Hydrogeophysical Assessment of Aule Area, Akure Southwestern Nigeria.

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ABSTRACT

The Aule area has witnessed an influx of people as a result of residential development; hence the need to have access to potable water since water plays a vital role in the day-to-day activities of human beings. To evaluate the groundwater potential of Aule and its environs, a total of sixty five (65) Vertical Electrical Sounding datasets were acquired using Schlumberger configuration with maximum current electrode spacing (AB) of 300 m.

The VES data were interpreted quantitatively using partial curve matching technique. The resulting layer parameters (resistivity and thickness) were fed into computer for iteration using Win Resist software. The results obtained were used to generate geoelectric sections and maps as related to the objectives of the study. Three to four subsurface layers were delineated within the study area which is the topsoil, weathered layer, weathered/fractured Basement and the fresh Basement. The weathered layer/fractured Basement constitute the main aquifer unit in the area, but this layer is relatively thin and composed of high percentage of clay, hence of low groundwater yield. About 95% of the area falls within the zone of low groundwater potential. The overburden protective capacity is majorly poor/weak in most parts of the area except for small portions of moderate protective capacity in the northeastern end of the area.

(Keywords: vertical electrical sounding, electrical resistivity, potable water, ground water potential)

INTRODUCTION

The usefulness of water to man cannot be overemphasized as it is needed for most of his activities (both domestics and industrial usage). Groundwater is the water beneath the subsurface and it is evenly distributed across the whole world and less susceptible to pollution. Due to human activities, most of the surface water has been polluted and cannot be relied upon to supply the needed water for human activities. It originates from the percolation and infiltration of water into the ground after precipitation. These waters move through pores within the ground into a convenient storage formation called aquifer. Groundwater provides a reasonable constant supply which is not completely susceptible to drying up under natural condition unlike surface water (Akintorinwa and Olowolafe, 2013).

The successful exploitation of Basement terrain groundwater requires a proper understanding of its geo-hydrological characteristics of the aquifer in relation to its environmental susceptibility. This is important in view of the discontinuous nature of the Basement aquifers (Abiola *et al*., 2009). Hence, drilling for groundwater development in areas of Basement terrain is generally preceded by detailed geophysical investigation. The use of surface geophysical techniques has revolutionized groundwater development in the Basement Complex areas as it is employed in locating areas with high groundwater prospect.

Groundwater occurrence in the crystalline Basement rocks can be irregular due to the abrupt discontinuity in lithology, thickness and electrical properties of the bedrock (Olayinka and Olorunfemi, 1992). In this research, Electrical Resistivity method was employed for assessment of groundwater potential of the study area. Over the years, the Electrical Resistivity method has become increasingly successful in the search for groundwater. It requires a quantitative knowledge of geophysical parameters of the geologic units, that is, the superficial materials that overlies the crystalline bedrock and the bedrock structure/relief (Omosuyi *et. al.,* 2003). Nevertheless, it could be limited by the presence of conductive bodies such as clay and the fact that it only gives information about a point i.e. 1-D information.

Site Description

The study area is located within Akure metropolis, South-Western Nigeria and fall within longitudes 5^0 08' 7.63" and 5^0 09' 41.12" E and latitudes 07^0 15' 59.69" and 07^0 17' 6.06" N and it can be accessed through several networks of roads (Figure 1). The study area is accessible through the popular Oyemekun road, Akure with other minor roads and footpath interconnecting the area.

Geology of the Study Area

Field observation showed that the Basement Complex rocks present in the study area comprise the following rock units Migmatite Gneiss, Quartzite and Charnokitic rocks. The area is predominantly underlain by Charnokitic rocks and covers more than half of the area (Figure 2).

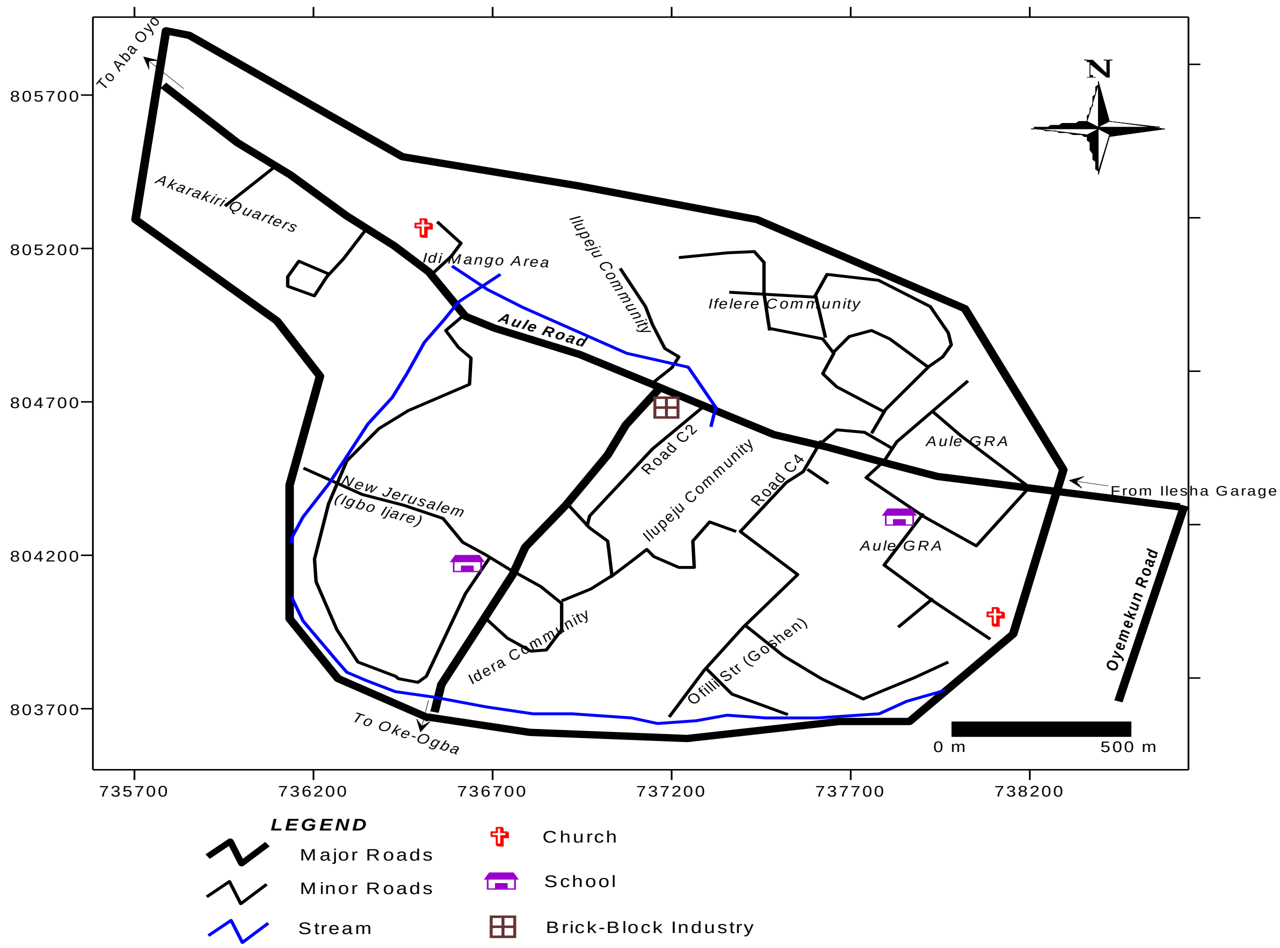

Figure 1: Base Map of the Study Area.

