Journal of the Nigerian Association of Mathematical Physics
Volume32,(*November, 2015*), pp 365 – 372
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Geo-electrical Exploration for Groundwater in Ajelanwa, Owa Otunand Ogga Communities in the Middle-Belt Region of Nigeria

A.K. Olawuyi

Department of Geophysics, University of Ilorin, Nigeria.

Abstract

Schlumberger Vertical Electrical Soundings (VES)for groundwater explorationinAjelanwa and Owa Otun Communitiesin Kwara State and Ogga in Kogi State,in the Basement Complex terrain ofthe Middle-Belt Region of Nigeria were carried out with a view to establishingthe different subsurface geoelectric layers and the aquifer units.Data were collected from 4, 5and 5 VES stationsat Ajelanwa, Owa Otun and Ogga Communities respectively. From the quantitative interpretationsof the data collected, using the usual method of curve matching with the Orellana-Mooney Master curves and 1-D forward modelingwith WinResist 1.0 version software, up to fourlithologic units were identifiedin these Communities. These include: the topsoil, the weathered layer, the partly weathered/fractured basement and the fresh basement. The weathered layer and the partly weathered/fractured basement constitute the main aquifer units. The depth to bedrock at the chosen VES locations vary from 6 to 30 m at Ajelanwa Community while at Owa Otun and Ogga Communities, it vary from 7 to 13 m and 25 to > 60 m respectively along the chosen traverses. The geoelectrical interpretations of data obtained in these areas have permitted the delineation of some lobesor areas of low resistivity which constitute the prospective zonesfor water exploration in these areas.

Keywords: Aquifer, Basement, Lithologic unit, Geoelectric and Lobe

1.0 Introduction

The ever increasing population in the developing world, especially in the sub-Sahara Africa, coupled with increasing agricultural and industrial development warrants greater demand for essential public utilities, most especially water supply for domestic and agricultural purposes[1].Communities located on Basement Complex terrains commonly have problems of potable groundwater supply due to the crystalline nature of the underlying rocks which lack primary porosity. Groundwater storage capacity in those areas is dependent on depth of weathering and intensity of fracturing of the underlying rocks. For Basement Complex rocks to become good aquifers, they must be highly fractured and/or deeply weathered [2].

Groundwater occurrence in Basement rocks is limited to the upper weathered section and fractured portion of the underlying fresh rocks [3]. The location of potential groundwater zones in the Basement is often problematic, so to overcome these problems, many boreholes were drilled in the rural areas by the State, National and International agencies (e.g. FGN/EEC Middlebelt Programme) for groundwater exploration**.** The boreholes drilling were preceded by detailed geophysical investigations in order to evaluate the geologic and geoelectric characteristics of the aquifers.The Vertical Electric Sounding (VES) method was preferred for its simplicity, easy interpretation and rugged nature of the associated instrumentation [4].

2.0 The Study Area

The study areas include: Ajelanwa and Owa Otun Communities inKwara State and Ogga in Kogi State (Fig. 1) in the Basement Complex terrain of the Middle-Belt Region of Nigeria (Fig. 2). Ajelanwa is located beside Kulende Estate along the old Ilorin - Jebba road in Ilorin East Local Government Area of Kwara Central Senatorial District. It is bounded by the

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Corresponding author: A.K. Olawuyi, E-mail: gideonola2001@yahoo.com, Tel.: +2348052239989

Kulende Estate, Rail roadand a stream in the North, West and Southrespectively. A tarred road now passes through this community. Owa Otun community is located in Osi - Isapa area, north of the Egbe - Omuaran road, while Ogga Community is located about 23 km south of Odo-Eri community along Isanlu Makutu- Egbe road.The study locations fall within the tropical savannah climate and exhibit a well marked rainy season and a dry season. Temperatures are above 18 °C (64 °F) throughout the year and the vegetation is that of woodland and tall grass savannah.

The study locations fall within the Pre-Cambrian Basement Complex of Southwestern Nigeria which consists of migmatite, gneisses, schist and quartzite into which has been an emplacement of granitic, and to a lesser extent, more basic materials [5]. The major fracture zones in Ajelanwa are Northeast- Southwest trending which coincide with the river channels while the dominant rock types in Ogga are the quartzite/ quartz- schist.

Fig. 1: Map of Nigeria Showing the Different States and the Study Locations (Adapted from NgEx[6]).

