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2D Electrical Resistivity Prospecting For Groundwater At The Premises Of The Staff Quarters Of Elizade University, Ilara Mokin, Ondo State, Nigeria

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***Abstract*— A shallow geophysical investigation for groundwater exploration using 2D electrical resistivity imaging was conducted at the Staff Quarters ofElizade University, Ilara-Mokin, Ondo state, Nigeria. This study was carried out with the aim of delineating areas with groundwater potentials in the study area.**

A total of four horizontal profiling using the Wenner array technique with varying length from 95 to 125m were established in the East-West and South-North directions of the study area. Qualitative interpretation was done by visual inspection of the pseudosections generated using the DIPPRO™ software. The pseudosections revealed layers that were interpreted to be clay, sandy clay and clayey sand. Though these layers were not clearly divided, partly because of the inhomogeneous properties of the soil material. The overburden thickness was found to range from 2.5 to 25m and the resistivity of the fractured basement rock varies from 247 to 628Ωm. The fractured basements are interpreted as water bearing zones.

A VES data acquired on traverse 2 near a failed borehole was interpreted and it was found out that the failure of the borehole may have been as a result of wrong location and probably not drilled to required depth. In general, the results show that groundwater exploration and development is feasible in the study area.

***Index Terms*— 2D resistivity imaging, vertical electrical sounding, groundwater, borehole, Ilara-Mokin.**

I. Introduction

Water is one of the mankind's most vital resources, it is the most common element on earth and it covers about 71.4% of the earth and as a result, it is an important resource for human development. Its uses vary from domestic, irrigation, power generation, recreation and industrial purposes. An adequate supply of water is one of the pre-requisites for development and industrial growth [1]. Water is generally classified into two groups: surface water and groundwater.

Groundwater is a mysterious nature's hidden treasure.Its exploitation has continued to remain an important issue due to its unalloyed needs. Though there are other sources of water; streams, rivers, ponds. But none is as hygienic as groundwater because groundwater has an excellent natural microbiological quality and generally adequate chemical quality for most uses.

The early part of the 20th century saw a rapid expansion of the exploration of groundwater supplies due to industrialization and increase in demand for water [2].

However, the portability of and availability of this natural and precious resource is often limited by nature. Although, there is plenty of water on earth, it is not always in the right place, at the right time and of the right quality [3].

Groundwater is the largest available reservoir of fresh water [4].

It is among the natural resources bestowed to the human race. Observation shows that groundwater comes from precipitation such as rain, snow, sheet and hail that soak into the ground and become the groundwater responsible for the spring, wells and boreholes.

To unravel the mystery out of groundwater, a detailed geophysical and hydrogeological understanding of the aquifer type(s), its spatial location is paramount in order to characterize the hydric zones in an area. To avoid drilling wells in unfavourable locations, a reliable method is required for assessing formation parameters before drilling takes place. This may ensure that a prospective productive well is sited where the aquifer is of adequate thickness and probably good quality [2]. Exploration of groundwater in hard rock terrain and in fissure media is a very challenging and difficult task. In this environment, the groundwater potential depends mainly on the thickness of the weathered/fractured layer overlying the basement. The weathered material, which constitutes the overburden, has high porosity and contains a significant amount of water, and at the same time, it presents low permeability due to its relatively high clay content. Fractures are the primary source to store water and allow movement of groundwater in hard rock areas. The size and location of fractures, interconnection of the fractures and recharging sources determine how much water one can get out of the hard rock. Boreholes, which intersect fractures, but which are not overlain by thick saturated weathered material, cannot be expected to provide high yields in the long term. Boreholes which penetrate saturated weathered material but which find no fractures in the bed are likely to provide sufficient yield for a hand pump only. Fractures in a geologic

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medium can greatly influence its hydrogeological characteristics. They can increase the hydraulic conductivity of an otherwise impermeable rock or soil by orders of magnitude in the dominant fracture directions. The geological importance of distribution of fractures in an area cannot be overemphasized. Areas that is extensively fractured and where the fractures are deep are considered as weak zones and are considered best or suitable zones for groundwater development [5].

Therefore knowledge of the presence, extent, intensity, and direction of fractures is desirable for any hydraulic engineering project. Hence, the location of potential fracture zones in hard rock area is extremely important to yield large amounts of groundwater.

The increased interest in recent years in underground sources of water has led to a need for more intensive studies of the geometry and properties of aquifers. Geophysics has played a useful part in such investigations for many years and improvements in instruments and the development of better methods is resulting in a widening of its applications [6]. A geophysical model created can be used to support other studies which involve, primarily one-, two-, and three-dimensional modeling. Resistivity imaging is one of the geophysical surveys which have been used to map groundwater contsmination and it is widely used for environmental surveys [6, 1, 7].

This technique has been used to determine the subsurface resistivity anomalies and recently it has become popular for the investigation of water movement in vadose zone.

Geophysical surveys have been the most widely used method in exploration of groundwater because of the basic advantage of providing more accurate results than other methods like the geochemical and remote sensing methods.

The electrical resistivity method has been the most commonly used geophysical tool for groundwater investigation because of its advantage which include simplicity in field technique and data handling procedure [8, 7]. Electrical resistivity methods are effectively used for groundwater exploration in areas where good electrical resistivity contrast exists between the water bearing formation and the underlying rocks [9]. The method enables the determination of subsurface resistivity by sending an electric current into the ground and measuring the electrical potential produced by the current.