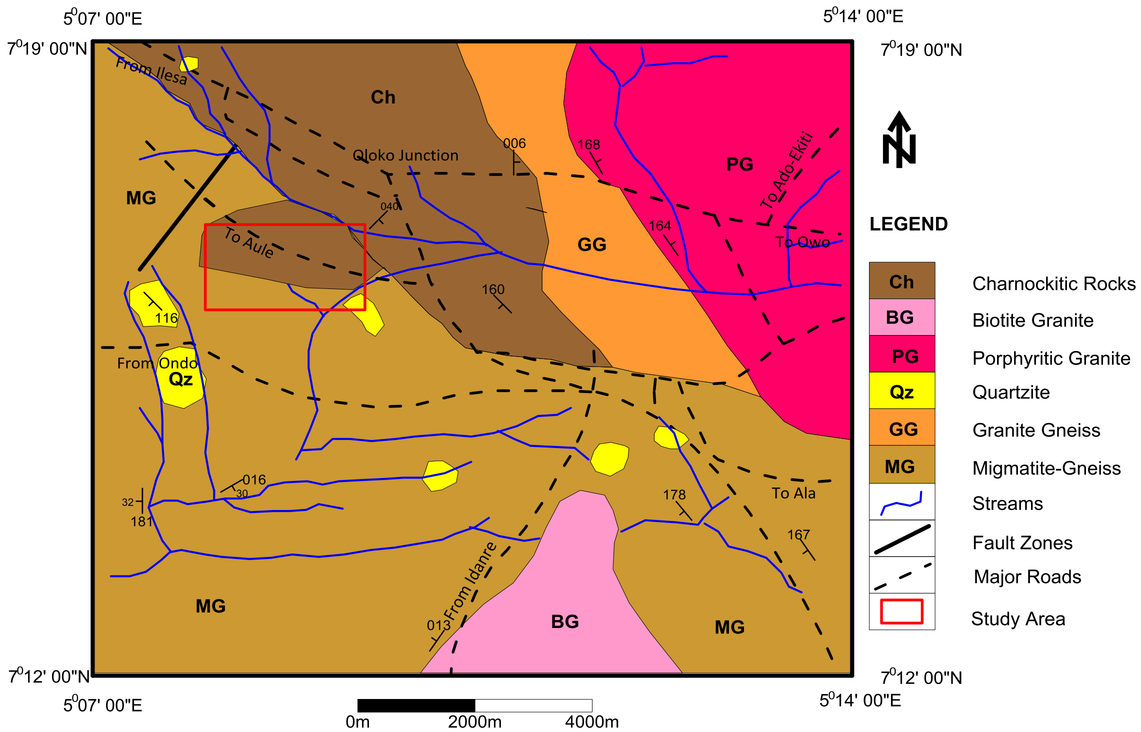

Figure 2: Geological Map of Akure Showing the Study Area (After Owoyemi, 1996).

METHODOLOGY

The detailed geophysical investigation adopted for the study employed Electrical Resistivity (Vertical Electrical Sounding technique) method using Schlumberger configuration. A total of sixty– five (65) sounding data were acquired within the study area with (AB/2) varying from 1 to 150 m. The sounding data were acquired along roads, linear routes between houses and any other available undeveloped plots of lands and open spots (Figure 3). The apparent resistivity ($\boldsymbol{\rho_a}$) measurements at each of the VES stations were plotted against electrode spacing (AB/2) on bi – logarithmic graph sheet. The resulting curves were then inspected visually to determine the nature of the subsurface layering.

In this way each curve was characterized depending upon the number and nature of the subsurface layers. Partial curve matching was done for the quantitative interpretation of the curves. The results of the curve matching (layer resistivity and thicknesses) were fed into the computer as starting model parameter in an iterative forward modeling technique using Win Resist (Velper, 2004).

RESULTS AND DISCUSSION

Field Curves

Eight (8) curve types have been identified in the study area. These sounding curves are A, H, HA, KH, QH, HKH, KHA and HKHKH. The curve type with highest frequency of occurrence is the H-type and the HKHKH-type having the lowest frequency of occurrence. These curve types are typical of Basement Complex in the succession of relatively low and high resistivity layers. They are classified as classes. Class 1 type curve (A) (Figure 4a) represents a subsurface condition in which there is an increase in resistivity from the topsoil to the bedrock. The VES curve type of Class 2 (H, HA, and QH) are characteristic of the Basement Complex saprolite curve produced from in-situ weathering. Example is shown in Figure 4b.

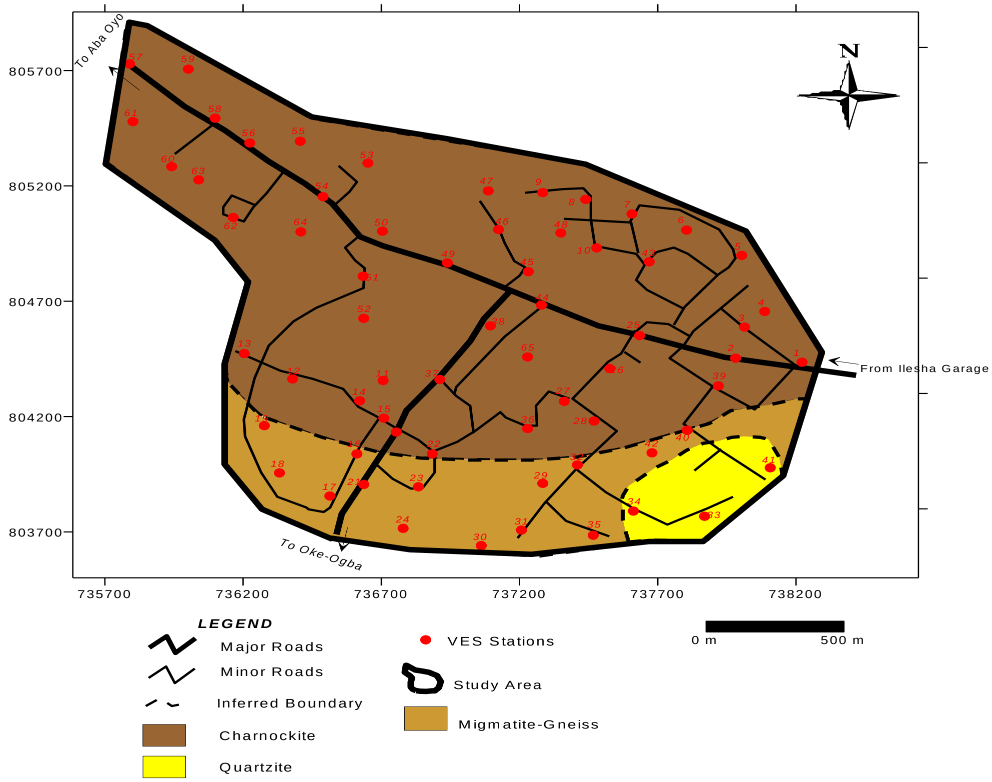

Figure 3: Geophysical Data Acquisition Map of the Study Area Showing VES Stations.