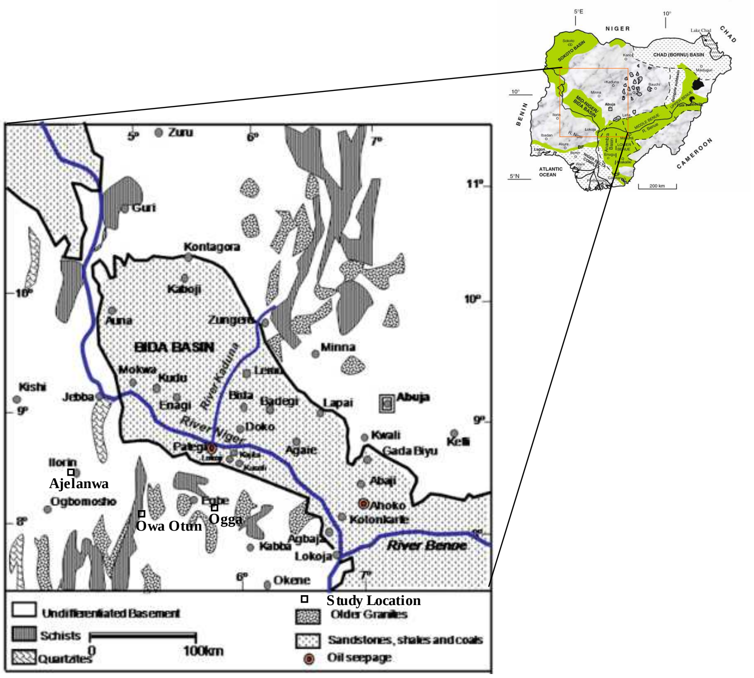


Fig. 2: Geological Map of Bida Basin and Environs Showing the Study Locations. Inset is the Geological Map of Nigeria (Adapted from Obaje et al.[7]).

3.0 Principle and Method

The Schlumberger array of the Vertical Electrical Soundings (VES) method was employed in this work with the use of PASI (E2 DIGIT) Resistivity Meter.The electrode spreading followed the description [8]where half electrode spacing (AB/2; Fig. 3) range of 1 – 100 m was used to generate maximum information about the subsurface lithology and overburden thickness. Four VES were conducted in the Ajelanwa study area (Fig.4). The profiles were chosen based on the existing wells in the area. In the case of Owa Otun and Ogga Communities (Figs. 5 and 6 respectively), five VES were conducted in each of them. In the Schlumberger array the separation between the current electrodes is kept much larger than that of the potential electrodes [9].Apparent resistivity (ℓa) for the Schlumberger array is computed from the equation (1) below [8]:

$$\ell_a = \frac{\pi L^2}{I}\frac{\Delta v}{2l} \qquad (1)$$

Where (2L) is the distance between the current electrodes (AB), (2l) is the distance between the potential electrodes (MN), $\frac{\Delta v}{2l}$*is the surface gradient of potential at the midpoint between M and N, and I is the input current.*

The current from battery was sent into the ground through the outer electrodes. The potential difference generated by this current was measured using a voltmeter. The apparent resistivity value for the electrode spacing was calculated by multiplying the resistance obtained at the point with the geometric factor.The VES curves were quantitatively interpreted by partial curve matching[9]and computer iteration techniques. The partial curve matching involved segments by segment matching of the field curves with two layers model curves and their corresponding auxiliary curves. The VES data presented as depth sounding curves were inverted with the Computer aided iteration curve matching techniques using WinResist Version 1.0 [10]. Typical sounding curves are shown in Figs.7 - 9.Fig. 7 is the QH type curve, Fig. 8 is the A type curve while Fig. 9 is the HKH type curve. The geoelectric layers for the sounding curves vary from three to four in the three locations. The results obtained from the VES interpretation was employed in the production of thefield and theoretical data pseudosections as well as the 2-D resistivity structure along traverse 1 at Owa Otun study area (Fig. 10).