The resistivity distribution of the ground is sometimes related to some physical conditions such as lithology, porosity, degree of water saturation and presence of voids in the rocks [8]. The vertical electrical sounding method of electrical resistivity gives detailed information about the vertical sequence of the different conducting zones. In each case, the vertical electrical sounding is used to delineate the subsurface stratigraphy based on resistivity differences.

The resistivity of the subsurface material is a function of the magnitude of the current, the recorded voltage and the geometry of the electrode configuration. The electrical resistivity obtained is termed “apparent” because it is not likely that the subsurface materials beneath the survey area are homogenous. The traditional resistivity method of sounding and profiling gives 1-D model of the subsurface, which is not adequate in mapping areas of complex subsurface geology. In addition, the basic sounding interpretation assumption of horizontally stratified earth model, which do not match the local geological model, and failure of the profiling method to map changes in resistivity with depth are the major limitations of these methods. Electrical resistivity tomography (ERT) provides a more realistic 2D resistivity model of the subsurface, where resistivity changes in the vertical as well as in the horizontal direction along survey line are mapped continuously even in the presence of geological and topographical complexities [7]. The 2D ERT methods have been a powerful technique to investigate shallow subsurface electrical structures in various environments. Studies have showed that 2D electrical resistivity tomography has been employed in bedrock detection, geological mapping and groundwater investigation. In order to properly plan for the management and development of groundwater resources in the study area,a hydrogeological characterization of the area was carefully carried out using 2D electrical resistivity tomography.

The apparent resistivities are subjected to interpretation techniques including the curve matching and/or computer interpretation. Based on the resistivities and the thicknesses of the underlying formations and the available geology of the area, the depth to water bearing rocks (aquifer) can be estimated.

The aim of the study is to investigate the groundwater potential at the staff quarters ofElizade University using two-dimensional (2D) model of the subsurface to give a better view of the terrain.

II. Location, Climate and Geology of the Study Area

The area under study is situated within the premises of Elizade University, Ilara-Mokin, Ondo State, Nigeria. It lies within Latitudes 732723 and 733041 and Longitudes 815111 and 815340 (Fig.1). It is accessible through a tarred road from Ilara-Mokin junction (Fig. 2)

The study area is underlain by the Precambrian Basement complex rocks of South-western Nigeria [10].The local geologic units identified in the study area are the Migmatitic-Gneisses. They are composed of three main components namely: Early Gneiss, Mafic- Ultramafic Bands and Granitic or Felsic Component.

In basement complex rock areas, storage and transmission of groundwater is made possible through the presence of discontinuities within the rock media. These discontinuities can occur in the form of fractures, joints (and joint systems), faults, lineation and cracks within the rock masses [11].

The Area falls within the humid tropical climatic zone which has prominent wet and dry seasons. A typical wet season extends from April to October, while the dry season extends from November to March. Annual rainfall ranges between 100 mm and 1500 mm, with average wet days of about 100. Annual temperature varies between 18^0C and 34^0C [12].

Fig. 1: Map of Nigeria showing Ondo State and the study area

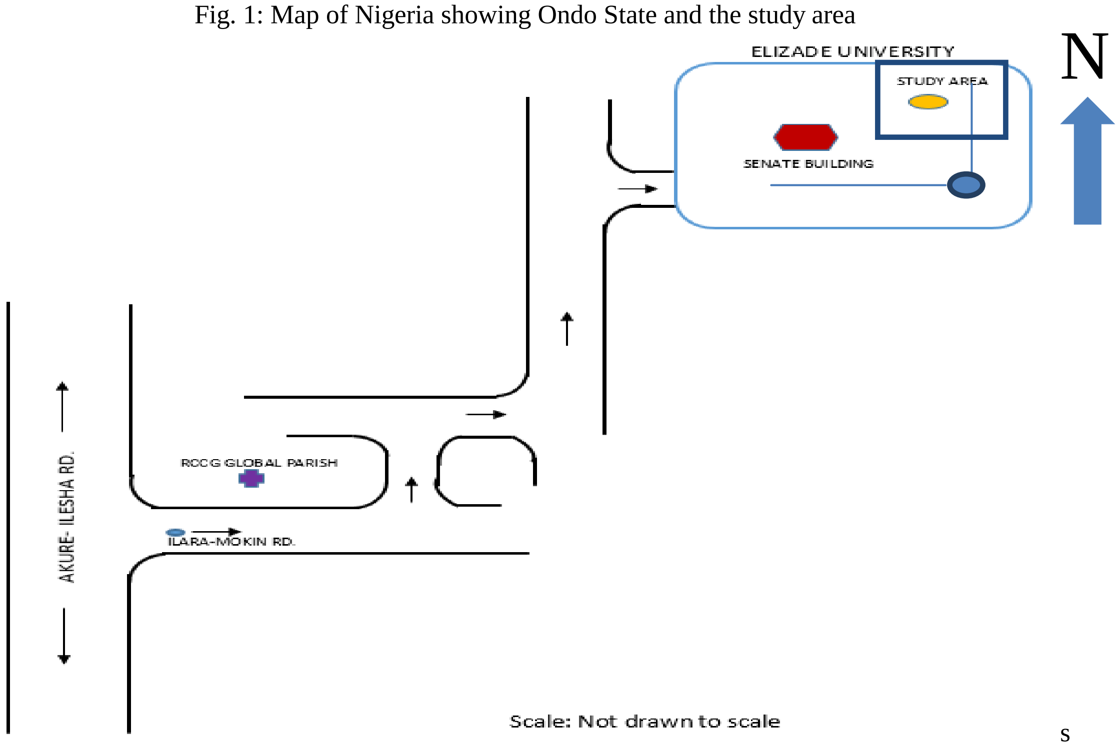

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Fig. 2: Location map of the study area

III. Materials and Methodology

In this research work, the Wenner electrode configuration was used during the resistivity measurements with electrode spacing of 5m and a maximum of between 95m and 125m spread.