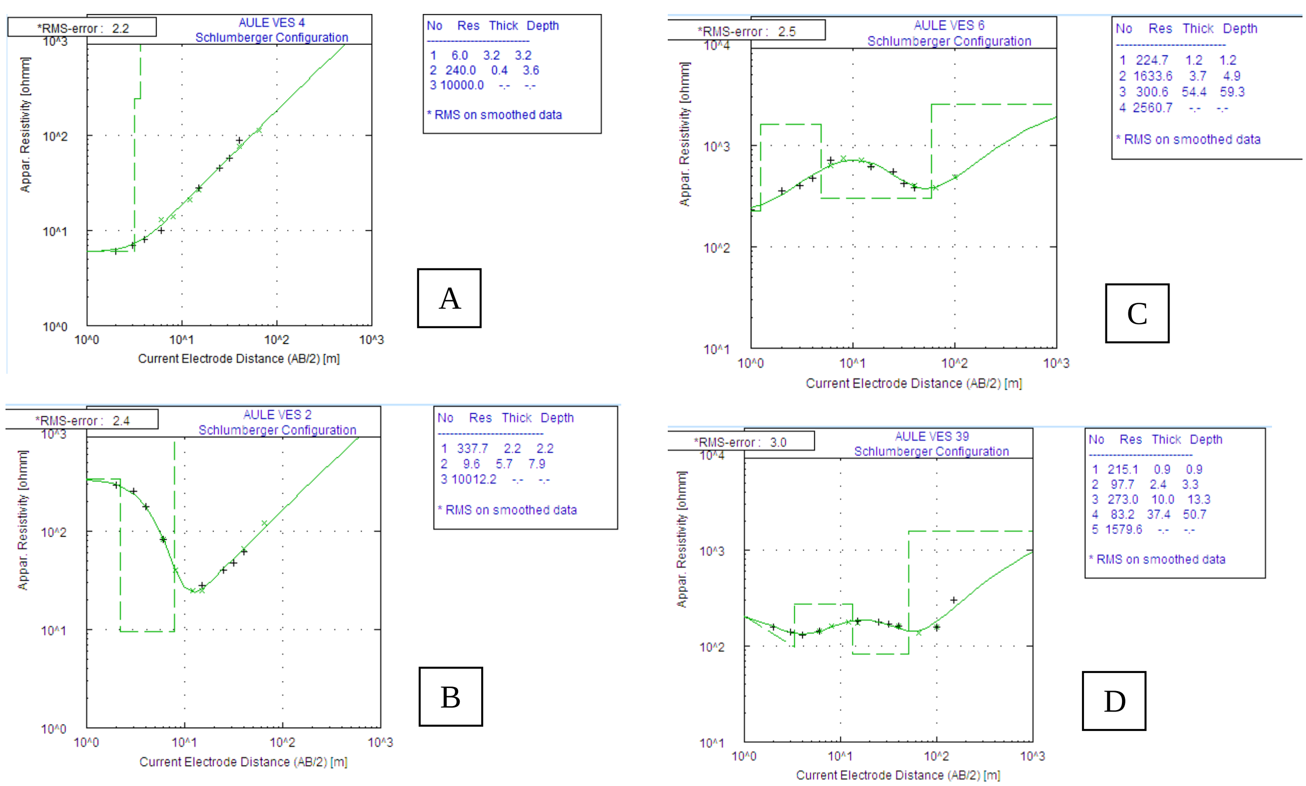

Figure 4: (A & B): Interpretation Model of Typical Class 1 and Class 2 Type Curves. (C & D): Interpretation Model of Typical Class 3 and Class 4 Type Curves

In the curve, when not leached, are usually clayey and the main aquifer zone is found at the base where selective mineral decomposition has produced a gravel-like material (Akintorinwa, 2009). Class 3 curves types (KH and KHA) as shown in Figure 4c are typical of succession of relatively low and high resistivity layers. The KH four layers setting is found where a high resistive lateritic hard pan underlies low resistivity clayey topsoil, and the weathered underlies the former. The curves in Class 4 (HKH and HKHKH) are shown in Figure 4d. The HKH type is a succession of five layers i.e. the topsoil, weathered layer, fresh Basement, confined fracture Basement and fresh Basement.

Geo-electric Sequence

Geoelectric sections shows the distribution of the resistivity of the various delineated layers with respect to depth and the insight of the subsurface geologic sequence and structural disposition in a two dimensional form. Four geoelecric sections were drawn across the study area in NW-SE, SW-NE, N- S and W- E direction (Figure 5). The geo-electric sections display three to four distinct subsurface geoelectric layers.

The layers are topsoil, weathered layer, partly weathered/fractured Basement and the fresh Basement. In the first layer (topsoil), resistivity values ranges from 12 to 297 ohm-m and it is composed of clay, sandy clay and clayey sand while thickness varies from 0.6 to 3.6 m. In the second layer (weathered layer) resistivity values vary from 10 to 499 ohm-m, while thickness varies from 2.0 to 11.6 m. It is composed of clay, sandy clay, clayey sand and laterite. The resistivity values in the third layer (partly weathered/fractured Basement) varies from 92 to 614 ohm-m and thickness ranging from 5.9 to 27.4 m. Resistivity of the fresh Basement ranges from 497 to ∞ ohm-m. Depth to bedrock ranges from 4.0 to 43.3 m across the sections.

Isoresistivity and Isopach Map of the Top Soil

The resistivity map (Figure 6) of the topsoil shows the resistivity values ranging from 6 to 540 ohm-m but generally less than 300 ohm-m. The resistivity of the topsoil is low towards the northwestern and sparingly towards the northeastern part and southern part of the study area with resistivity range of 6 to 140 ohm-m.

This reveals the highly heterogeneous nature in the composition of the topsoil from clay, sandy clay to clayey sand and laterite. The topsoil resistivity is moderate to slightly high towards the western part and southeastern part with resistivity range of 140 to 420 ohm-m.

The thickness map of the topsoil reveals the thickness distribution of the topsoil within the study area. The thickness of the topsoil ranges between 0.4m to 6.4m but generally less than 1.2m indicating that the topsoil are generally thin with no hydrological significant. Areas such as southwestern parts of the study area which show thin topsoil and moderate resistivity (Figure 7) are indicative of areas that are easily susceptible to aquifer pollution.

Isoresistivity and Isopach Maps of the Weathered Layer

The resistivity value of the weathered layer varies from 6 to 850 ohm-m (Figure 8) but generally less than 100 ohm-m. This reveals the highly heterogeneous variation in the composition of the weathered layer from clay, sandy clay, clayey sand, to laterite. The resistivity is generally low across the study area with resistivity less than 100 ohm-m typical of predominant clayey composition. The resistivity value is slightly moderate to high at the center, southwestern and northeastern parts of the study area and resistivity variation from 100 to 1000 ohm-m is typical of clayey sand and laterite.

The implication of the predominant clayey composition of the weathered layer which is the major aquifer unit in the area is that, the groundwater potential of the area is low since clay is porous but not permeable. The isopach map depicts the variation in the thickness of the weathered layer over the study area (Figure 9). It varies from 0.5 to14 m but generally less than 9 m, indicating thin weathered layer across the study area. The thickness (9 to 14 m) occurs towards the western parts of the study area at the portion marked green. This indicate that the major aquifer unit in the area is very thin and of low groundwater yield.

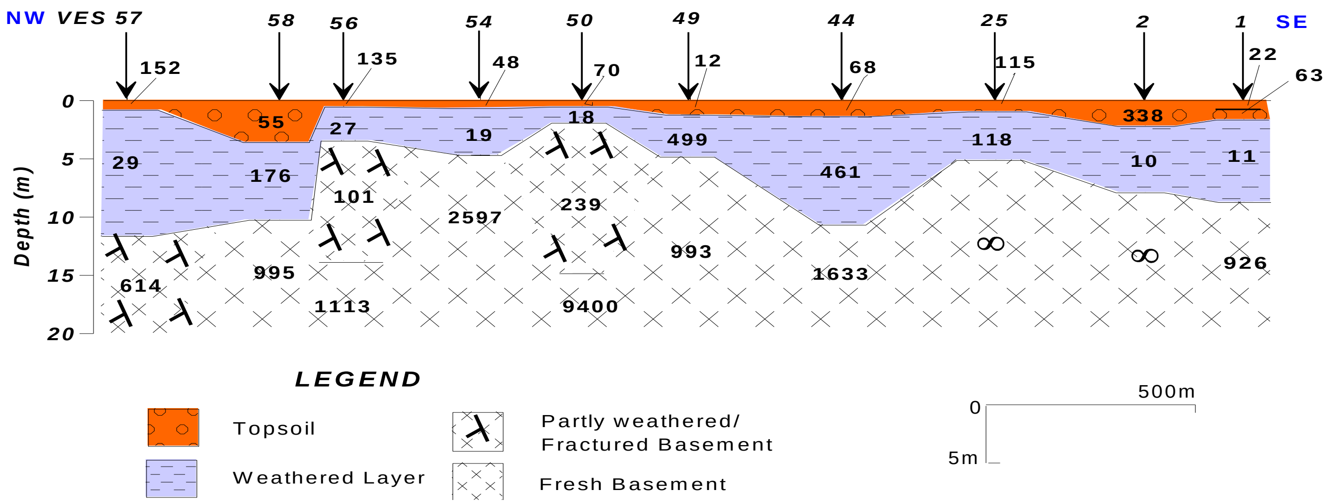

Figure 5a: Geoelectric Section Along NW – SE.