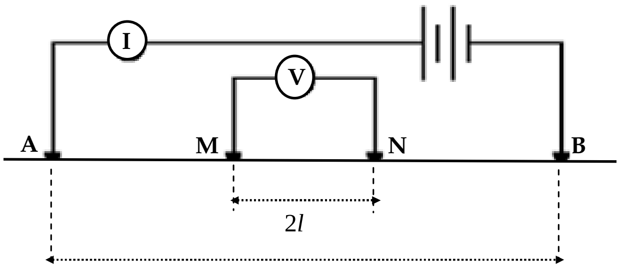


Fig. 3: Diagram of VES Schlumberger Configuration

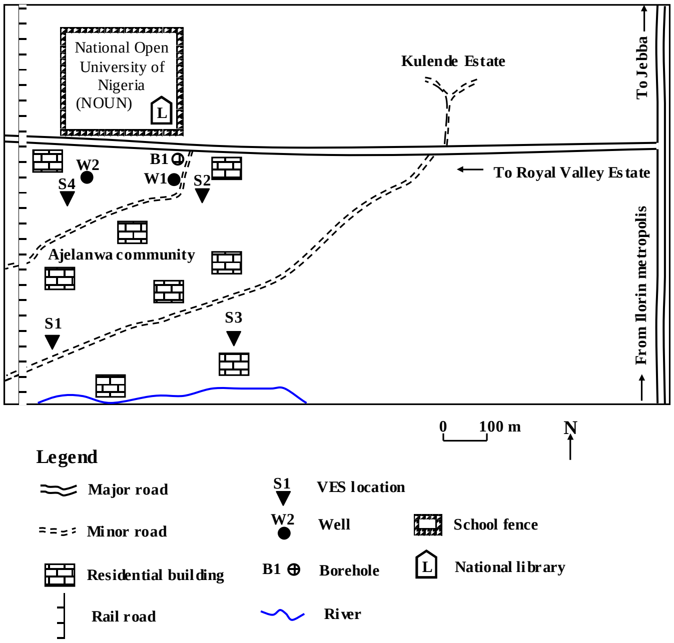


Fig. 4: A Sketch Map of Ajelanwa Communityand Environs Showing the VES Sites

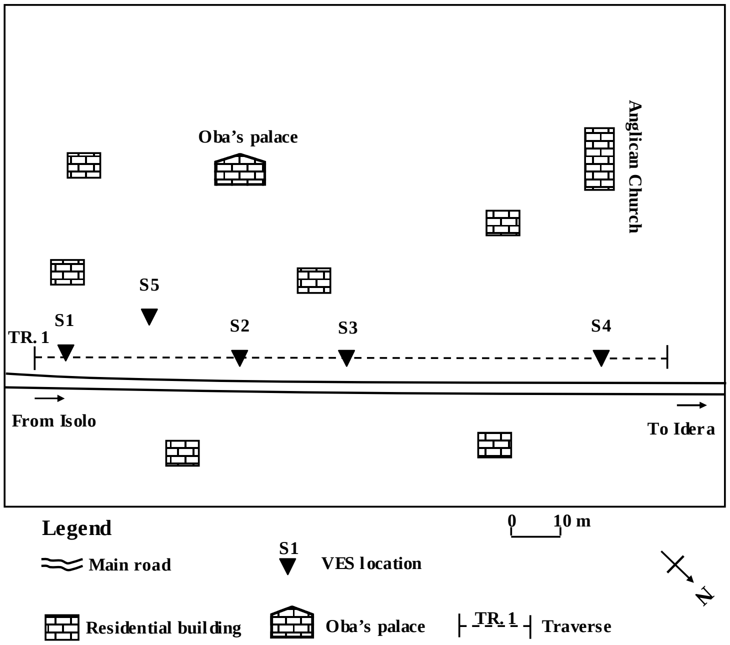


Fig. 5: A Sketch Map of Owa Otun Community Showing the VES Sites

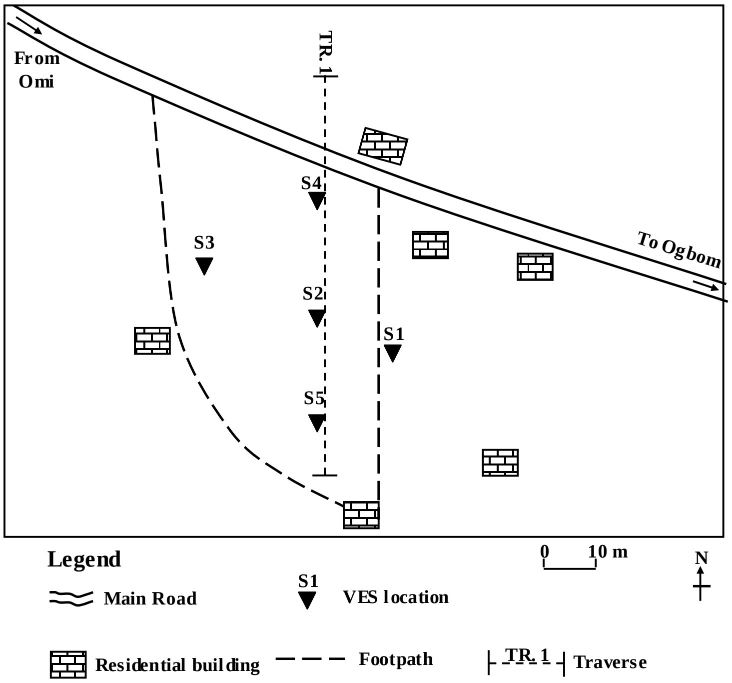
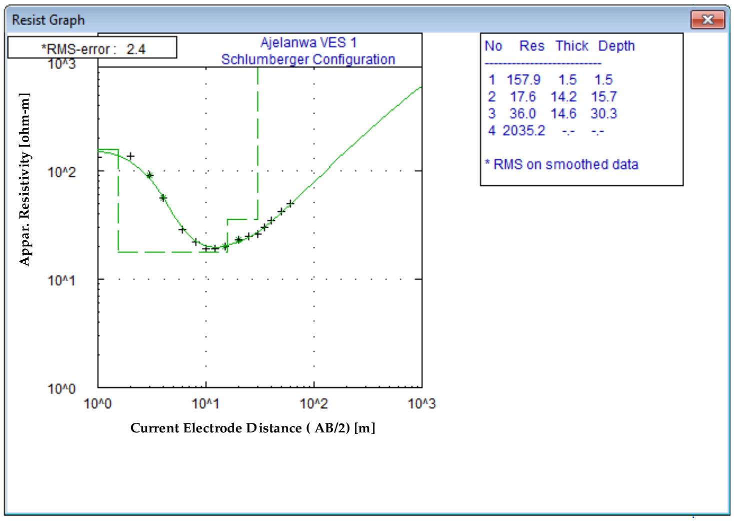


