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RESISTIVITY TECHNIQUES FOR GROUNDWATER EXPLORATION IN PARTS OF BASEMENT COMPLEX OFSOUTHWESTERN NIGERIA

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Abstract
Quality water for use has been abysmally difficult to come by in the Oye Ekiti metropolis. Thus, an aggressive exploration effort toward providing clean water is essential in the area. The study is within the coordinates of longitudes 5^0 41' 40 "E - $5^0$43' 20"E,and latitudes 7^0 31'50"N -7° 62' 50"N. Thus 9 Horizontal Profiling (HP) traverses, 9 Spontaneous Potentials (SP) traverses, and 31 Vertical Electrical Sounding (VES) points were employed to assess the groundwater potential of the area. The SP identified zonesthat show a peak of varying polarity indicating streaming potential which is evidence of groundwater movement.The movement is majorly directed in the East-to-west axis, indicating the major groundwater flow directions in the area.HP inversions and 2D models from most of the traverses indicate aquiferous layers with average resistivity and depth range of 10.5 – 93.5 Ωm and 50 – 90 m in the area. The geologic sections delineated five subsurface geologic layers; this includes the topsoil, laterites, sandy clay, weathered basement, and fresh basement. The resistivity range of the fresh basement is 535 – 6176 Ωm. The weathered basement is generally thin and constitutes the main aquifer unit within the area. The resistivity low of the weathered basement could indicate enhanced permeability due to significantly fractured density and the tendency for moderate groundwater potential and yield through the groundwater potential map. The area could therefore be said to portray a moderate groundwater potential.
***Keywords:** Hydro-geophysical, Resistivity, Delineation, Fracture and Aquifer*

Introduction

The need for good water for domestic use can not be overemphasized in a developed area dwelled by humans and animals. Sporadic population growth makes the available water sources, surface, and rainwater, inadequate in the area of study. The pipe-borne water is not forthcoming due to inadequate funding. It is a known fact that the subsurface water is about a thousand times more than the surface water. This necessitates the search for underground water which can be tapped by boring in the form of a borehole.Near-surface Geophysics for groundwater investigations is proven adequate for moderate depth investigations for a depth up to300 m.

Water is a basic necessity of life which constitutes two-thirds of the whole body of human beings and coincidentally, that of the total earth's mass. Underground water constitutes an important source of supplying drinking water. Virtually, every activity of man requires the use of water; whether domestically, industrially, in experiments in laboratories, or any other form of human daily activities. Wells drilled without proper geophysical and hydro-geological study often face failure challenges. In hard rock areas, groundwater is found in the cracks and fractures of the local rocks. Groundwater yield depends on the size of fractures and their interconnectivity. Groundwater generally occurs in rocks that are permeable enough to allow the accumulation and circulation along the geologic micro-structures. Generally, the information concerning the lithology, stratigraphic sequence, geologic structures, and hydro-geological characteristics of the subsurface materials can be provided through the application of the Electrical resistivity method (Koefoed, 1979). A large proportion (47%) of people in sub-Saharan Africa live without access to safe water sources in rural areas (JMP, 2008). The need for sustainable development and management of water resources, particularly groundwater resources, remains a major priority, especially within the context of climate variability, population growth, and pressures to increase food production (UN, 2000).

This work targets the investigation of the availability of exploitable groundwater in and around Oye Ekiti using three geophysical electrical techniques. This effort would provide a database for future groundwater exploitationsin the area.

Study area

Oye Ekiti is located in the Northeastern part of Ekiti State, Southwestern Nigeria. It lies between geographic coordinates of 5^{0} 41' 40 ''E and 5^{0}43' 20''E,and latitude 7^{0} 31'50''N and 7^{0} 62' 50''N (Fig. 1). The topographic elevation in the area ranges from 345.0 to 375.0 m above mean sea level. The study covers an area extent of about 21000 km^{2}. The study area is located within the tropical rainforest of Southwestern Nigeria with dry and wet seasons. The wet season starts around mid-March and ends in October with an average annual rainfall of between 1500 mm and 2100 mm while the dry season starts around November and ends in March. Further, the average maximum temperature is about 33 ˚C (Iloeje, 1980).

The area is accessible through Ifaki – Ikole Express road. Other minor roads and footpaths interconnect the studying area due to farming activities which are the major human activities in the area.