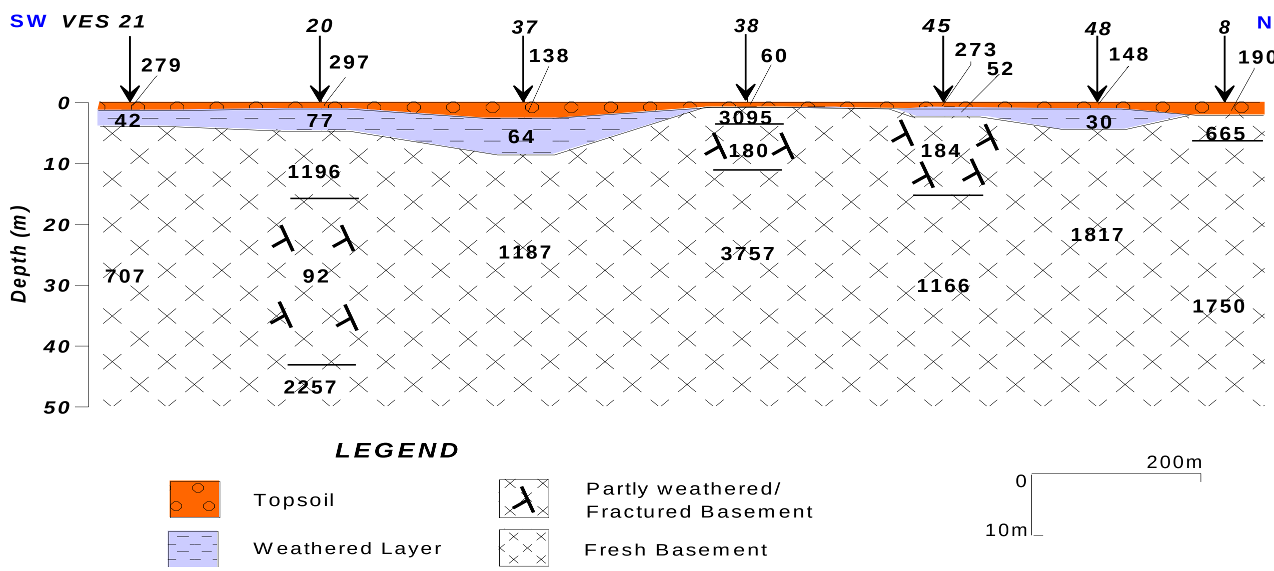

Figure 5b: Geoelectric Section Along SW – NE.

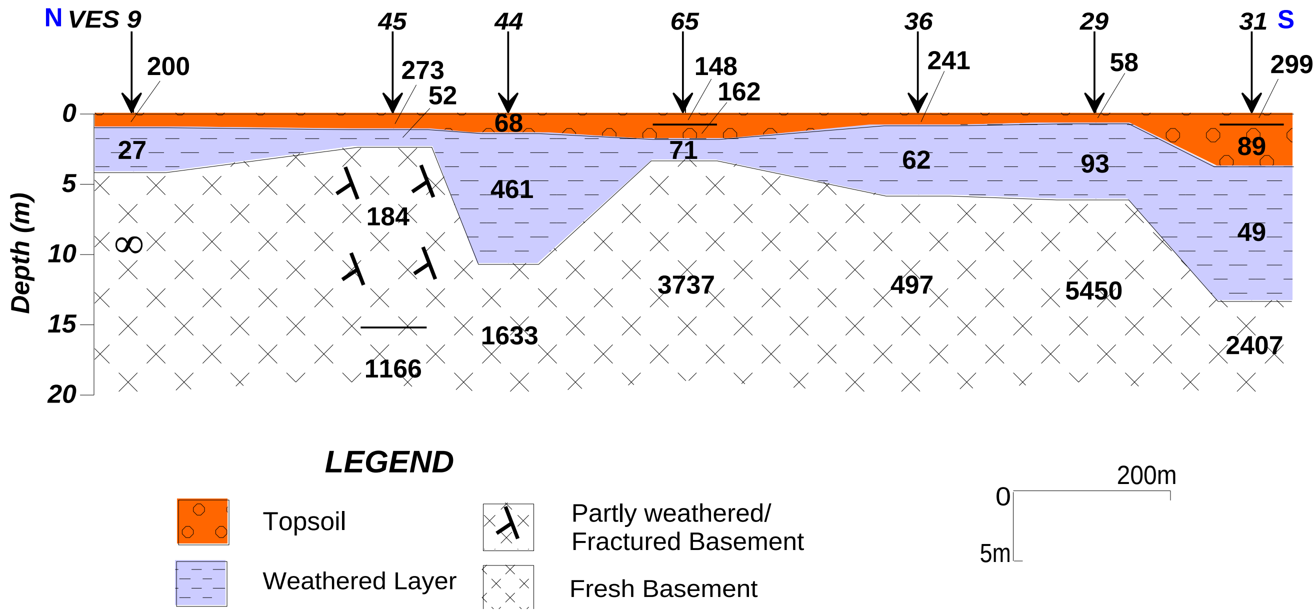

Figure 5c: Geoelectric Section Along N – S.

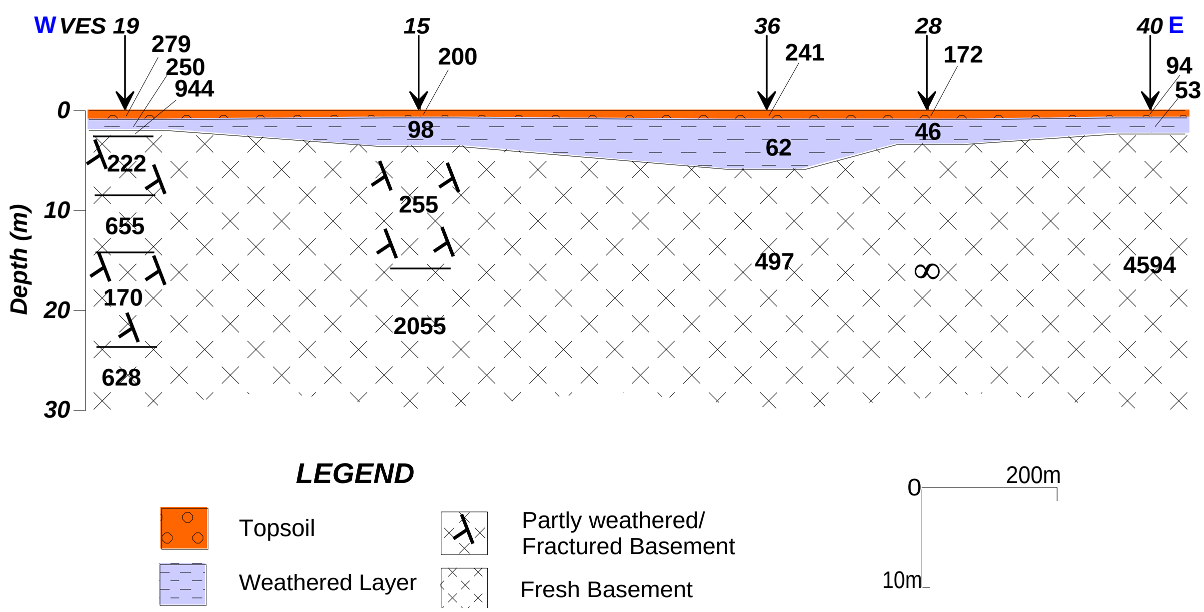

Figure 5d: Geoelectric Section Along W – E.

