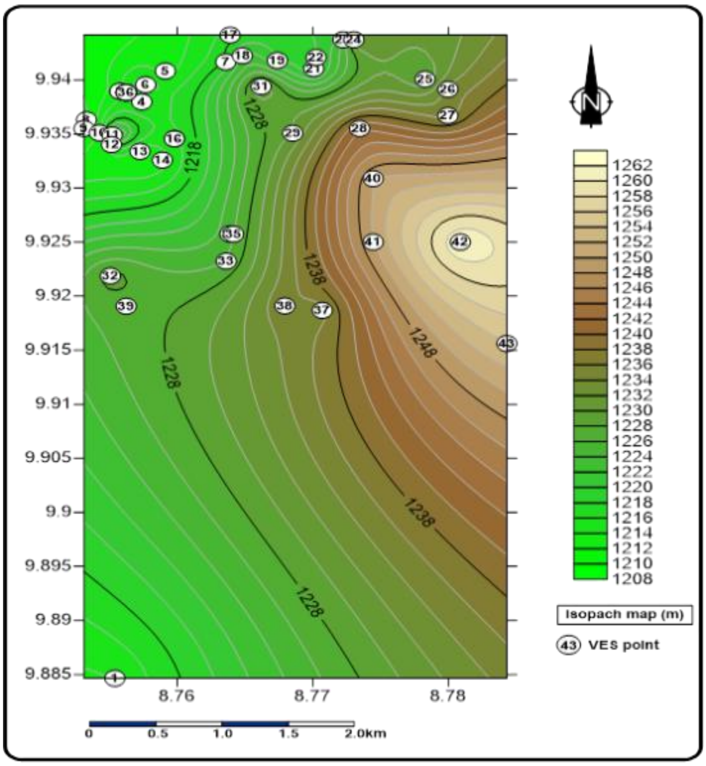


Figure 9: Isopach contour map of the study area

Fig 8 shows the depth to bedrock of the study area. The bedrock in the middle to the southern portion of the area ranges from 30m to 32m with the southwestern position ranging between 28m to 30m. The thickest portion is towards the north but not extending to the extreme north. The depth to bedrock thickness in the northwestern portion is generally low ranging between 4 to 18m. A small portion toward the northwestern position created an exemption with about 30 to 34m. The areas with large depth to bedrock thickness have high probality of being aquiferous.

Fig 9 shows the isopach contour map of the study area. These are lines joining points of equal stratigraphic thickness.

Fig 10 shows the piezometric map of the study area exhibiting the direction of underground water flow. The underground water flow is generally in the east to west direction. This shows two water collecting zones. One in the north western portion covering an area of about 2km^2 and the other in the south western corner of the area covering an area of about 1 km^2. The middle portion of the eastern flank serves as the source of the flow.

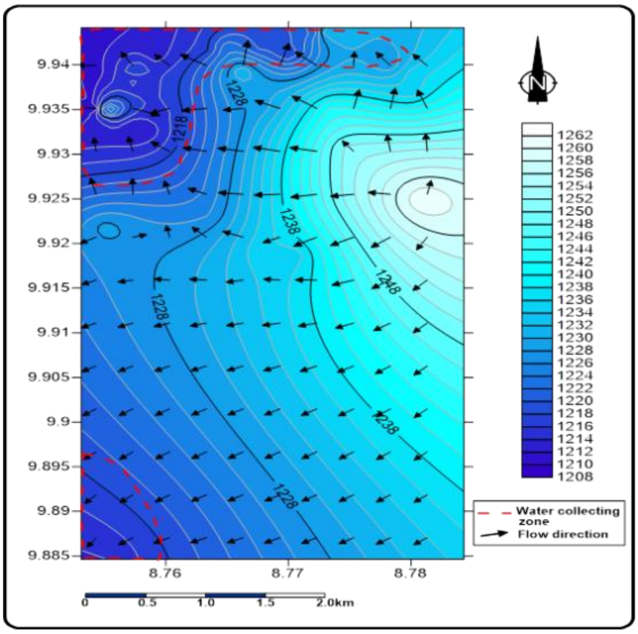


Figure 10: The piezometric map.

Conclusion

The geoelectrical soundings carried out on the older basalts and Rukuba biotite granite of Rukuba Cantonment revealed that it is possible to extract water in areas underlain by Basement Complex provided it has undergone weathering or fracturing. The value ranges got for most of the VES were not too far from the well logs of the two existing boreholes which were highly productive. The areas with distinctly high resistivity values fell on a slopy area indicating that slope could reduce rate of weathering.

From the digital maps of the area, the top soil resistivity value is higher in the northern part and lower in the central to the southern part. The thickness of the weathered layer is higher in the eastern periphery extending to the center towards the north while the middle to the western portion has generally low thickness. This implies that the eastern portion will contain more water. For the depth to bedrock, the middle is the southern portion of the area with large value of depth to bedrock has higher probability of being aquiferous. The flow of water is generally from the east to the west resulting into two water collecting zones in the north western portion and the south western corner of the area while the middle portion of the eastern flank is the source of the flow.

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