The data were processed by using inversion software DIPRO. Basically, the data from these surveys are commonly arranged and contoured in the form of a pseudosection which gives an appropriate picture of the subsurface resistivity. The apparent resistivity of the subsurface can be computed using the following formular : $\rho = 2\pi aR$, where a = electrode spacing and R = resistance. The use of the DIPRO, essentially involves the readuing of the field data, inversion of the data using least square inversion procedure to get the true resistivity and the true depth of the field resistivity image. Topographic corrections to account for variations in the surface elevation are also included in DIPRO software.

The basic field equipment for thisstudy is the resistivity meter which displays apparentresistivity values digitally as computed from ohm's law. It ispowered by a 12 Volt (V) Direct Current (DC) power source. Other accessories to theResistivity meter include the four metal electrodes, cables forcurrent and potential electrodes, harmers (four), measuring tapes, writing pads.

Four profiles/traverses were established in the North-South (TR 2 and TR 3) and East-West (TR 1 and TR 4) direction in the study site (Fig. 3). Data from *the* electrical resistivity imaging is presented as pseudo-sections (Fig. 4 to 7).

One Vertical Electrical Sounding (VES) was established along traverse TR 2 (X in Fig. 3) near a failed borehole in the study area. The data obtained from VES was processed and presented as sounding curve. A maximum of $AB/2$ of 65m spread was used.The geoelectric parameters (resistivity, thickness and depth) obtained was appropriately iterated with the use of a commercial computer program called WinRESIT. Columnar section was also generated with the aid of SURFER 12 software. The columnar section showed the subsurface layer resistivities and depths.

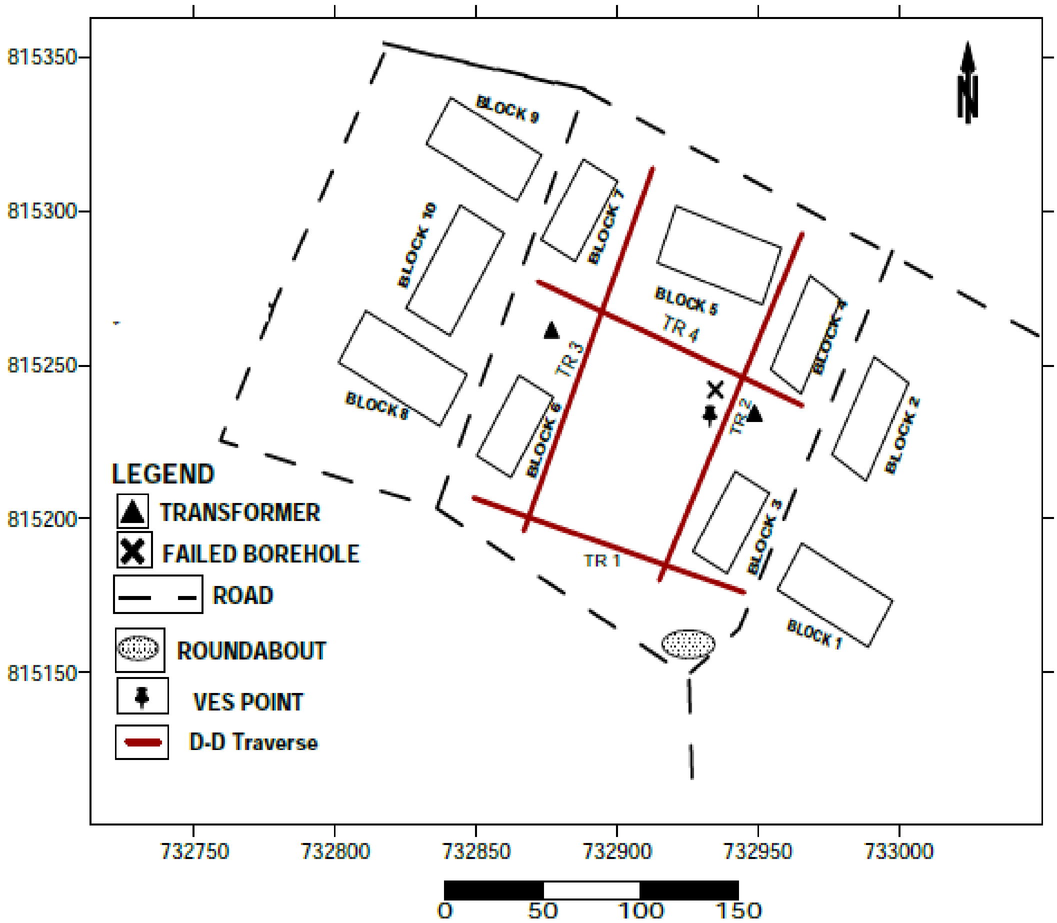

Fig. 3: Showing the positions of the traverses and VES

IV. RESULTS AND DISCUSSION

The dipole-dipole array was utilized for the 2-D resistivity imaging of the survey area to determine both lateral and vertical variation in apparent resistivity of the subsurface materials. Qualitative interpretations were made by visual observation of the pseudo-sections. The geoelectric layers delineated varies in resistivity and it is denoted by different colours ranging from blue, green, yellow, red and purple colour bands.