Fig. 1: Map of Ekiti State Showing Oye Ekiti L.G.A., the Study Location

Geology and Hydrogeology

The study area is underlain by rocks of the Precambrian basement complex of southwestern Nigeria (Rahaman, 1976). Oye Ekiti falls within three major lithostratigraphic units*viz:* Migmatite, Chanokite, and other intrusive igneous rocks. Gneiss and Granites are more pronounced. The Granitic rocks dominate the area (Fig. 2). It is coarse-grained in texture, and corresponds to the Precambrian age,which is known as Porphyritic Granite. The Granites occur as intrusive in low-lying outcrops within the Biotite Gneiss. In basement terrain, groundwater occurs in the weathered basement and the joints, fractures, or faults within the bedrock (Ademilua and Olorunfemi, 2000). The rock consists of Precambrian metasediments, Migmatites, Gneisses, Granites, and other intrusive igneous rock.

The Geomorphology of the study area consists of lowlands and extensively forested plainland, forming high hills. These are prominent at Ire, Itapa, and Osin. Oye Ekiti has a low relief with an undulating surface formed as a result of differential weathering and erosion and the area is surrounded by hills which are moderate heights. Some of the hills are characterized by steep sides and deep valleys. It falls within the tropical rainforest zone of southwestern Nigeria. It has a tropical climate characterized by alternating dry and wet seasons. Rainfalls serve as a source of groundwater replenishment (Akinola, 1986).

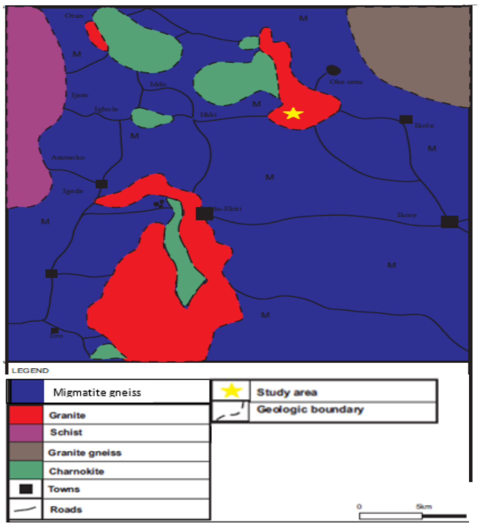


Fig 2: Geology map of the study area

Materials and Method

Three techniques of electrical methods *viz:* SP, HP, and VES were accomplished using the *Campus Omega* resistivity meter. The surveys involved a multi-electrode spacing (i.e. a = 10 m and 30 m), with Wenner array for HP, Schlumberger array for VES, and Leap-Frog array for spontaneous potentials along profiles. The multi-electrode spacing profiling was adopted so that the subsurface can be imaged at two different depth levels. The interpreted Wenner data were presented along the profiles and used to delineate low resistivity, and suspected fault/fractured ne zones. Such areas were subsequently depth sounded using VES and SP simultaneously. Thirty-one (31) VES points were acquired along nine traverses (Fig. 3). Maximum electrode spacing (AB/2) m of 100 m was used. The VES data interpretation involved 2-D resist with computer-assisted forward modeling. The interpreted layer geoelectric parameters (resistivities and thicknesses) were used to generate geoelectric sections.

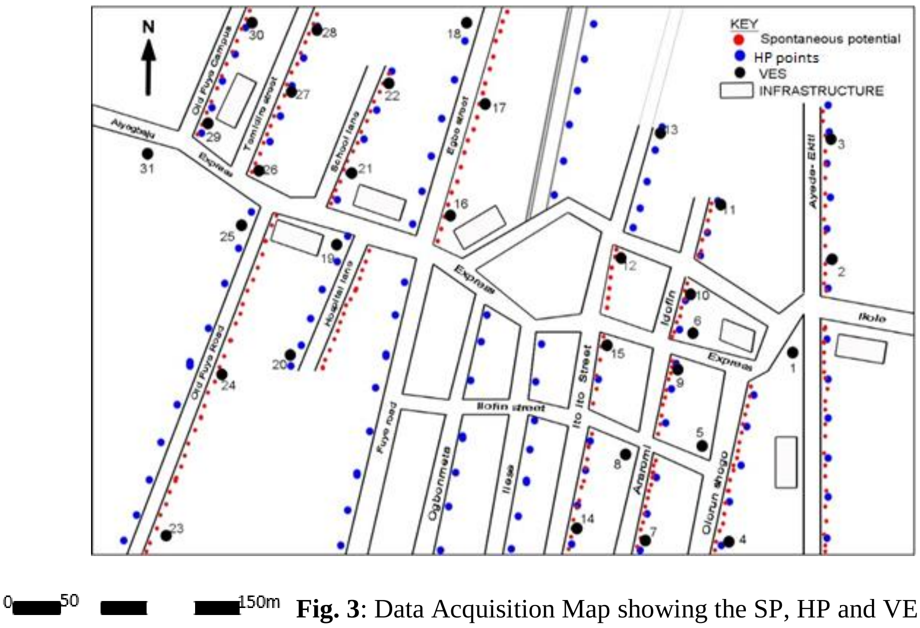


Fig. 3: Data Acquisition Map showing the SP, HP and VES station.