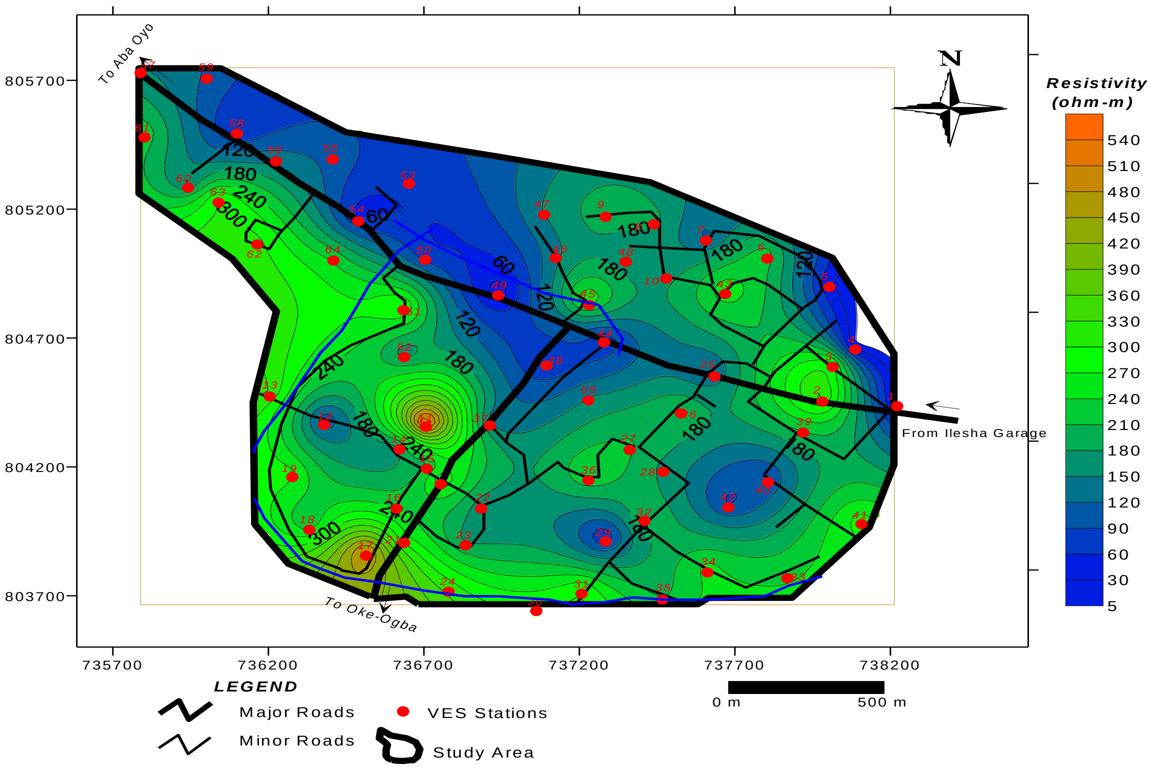

Figure 6: Isoresistivity Map of the Topsoil.

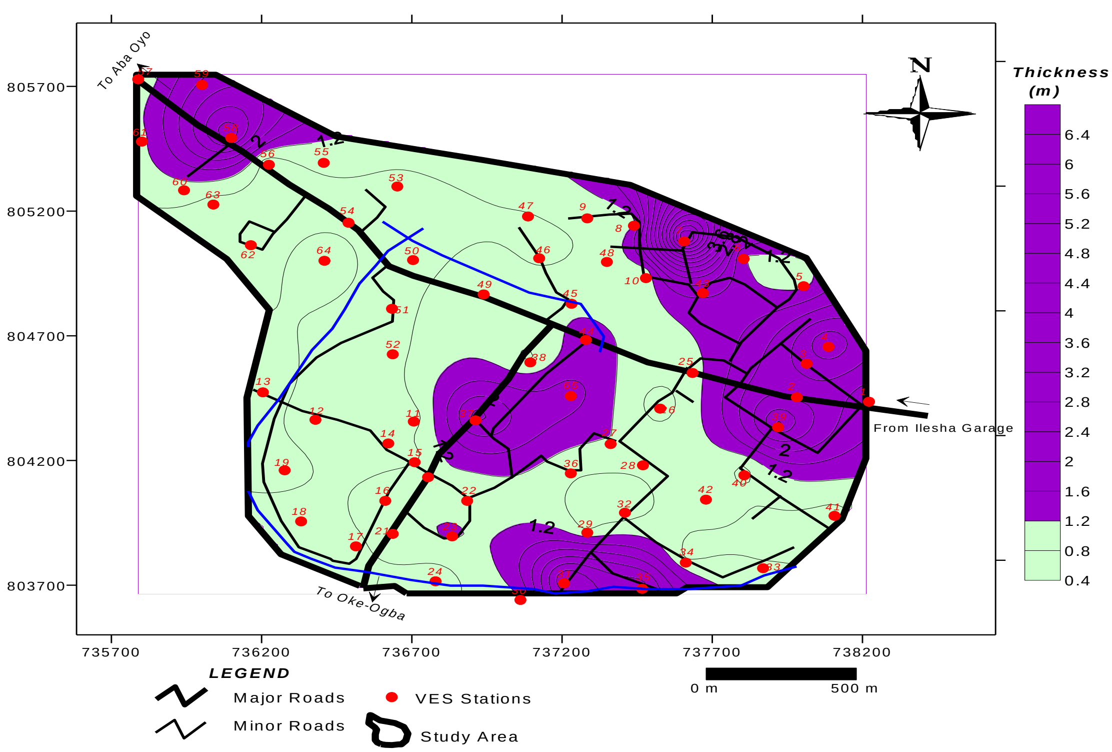

Figure 7: Isopach Map of the Topsoil.