A. TRAVERSE ONE (TR1)

Along traverse 1(Fig. 4), electrode spacing of 5m was used with a total length of 100m and the apparent resistivity plotted against the pseudo-depth in the East-West (E-W) direction. The 2D electrical resistivity section along TR1 is a reflective of the subsurface resistivity along the traverse. The resistivity distribution revealed the complex nature of the subsurface along the traverse which is highly heterogeneous. A conductive zone with resistivity values ranging between 52.6 and 75.9Ωm (green colour) is revealed at two zones along the traverse. The first zone appears between stations 4 and 10, occurring at depths ranging between 0 and 10m, while the second zone occurs at the eastern part of the traverse between stations 15 and 18 with depth ranges between5 and 25m. This portion is interpreted to be clay formation. Underlain this layer, is a medium conductive zone (yellow colour) with resistivity values ranging between115 to165Ωm. This zone also appears at two flanks of the traverse, in the western and the eastern flanks with depth values ranging between0 and25m. The zone is interpreted as sandy clay. It occurs between stations 0 to4 and 14 to 18, with a discontinuity between stations 5 and 14. Underlain this medium conductive layer is a resistive layer (red colour) with resistivity values between 183 and 306Ωm. This layer is interpreted to be clayey sand, appearing between stations 7 and 11 with depth ranges between 10 and 25m. The last layer along this traverse is the assumed basement (purple colour) with resistivity values ranging between 317 and525Ωm. It is interpreted as fractured basement with clayey sand materials and occurring between stations 6 and 13. For any meaningful groundwater development along this traverse it has to be between stations 7 and 13 and to a depth beyond 20m but preferably within station 9 and 10 because of an observed depression at the station.The cone shaped feature (depression) may assist in groundwater accumulation of the fractured basement.