Result and Discussions

Spontaneous potential method

Spontaneous potential data are presented and plotted as a profile. The plot of measuring spontaneous potential data against the midpoint of P1 and P2 is presented in Fig.4. Spontaneous potential (SP) plotsshow peaks of varying polarity, indicating streaming potential which isevidence of fluid (groundwater) movement. This potential is relevant in seepage flow investigation in leaking dam axis or reservoir flow or groundwater flow mapping around fault fracture or lithological boundaries is believed to result from electrokinetic coupling between the ions in the fluid and wall of the capillary which could be a pipe, a fractured or jointed plane. Hence, fractures are more likely encountered along traverse 5 and traverse 8 where very high peak positive and negative anomalies occurred respectively.

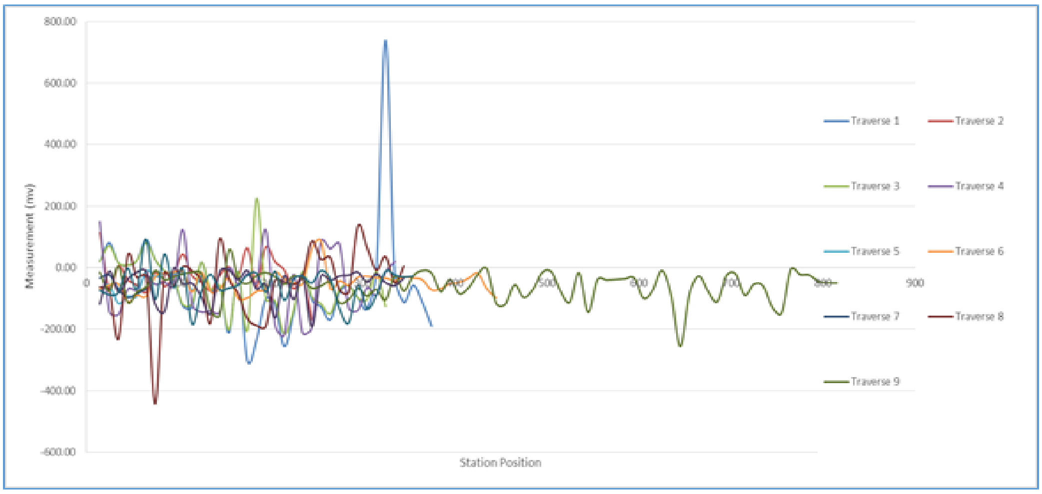
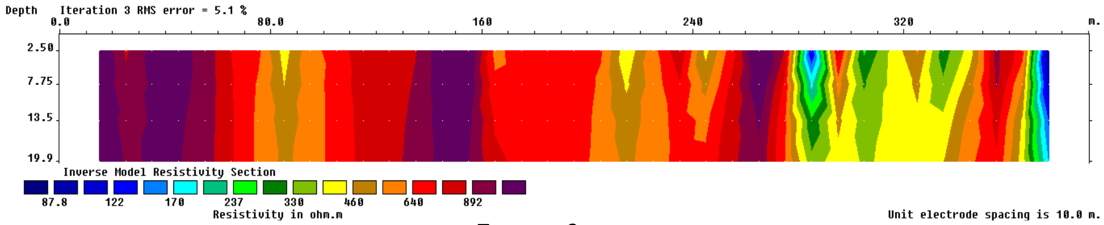