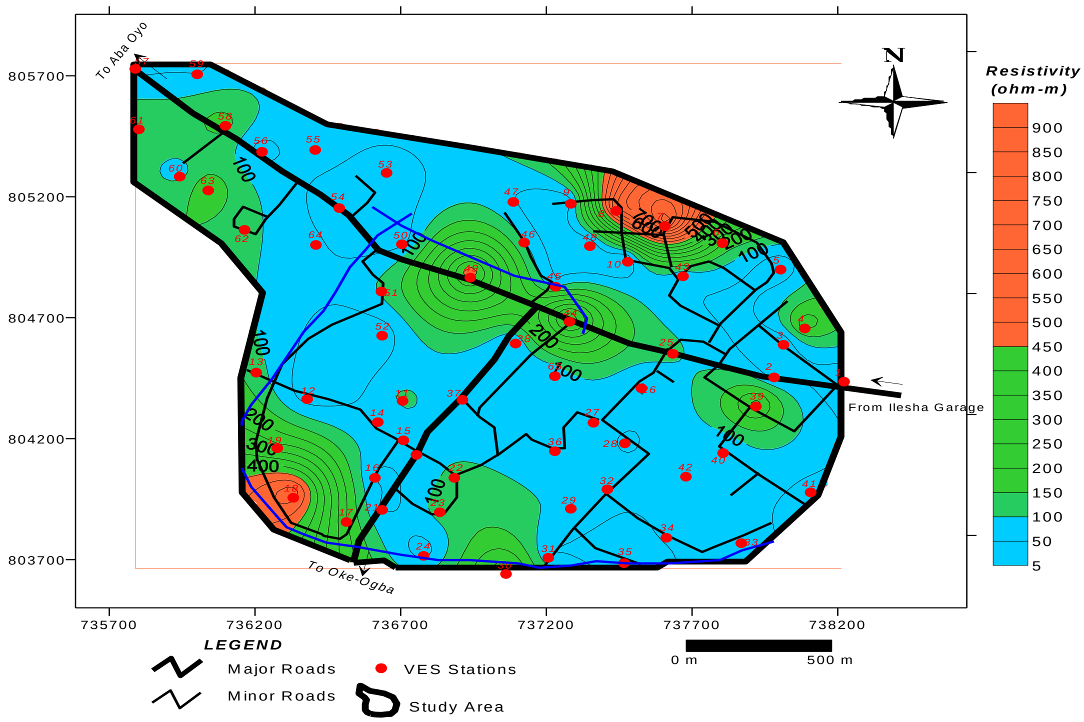

Figure 8: Isoresistivity Map of the Weathered Layer.

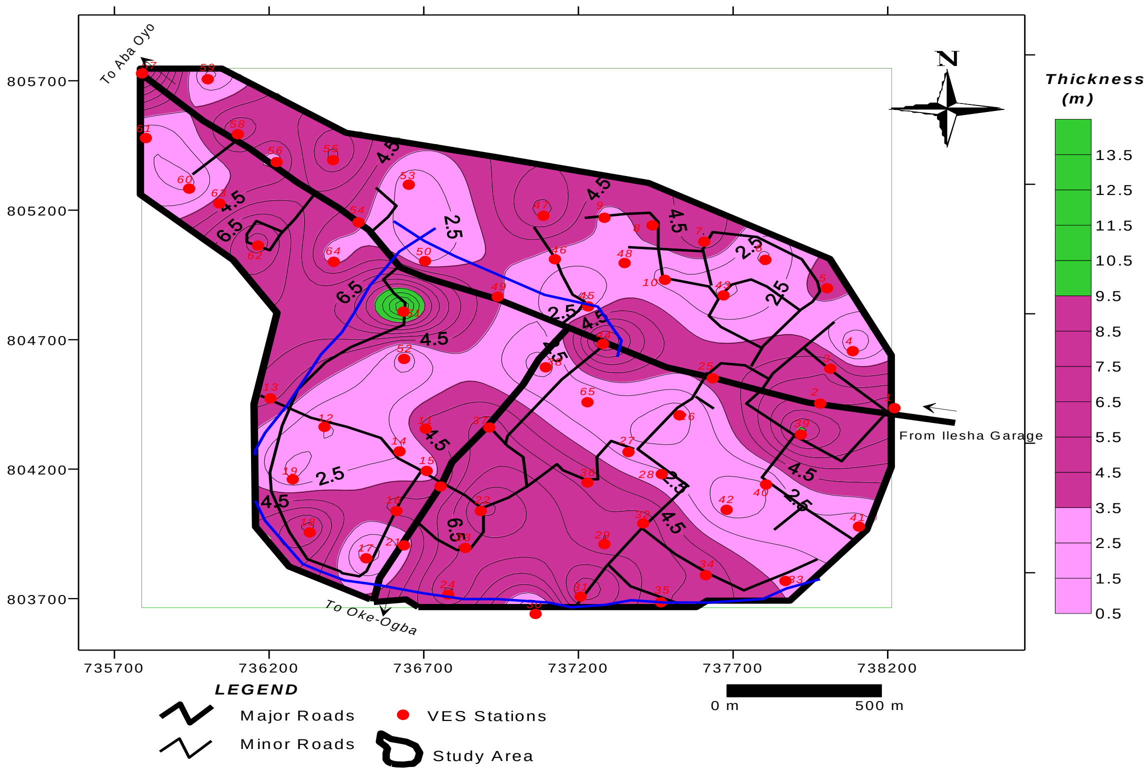

Figure 9: Isopach Map of the Weathered Layer.

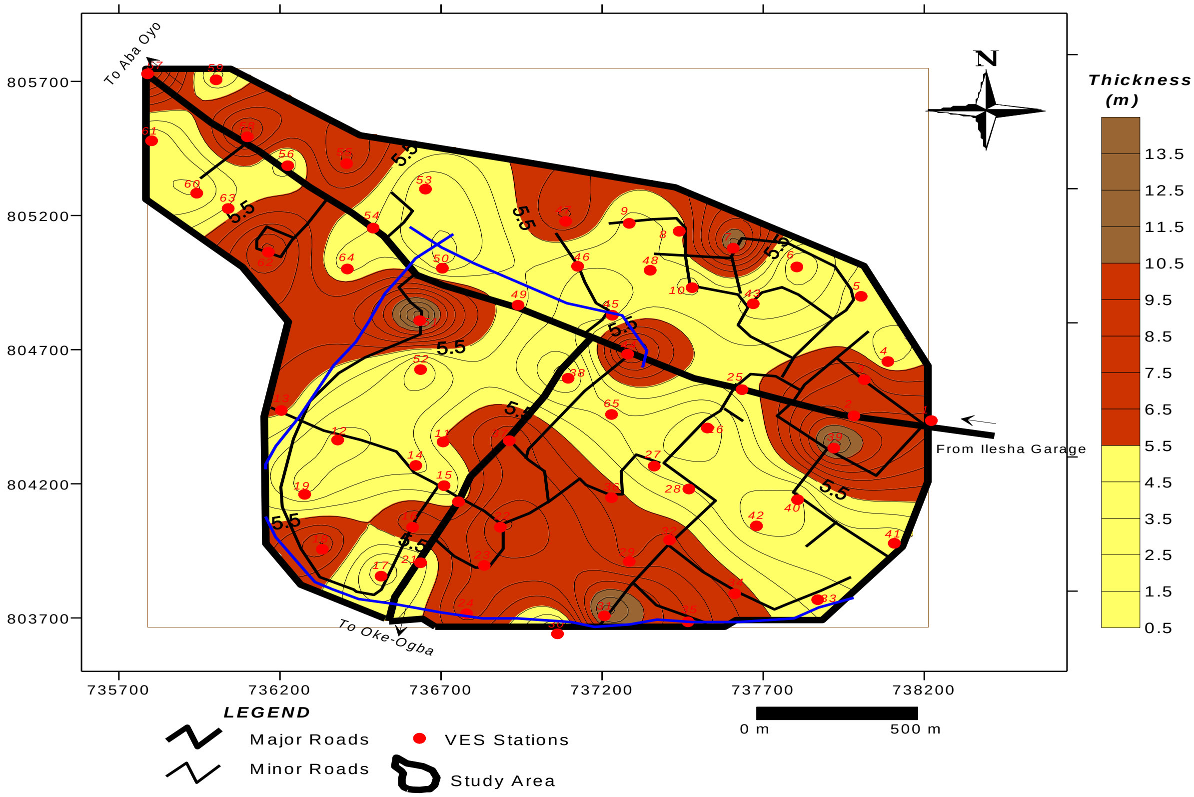

Figure 10: Isopach Map of the Overburden.