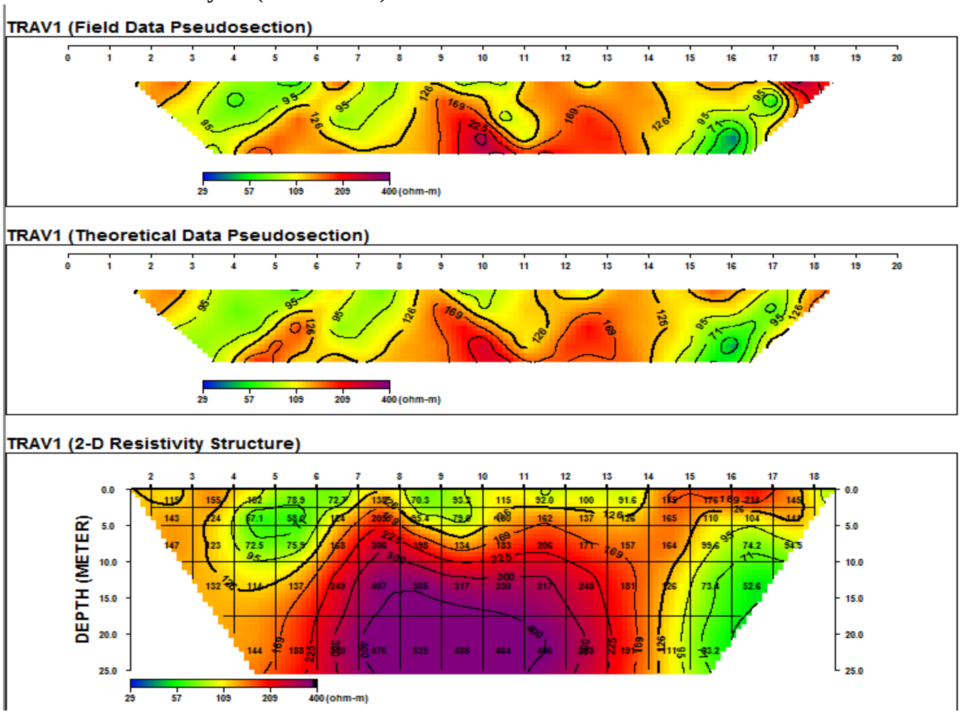

Fig. 4: Showing Pseudosection along TR1 in the E-W direction

B. TRAVERSE TWO (TR2)

In Fig. 5, electrode spacing of 5m was used with a total length of 125m and the traverse runs in the South-North (S-N) direction. The resistivity distribution revealed the complex nature of the subsurface along the traverse which is also heterogeneous. A conductive zone with resistivity values ranging between 46.5 and 68.2Ωm (green colour) is observed at two isolated zones of the northwestern and northeastern part along the traverse. The first zone appears between stations 0 and 4, occurring at depths ranging between 0 and 5m, while the second zone occurs at thenortheastern part of the traverse between stations 21 and 23 with depth ranges between 2.5 and 17.5m. This portion is interpreted to be clay formation. Underlain this layer, is a medium conductive zone (yellow colour) with resistivity values ranging between 50.5 to 87.1Ωm. This zone also appears at two flanks of the traverse, in the northwestern and the northeastern flanks with depth values ranging between 0 and 10m. The zone is interpreted as sandy clay. It occurs between stations 0 to 4 and 21 to 23, with a discontinuity between stations 9 and 21. Underlain this medium conductive layer is a resistive layer (red colour) with resistivity values between 111 and 254Ωm. This layer is interpreted to be clayey sand, appearing between stations 3 and 20 with depth ranges between 0 and 25m. The last layer along this traverse which is the assumed basement (purple colour) with resistivity values ranging between 310 and 389Ωm. It is interpreted as fractured basement with clayey sand materials and occurring between stations 10 to 13, and 17 to 20. For any meaningful groundwater development along this traverse it has to be between stations 13 and 17 and to a depth beyond 20m. The traverse harbours a failed borehole between points 9 and 10. The failed borehole is assumed to have failed due to siting it on a resistive layer and also probably not drilled to a depth beyond 20m where it could have penetrated the fractured basement. The failed borehole should have been sited or located at stations between 15 and 16 which would have been directly above a suspected shallow fracture at station 16 (at depth of8m) and in between two major observed fractured basement (purple colour). So the borehole failure might be due to wrong siting or location point and not drilled to the required depth.

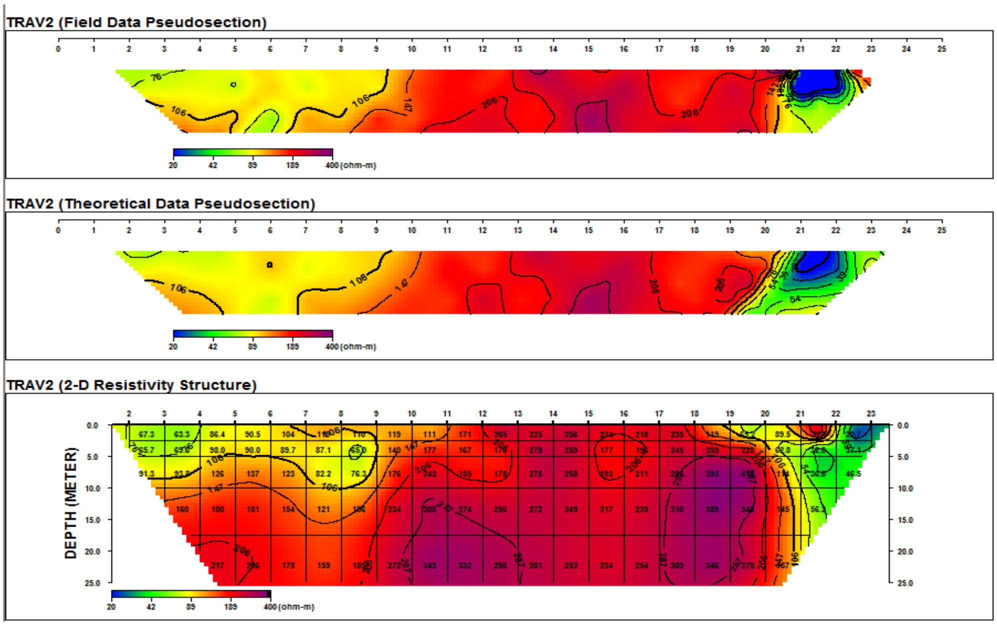

Fig.5: Showing Pseudosection along TR2 in the in the S-N direction

C. *TRAVERSE THREE (TR3)*

Fig. 6 is the third traverse which runs in the S-N direction with electrode spacing of 5m and a total length of 125m surveyed. The resistivity distribution revealed the complex nature of the subsurface along the traverse which is highly heterogeneous. A conductive zone with resistivity values ranging between 50.6 and 79.9Ωm (green colour) is observed at three isolated zones of the northwestern, north and northeastern part along the traverse. The first zone appears between stations 3 and 5, occurring at depths ranging between 0 and 5m, the second layer at stations 8 to 10 with depth between 2.5 to10m while the third zone occurs at the northeastern part of the traverse between stations 17 and 20 with depth ranges between 0 and 25m. This portion is interpreted to be clay formation. Underlain this layer, is a medium conductive zone (yellow colour) with resistivity values ranging between 102 to 126Ωm with depth values ranging between 0 and 17.5m. The zone is interpreted as sandy clay. It occurs between stations 3 to 5; 10 to12 and 16, with a discontinuity between stations 5 to 7; 12 to 16 and 17 to 23. Underlain this medium conductive layer is a resistive layer (red colour) with resistivity values between 145 and 197Ωm. This layer is interpreted to be clayey sand, appearing between stations 5 to 10 and 11 to 16 with depth ranges between 0 and 25m. There appears to be amore resistive body between station 13 and 16 at a depth range of 0 to 10m with resistivity value ranging between 225 and 272Ωm, which is suspected to be a bolder.A more conductive wet layer is observed at the eastern part of the traverse (blue colour) with resistivity ranges between 43.6 and 49.2Ωm with depth ranging between 5 and 25m. This layer appears to be good enough for consideration for productive borehole by reasons of its resistivity values and depth.