Fig. 4: Variation Spontaneous Potential along Traverses 1-9

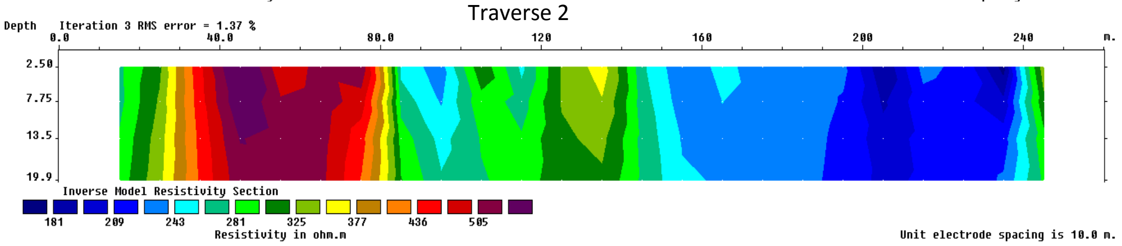
Horizontal profiling

The field data of the Horizontal profiling survey are presented. The inversion of the horizontal profiling data obtained along traverses 1-9 resulted in 2-D resistivity structures presented in Fig.5. Low resistivity values in some zones which are probable zones of groundwater accumulation are represented by a light colour (yellow-green-light blue) relative to the coloured scale on each of the 2-D resistivity structure. A higher resistivity zone represented by a lighter colour (red) relative to the coloured scale on each of the 2-D resistivity structure indicate poor aquifer potential while purple indicates very poor aquifer potential. A dark colour (deep blue) indicates very low resistivity which suggests the presence of clay and thus poor aquifer potential. Low resistivity values in some zones which are probable zones of groundwater accumulation occur at distances between 80 m-240 m and between 15 m-230 m along traverses 2 and traverse 4 respectively (Fig 5). Along traverse 8, the low resistivity zone occurs at distances ranging between 15 m-30 m and also between 55 m-345 m. The low resistivity zone is extensive along traverse nine extending from a distance of 40 m to 80 m and then extending further from 165 m to 800 m along the traverse.On traverse 10, the low resistivity zone occurs at distances ranging between 20 m-80 m and also occurs between 150 m-300 m. also, along traverse 9 low resistivity values in some zones which are probable zones of groundwater accumulation occur at distances between 20 m-145 m. High resistivity zones which rather suggest poor aquifer potential are more prominent along traverse 1 and traverse 3. The depth of investigation here is 19.9 m.