Isopach Map of the Overburden

Figure 10 reveals the depth to the top of the fresh bedrock beneath the sounding stations. The overburden is assumed to include the topsoil and the weathered Basement. The depth to the bedrock varies from 0.5 to 15 m. The overburden in the area is generally thin (< 10m). This shows that the Basement rocks are very close to the surface. There is moderately thick overburden at portion with brown color, which is less than 2% of the study area. Generally, areas with thick overburden and low percentage of clay in which intergranular flow is dominant are known to have high groundwater potential particularly in Basement complex terrain (Okhue and Olorunfemi, 1991); but the overburden in the study area are generally thin (Figure 10) and of high percentage of clay, hence the study area is of low groundwater potential.

Bedrock Relief Maps

The 2-D and 3-D bedrock relief maps of the study area are shown in Figure 11. It shows range in relief from 285-390 m. The uneven nature of the bedrock was revealed by the relief maps with series of ridges and depressions. The areas with low relief (depression) are areas favorable for groundwater accumulation, which acted as water converging zones. The areas with high relief (ridges) acted as water divergence zone. Hand dug wells and shallow boreholes for groundwater development in the area may be concentrated at the low bedrock relief (depression) zones.

The 2-D Bedrock relief map (Figure 11) depicts the water flow direction as observed in the study area. It shows that groundwater flows from high relief (ridges) areas to low relief areas (depression).

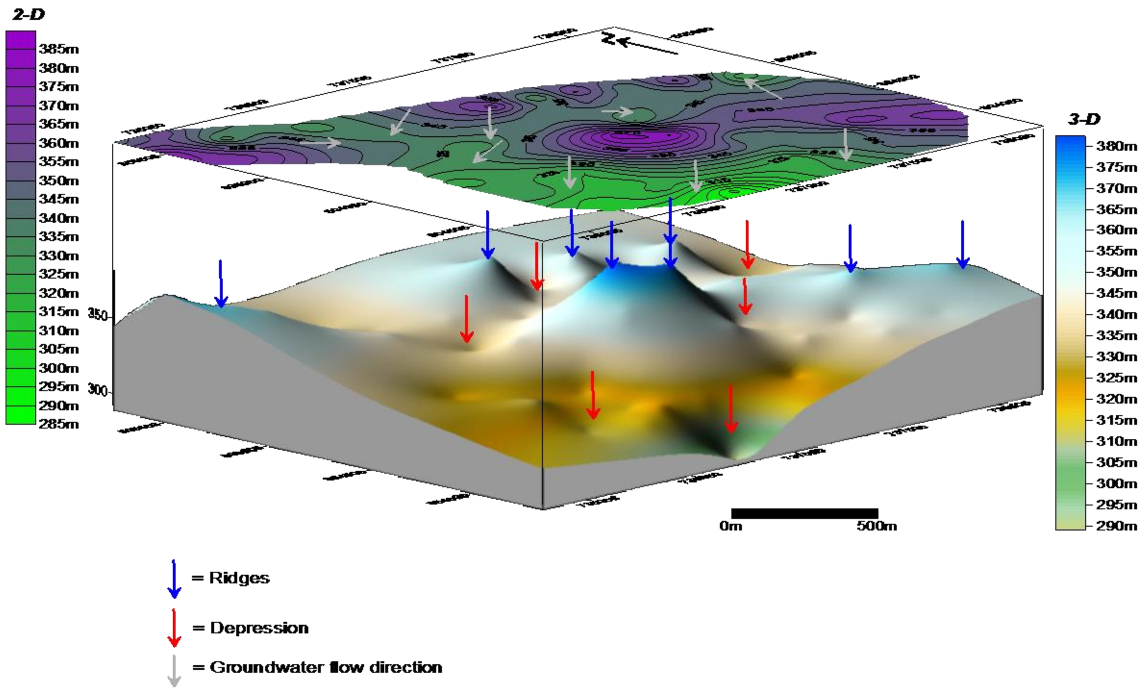

Figure 11: 2D and 3D Bedrock Relief Map of the Study Area.

Groundwater Potential Evaluation of the Study Area

It reveals the groundwater potential map of Aule and Ilupeju area of Akure. The observed thickness of the aquifer (weathered layer and/or fractured Basement) is an important parameter in the groundwater potential zoning of Basement complex terrain (Bala and Ike, 2001). The horizon (weathered layer and/or fractured Basement) is also regarded as a significant water bearing layer (Shemang, 1993; Bala and Ike, 2001) especially if significantly thick and the resistivity parameters suggest saturated conditions. Based on this, the groundwater potential of the study area was zoned into medium and low potentials (Figure 12).

In this study, zones where thickness of the weathered layer and/or fractured Basement which constitutes the major aquifer ranges from 10 to 26 m are classified as medium groundwater potential and could be seen at the northeastern, northwestern, southern parts and southwestern parts of the study area. The area where the aquifer thickness is less than 10 m are considered as low groundwater potential zones as observed generally across the study area. The groundwater potential map (Figure 12) reveals that about 95% of the study area falls within the low groundwater potential rating due to their thin aquifer while about 5% constitutes the medium groundwater potential rating. Therefore, the groundwater potential of the area is generally rated low.

Aquifer Protective Capacity Evaluation

The longitudinal conductance map generated in the study area is shown in Figure 13. The map was used for the overburden protective capacity rating of the study area. The longitudinal conductance values obtained from the study area ranges from 0.01 to 0.53mhos but generally less than 0.2mhos. The protective capacity of an overburden could be considered proportional to the longitudinal conductance (Oladapo and Akintorinwa, 2007). Clayey overburden, which is characterized by relatively high longitudinal conductance, offers protection to the underlying aquifer. According to Oladapo and Akintorinwa (2007), Table 1 shows that the protective capacity of the overburden could be zoned into good, moderate and weak protective capacity.

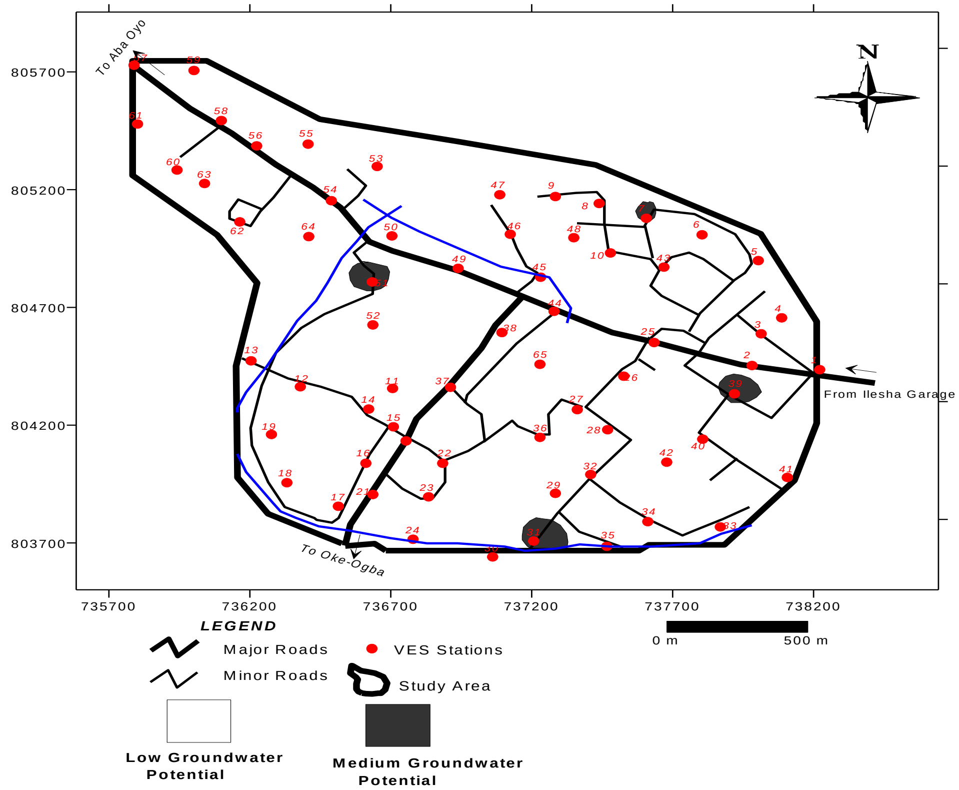

Figure 12: Groundwater Potential Map of the Study Area.