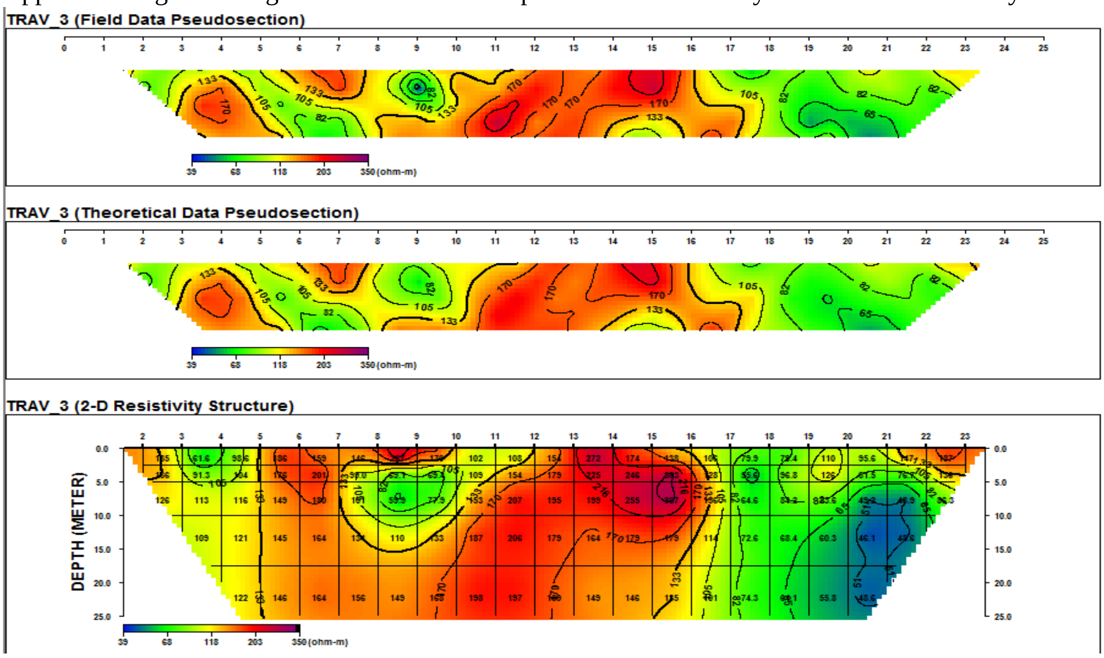

Fig. 6: Showing Pseudosection along TR3 in the S-N direction

D. TRAVERSE FOUR (TR4)

Traverse 4(Fig. 7) has electrode spacing of 5m with a total length of 95m and the profile running in the E-W direction. The 2D electrical resistivity section along the traverse is a reflective of the subsurface resistivity along the traverse. The resistivity distribution revealed the complex nature of the subsurface along the traverse which is highly heterogeneous. A conductive zone with resistivity values ranging between 46.5 and 68.2Ωm (green colour) is observed at two isolated zones of the northwestern and northeastern part along the traverse. The first zone appears between stations 0 and 6, occurring at depths ranging between 0 and 8m, while the second zone occurs at the northeastern part of the traverse between stations 11 and 15 with depth ranges between 0 and 24m. This portion is interpreted to be clay formation. Underlain this layer, is a medium conductive zone (yellow colour) with resistivity values ranging between 154 to 185Ωm. This zone also appears at two flanks of the traverse, in the north and the northeastern flanks with depth values ranging between 0 and 24m. The zone is interpreted as sandy clay. It occurs between stations 7 to 10 and 14 to 16, with a discontinuity between stations 11 and 17. Underlain this medium conductive layer is a resistive layer (red colour) with resistivity values between 220 and 315Ωm. This layer is interpreted to be clayey sand, appearing between stations 5 and 7 with depth ranges between 5 and 25m. The last layer along this traverse which is the assumed basement (purple colour) with resistivity values ranging between 453 and 655Ωm. It is interpreted as fractured basement with clayey sand materials and occurring between stations 5 to 7, with depth range between 6 and 25m. For any meaningful groundwater development along this traverse it has to be between stations 5 and 7 and to a depth of about 23m. This last layer (basement) appears to be fractured at two locations, one at about 13m and the other one at about 22m. So drilling to a depth of 23m will allow penetration into the second fractured zone where reasonable groundwater accumulation is expected. At the eastern part of the traverse is also a suspected isolated wet clay section between station 12 and13 with depth values between 0 to 7.5m