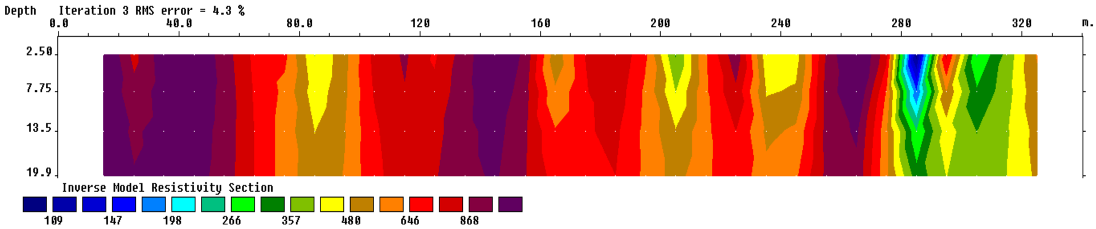
Traverse 1



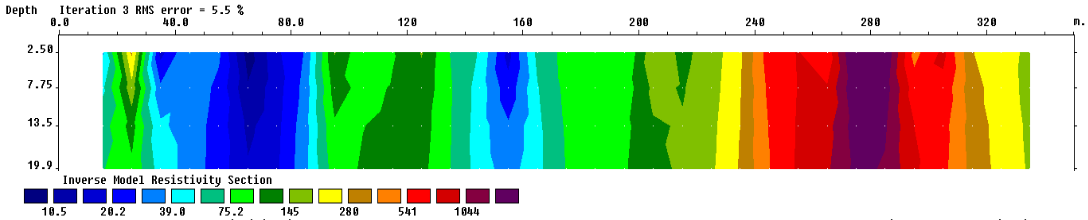
Traverse 2



Traverse 3



Traverse 4



Traverse 5

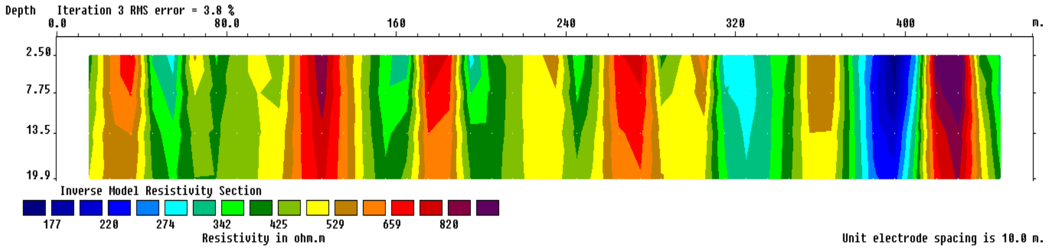


Fig.5a: Inverse Model Resistivity

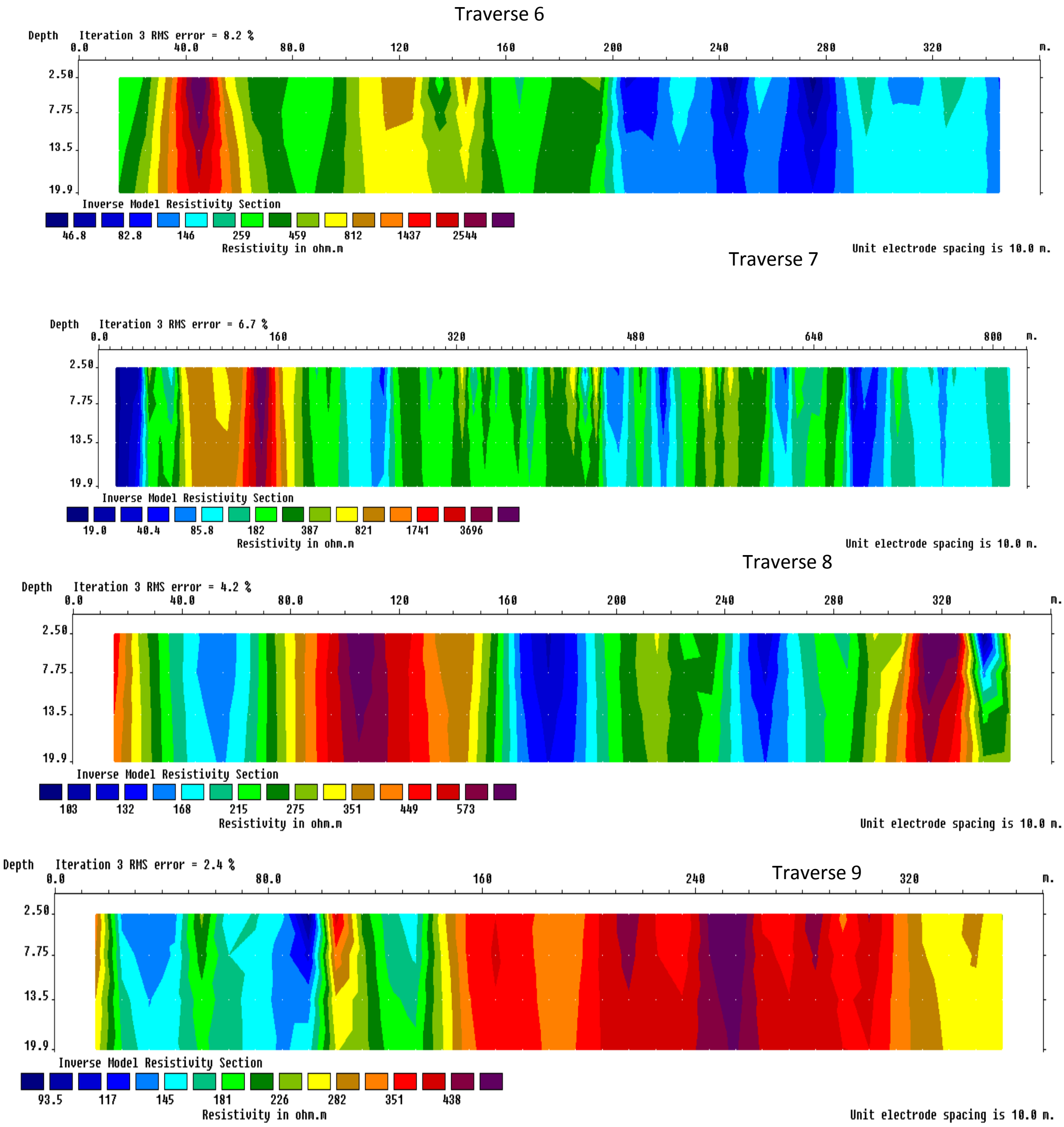


Fig.5b: Inverse Model Resistivity Section (Traverse 6-9)