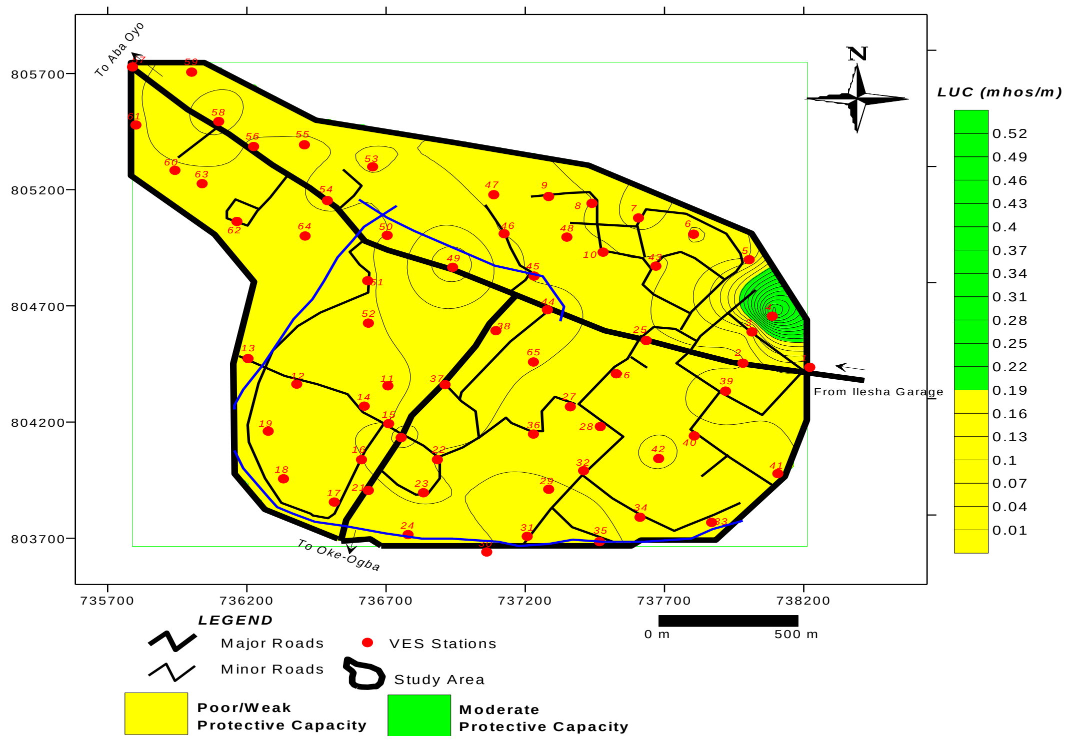

Figure 13: Overburden Protective Capacity Map of the Study Area.

Table 1: Modified Longitudinal Conductance/Protective Capacity Rating (After Oladapo and Akintorinwa, 2007).

Longitudinal Conductance (mhos)	Protective capacity rating
>10	Excellent
5-10	Very good
0.7-4.9	Good
0.2-0.69	Moderate
0.1-0.19	Weak
<0.1	Poor

Zones where the conductance is greater than 0.2 mhos are considered zones of moderate protective capacity (Figure 13). The portion having conductance value less than 0.2 mhos was classified as zone of weak/poor protective capacity. The overburden protective capacity map of the study area shows that about 78% of the area falls within the poor/weak protective capacity rating, while the remaining 5% constitutes the moderate protective capacity rating. This suggests that the area is characterized by low longitudinal conductance which inferred weak / poor protective capacity rating of the area. Therefore the study area is vulnerable to pollution from contaminant sources such as industrial waste, septic tanks, and underground petroleum storage tanks when located close to the study area.

CONCLUSION

Geophysical investigation have been used to evaluate the groundwater potential in Aule Area, Akure, South-Western, Nigeria. A total of sixty five (65) Vertical Electrical Sounding data were acquired. Eight curve types were identified in the study area. The curve types varies from simple three-layer A and H-type to the more complex HA, KH, QH, HKH, KHA and HKHKH. The predominant curve type is H-type and the HKHKH-type having the lowest. Three to four subsurface layers were delineated within the study area which are the topsoil, weathered layer, weathered/fracture layer and the Fresh Basement.

The weathered layer/fractured Basement constitute the major aquifer unit in the area, this layer is relatively thin and composed predominantly clayey formation, hence of low groundwater yield. About 95% of the area is of low groundwater rating, hence the area is rated as low groundwater potential. The overburden protective capacity is majorly poor/weak in most part of the study area except for small portions of moderate to good protective capacity in the northwest, south and eastern end of the area.

The bedrock relief of the area shows that groundwater flows from a region of high relief (ridges) to low relief (depressions). It could therefore be concluded that the groundwater in the study area is of low groundwater potential rating with poor/weak protective capacity.

REFERENCES

1. Abiola, O., P.A. Enikanselu, and M.I. Oladapo. 2009. “Groundwater Potential and Aquifer Protective Capacity of Overburden Units in Ado-Ekiti, Southwestern, Nigeria”. *International Journal of Physical Sciences*. 4(3):120-132.

2. Akintorinwa, O.J. 2009. “Geophysical and Geotechnical Investigations of the Failed Segments of Ilesa - Akure Highway, Southwestern Nigeria”. Unpublished Ph.D. Thesis, Federal University of Technology: Akure, Nigeria. 329p.

3. Akintorinwa, O.J. and T.S. Olowolafe. 2013. “Geoelectric Evaluation of Groundwater Prospect within Zion Estate, Akure, Southwest, Nigeria”. *International Journal of Water Resources and Environmental Engineering*. 5(1):12-28.

4. Bala, A.E. and E.C. Ike. 2001. “The Aquifer of the Crystalline Basement Rocks In Gusau Area, Northwestern Nigeria”. *Journal Mineral Geology*. 37(2):177-184.

5. Okhue, E.T. and M.O. Olorunfemi. 1991. “Electrical Resistivity Investigation of a Typical Basement Complex area- the Obafemi Awolowo University Campus Case Study”. *Journal Mineral Geology*. 27(2):66-70.

6. Oladapo, M.I. and O.J. Akintorinwa. 2007. “Hydrogeophysical Study of Ogbese Southwestern”. *Nigeria. Global J. Pure and Applied Sci.* 13(1):55-61.

7. Olayinka, A.I. and M.O. Olorunfemi. 1992. “Determination of Geoelectric Characteristic in Okene Area and Implication for Borehole Drilling”. *Jour. Min and Geol*. 28(2):403-412.

8. Omosuyi, G.O. , J.S. Ojo, and P.A. Enikanselu. 2003. “Geophysical Investigation for Groundwater around Obanla-Obakekere in Akure Area within the Basement Complex of Southwestern Nigeria”. *Journ. Geol*. 39(2):109-116.

9. Owoyemi, F.B. 1996. “A Geological-Geophysical Investigation of Rai-Induced Erosional Features in Akure Metropolis”. Unpublished M.Tech Thesis. Federal University of Technology: Akure, Nigeria, 11-18.

10. Shemang, E.N. 1993. “Groundwater Potentials of Kubami River Basin, Zaria, Nigeria, from D.C. Resistivity Study”. *Water Resources* .(1 and 2): 36-41.

11. Velpen, V. 2004. “WinResist Version 1.0 Resistivity Depth Sounding Interpretation Software”. M.Sc. Research Project, ITC, Delft Netherland.

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