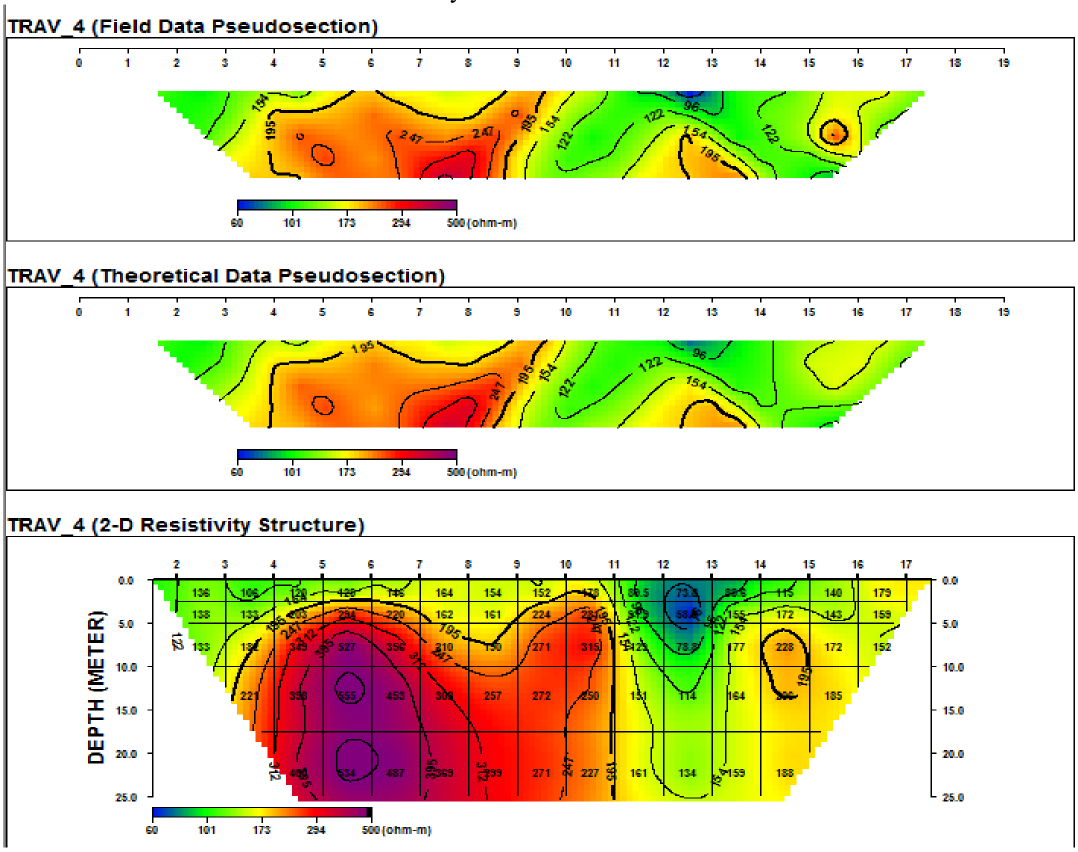

Fig. 7:Showing Pseudosection along TR4 in the E-W

E. COLUMNAR SECTION

The columnar section (Fig. 4.5) was generated using the processed VES data from the failed borehole which was interpreted by using manual curve matching and the WinResist software. The columnar section gives a qualitative and quantitative detail about the inferred layers or lithology beneath the VES point.

The columnar section delineated three subsurface layers. The sequence is from the top to bottom, the top soil, the weathered bedrock and the fresh bedrock.The first layer is the top soil with resistivity value of 190Ωm and the thickness is 2.6m suggesting sandy clay soil.The second layer is the weathered bedrock with resistivity value of 400Ωm and a thickness of 21.4m suggesting laterite/clayey sand materials.The last layer is the fresh bedrock with resistivity value of 2375Ωm.

The failed borehole may not have failed if it had been well and correctly sites or located and the thick weathered material of the second layer well penetrated probably to a depth of about 20m or more from the ground surface.