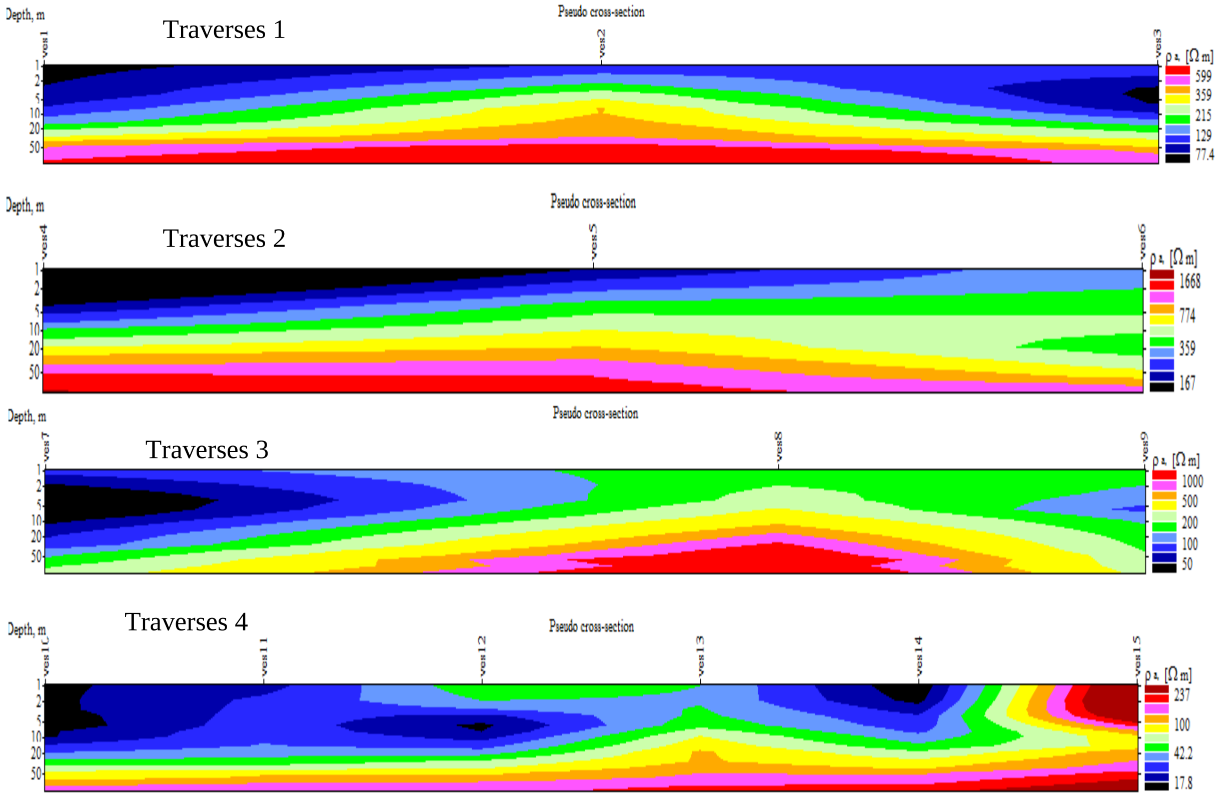


Fig. 5c: Resistivity Pseudosection along Traverses 1-

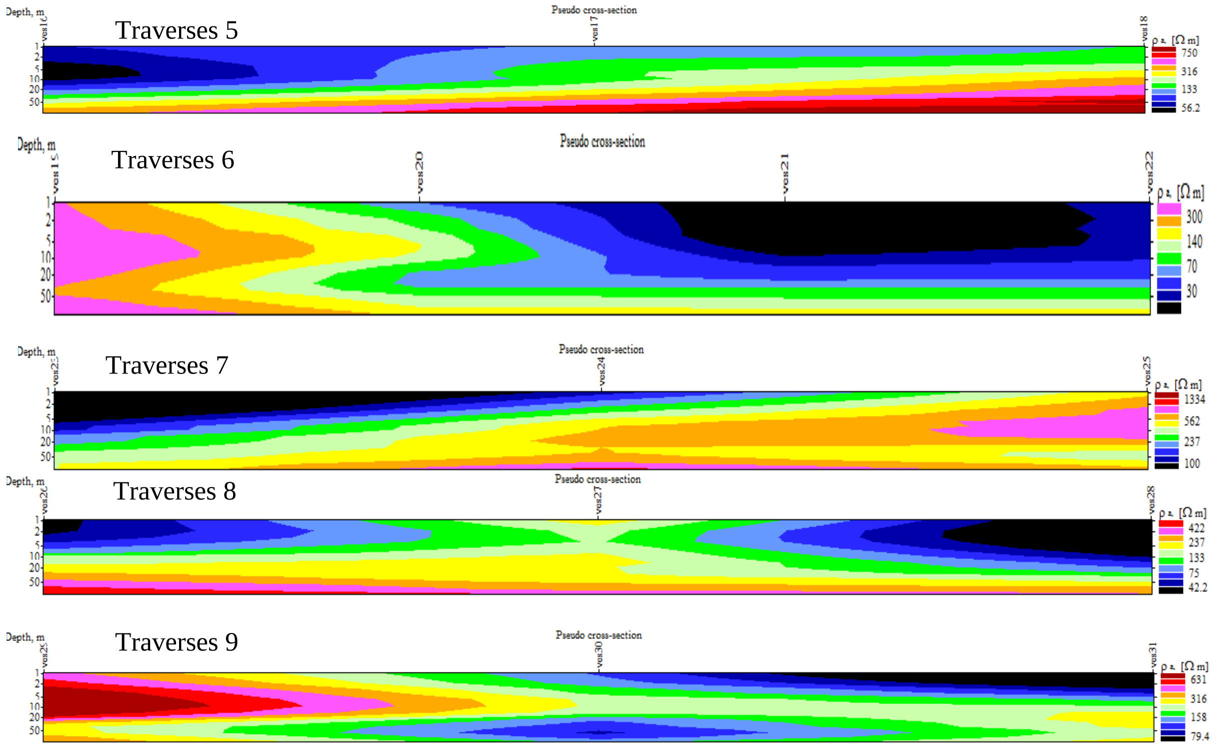


Fig. 5d: ResistivityPseudosection along Traverse 5-

Vertical electrical sounding (VES)