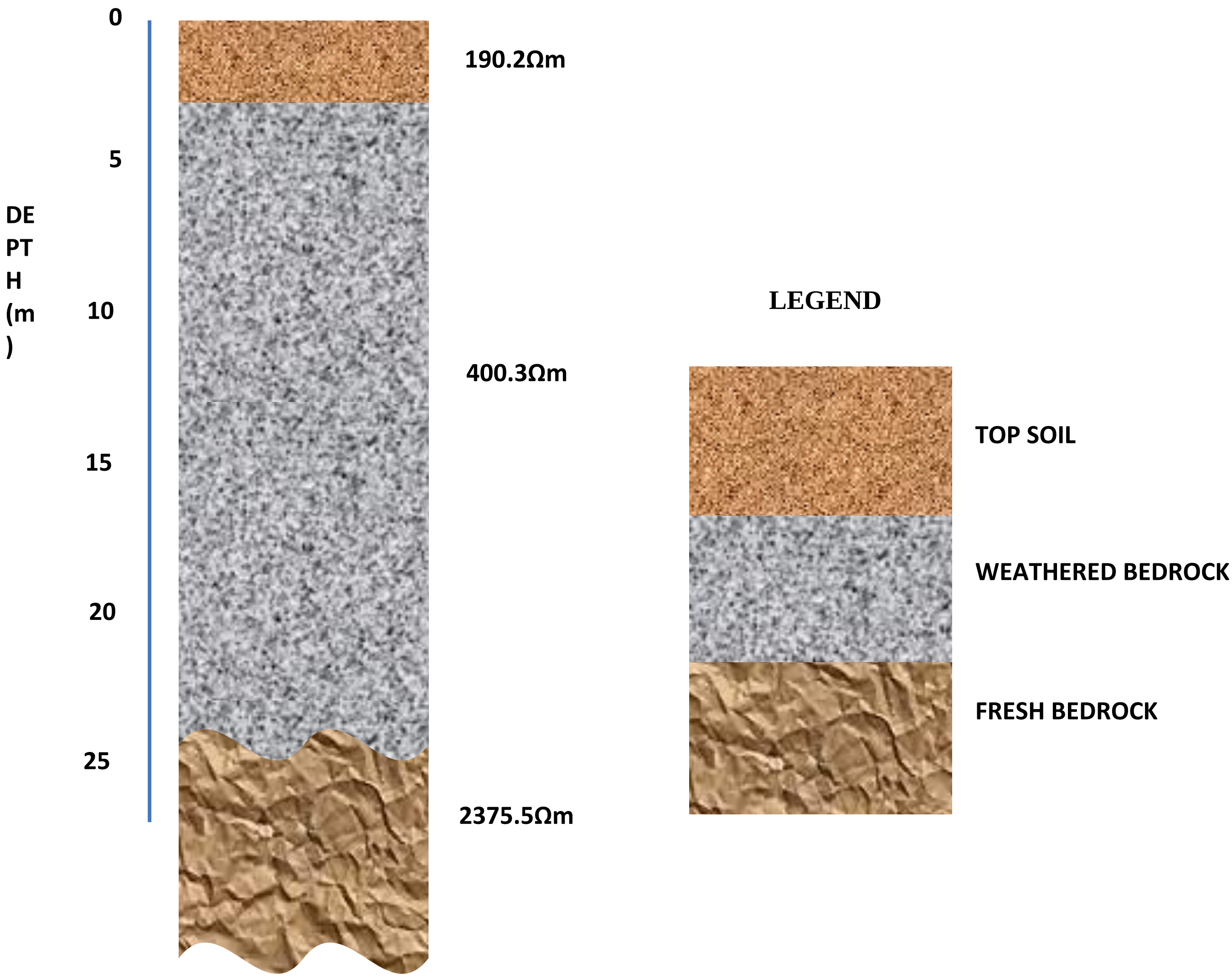

Fig. 8: Columnar section of the VES data

V. CONCLUSION

The electrical resistivity imaging in this study has been successfully used to determing the subsurface water bearing zones in the study area. However, these layers are not clearly divided partly because of the inhomogeneous properties of the soil material. The 2D electrical resistivity imaging has provided a clear view of the lithological units, weathering profiles and geological structures favourable for groundwater exploration and development in the study area. The analysis of the inverted pseudosections along the four profiles clearly show lithological sections of clay, sandy clay and clayey sand. The overburden thickness varies from 2.5 to 25m. The water-bearing zones in the study area is the regolith or weathered basement majorly derived from in-situ weathered crystalline rocks. The bedrock depressions and the fractured zones are generally being considered as groundwater collecting centres hence priority areas for groundwater development. Therefore, based on the results groundwater exploration and development in the study area should be targeted towards the fractured basement with relatively thick overburden areas.

REFERENCES

[1] Ayodeji, J. and Michael, A.O. 2015. 2-D Electrical Resistivity Tomography for Groundwater Exploration in Hard Rock terrain. International journal of Science and technology, Vol.4, No.4, pp 156-162.

[2] Brown, R.L. and Parizek, R.R. 1971. Shallow Groundwater Flow Systems Beneath Strip and Deep coal Mines at Two Sites, Clearfield County, Pennsylvania. Special Report of Research SR-84, 207.

[3] Olorunfemi, M.O. and Fasuyi, S.A. 1993. Aquifer types and geoelectric characteristics of part of central basement of Nigeria (Niger State). J. Africa Earth, 16(3), 309-317.

[4] United Nations. 1996. United Nations Educational, Scientific and Cultural Organization. World water Balance and water Resources of the Earth.

[5] Alagbe, O.A.; Sunmonu, L.A. and Adabanija, M. A. 2013. Fracture distribution within Bowen University Permanent site and Its Hydrogeologic Implication. Research Journal of Physical Sciences, Vol.1(3) pp 1-5.

[6] Zeinab, A.; Abdul, R.S.;Wan, Z.Y. and Jasni Y. 2012. Groundwater investigation using electrical resistivity imaging technique at Sg. Udang, Melaka, Malaysia. Bulletin of the Geological Society of Malaysia, Vol.58, pp 55-58.

[7] Alagbe, O.A. 2018. 2D Geoelectrical Resistivity Imaging for the Assessment of Subsurface Soil Corrosivity Zones at a Proposed Filling Station Site in AkureSouthwestern Nigeria.International Advanced Research Journal in Science, Engineering and Technology, Vol.5, issue 11, pp 58-73.

[8] Anomohanran, O. 2013. Geophysical Investigation of groundwater potential in Ukelegbe, Nigeria. Journal of Applied Sciences, 13(1), pp119-125.

[9] Nejad, H.T. 2009.Geoelectric Investigation of the aquifer Characteristics and Groundwater Potential in Behbahan Azad University Farm, Khuzestan Province, Iran. Journal of Applied Sciences 9(20) pp3691-3698.

[10] Rah man, M.A. 1976. Review of the basement geology of southwestern Nigeria. In C.A.Kogbe (Editor). In Geology of Nigeria (pp 41-58). Lagos: Elizabethan publishing Co.

[11] Teme, S.C. and Oni, S.F. 1991. Detection of groundwater flow in fractured media through remote sensing techniques- some Nigeria cases. Journal of African Earth Sciences, Vol.12, No 3, pp461-466.

[12] Iloeje, N.P. 1980. A new Geography of Nigeria (New Revised Edition). London, UK; Longman Group.