Vertical electrical soundings were carried out in the study area to obtain a geologic model from the resistivity data, the VES data were inverted using the software IP2Win developed by Alexey Bobachev, Moscow State University, Russia. The 1D profiles generated from the inversion of the resistivity data VES1-VES8 are presented in Fig. 5, Summary of the computer iteration results are presented in Fig. 6. Analysis of the 1D resistivity profile produced a system of three to five geo-electric layers which are the top soil, lateritic layer, clayey soil(sandy clay and clayey sand), weathered basement which overly the fresh basement. The topsoil apparent resistivity values vary from 12.3 Ωm at VES21 – 411 Ωm at VES25. The thickness of these layers varies from 0.204 m at VES28 to a maximum of 5.31 m at VES1. The second layer is the lateritic layer whose apparent resistivity ranges from 5.85 Ωm-2779 Ωm at VES21 and VES15 respectively.

The thicknesses of the lateritic layer vary from 0.413 m at VES15 to 10.40 m at VES25. The second layer is not present at VES1, VES4, VES5, VES8, VES11, VES16, and VES18 where only 3 geoelectric layers were delineated.The third layer is the clayey soil (Sandy clay and clayey sand) layer whose apparent resistivity depends on the percentage of clay present and ranges from 45.8 Ωm at VES29 to 626 Ωm at VES15. The thickness of these layers varies from 3.10 m to 7.11 m at VES29 and VES27 respectively. The third layer is only present at VES15, VES27, and VES29 where 5 geoelectric layers were delineated. The fourth layer is the weathered basement which represents the deep-seated aquiferous layer in the area. The layer resistivity varies from vary from 26.3 Ωm- 876 Ωm at VES20 and VES4 respectively while its thickness varies from 4.04 m at VES17 to 71.5 m at VES9. This layer is very important in groundwater accumulation. In hard rock terrains, composite aquifers of the weathered basement zone and fractured basements are known to give the highest groundwater yield (Oyedele and Olayinka, 2012).The last layer is the basement which has an apparent resistivity value ranging from 535 Ωm at VES 23 to 6176 Ωm at VES9. The resistivity pseudosectionof the layer are presented in Fig. 6.

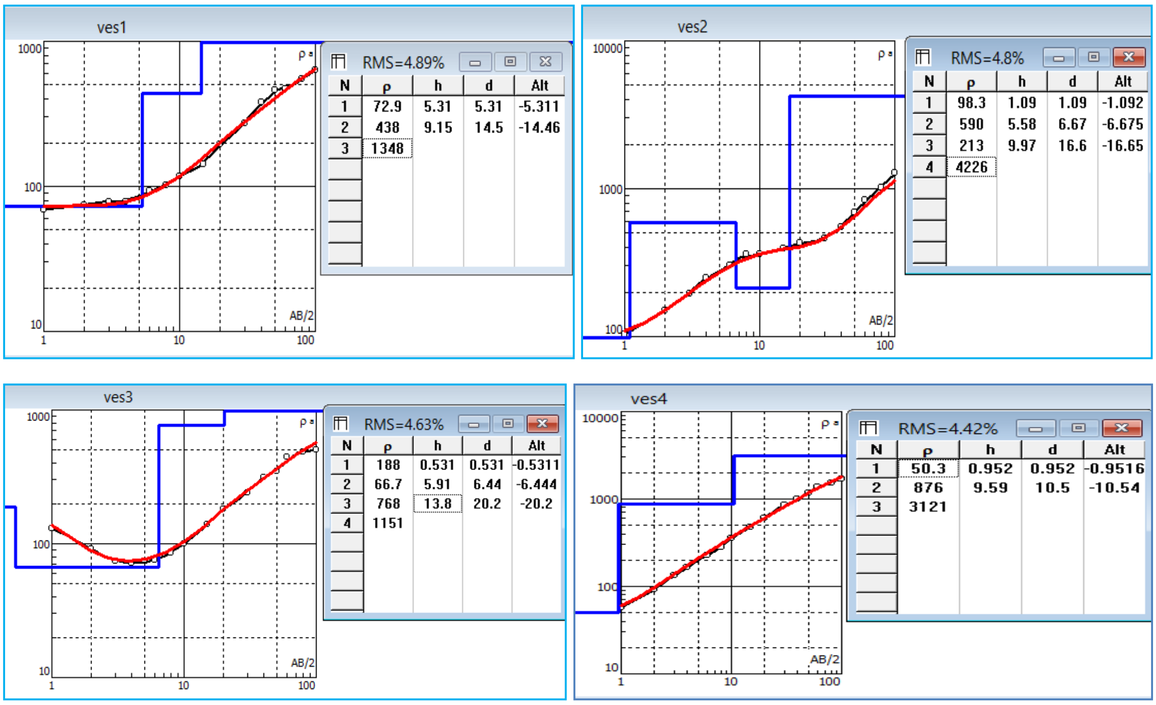


Figure 6a: The 1D Profiles Generated from Inversion of the Resistivity

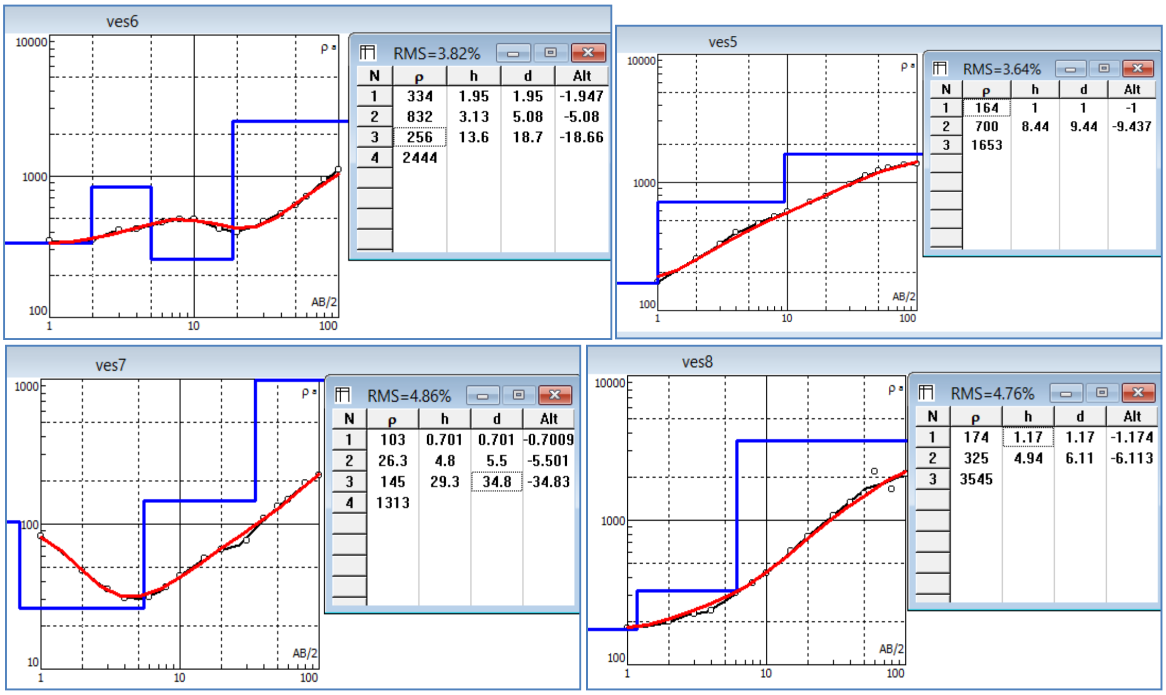


Figure 6b: The 1D Profiles Generated from Inversion of the Resistivity Data *VES5-VES8*

Conclusion

In conclusion, SP responses confirmed peaks of varying polarity,showing streaming potential which isevidence of fluid (i.e. groundwater) flow. The major direction is an east-west trend. The presence of a low resistivity zone appears along all the traverses, which could indicate water-bearing fracture/fault and joint within the weathered basement in the area.

The VES results from the conductive zones identify the most promising area with resistivity and depth range of 10.5 – 93.5 Ωm and 50 – 90 m scattered in the area. The aquifer in the area resides in the weathered and fractured basement in the area. This gives a clue into the probable depth expected of groundwater exploitation activity in the area.

The number of lithological layers in the study area varies from 3-5. These layerswere identified to be the topsoil, laterites, sandy clay, weathered basement, and fresh basement.The topsoil apparent resistivity values vary from 12.3 Ωm – 411 Ωm. The thickness of these layers varies from 0.204 m-5.31 m. The second layer is the lateritic layer whose apparent resistivity ranges from 5.85 Ωm-2779 Ωm. The thicknesses of the lateritic layer vary from 0.413 m-10.40 m.The weathered basement represents the aquiferous layer in the study area. This layer is very important in groundwater accumulation. The variation in apparent resistivity of this layer is probably due to varying degrees of saturation resulting from the topographical gradient. There is virtually no cusp on the resistivity profile to define a fractured zone.

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