Fig. 6: A Sketch Map of Ogga Community Showing the VES Sites



*RMS-error : 2.4

Ajelanwa VES 1
Schlumberger Configuration

```
No   Res  Thick  Depth
-------------------------
 1  157.9   1.5   1.5
 2   17.6  14.2  15.7
 3   36.0  14.6  30.3
 4 2035.2   -.-   -.-

* RMS on smoothed data
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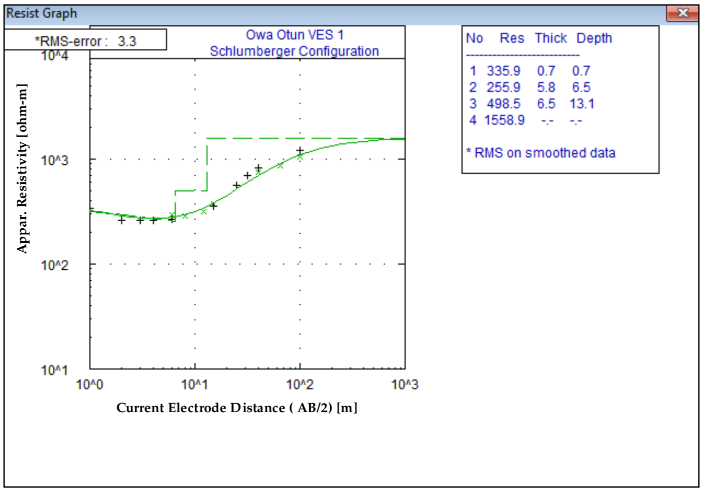
Fig. 7: Typical VES Curves Obtained at Ajelanwa Study Area



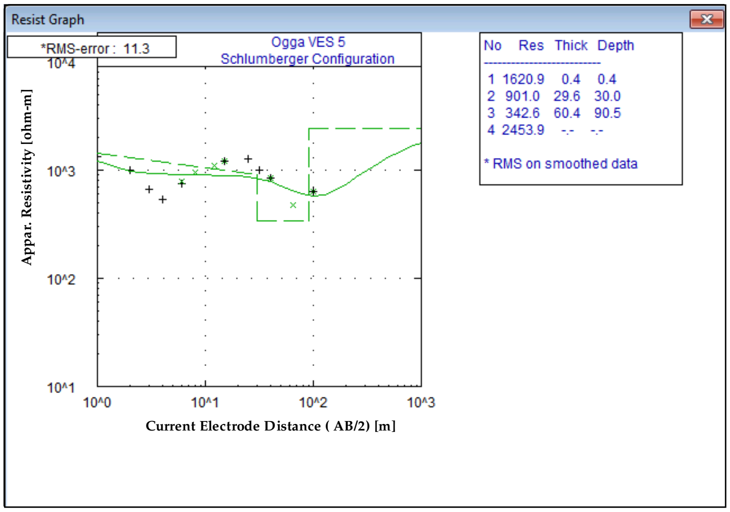
*RMS-error : 3.3

Owa Otun VES 1
Schlumberger Configuration

```
No   Res  Thick  Depth
-------------------------
1  335.9   0.7   0.7
2  255.9   5.8   6.5
3  498.5   6.5  13.1
4 1558.9   -.-   -.-

* RMS on smoothed data
```

Fig. 8: Typical VES Curves Obtained at Owa Otun Study Area



*RMS-error : 11.3

Ogga VES 5
Schlumberger Configuration

```
No   Res  Thick  Depth
-------------------------
 1 1620.9   0.4   0.4
 2  901.0  29.6  30.0
 3  342.6  60.4  90.5
 4 2453.9   -.-   -.-

* RMS on smoothed data
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Fig. 9: Typical VES Curves Obtained at Ogga Study Area

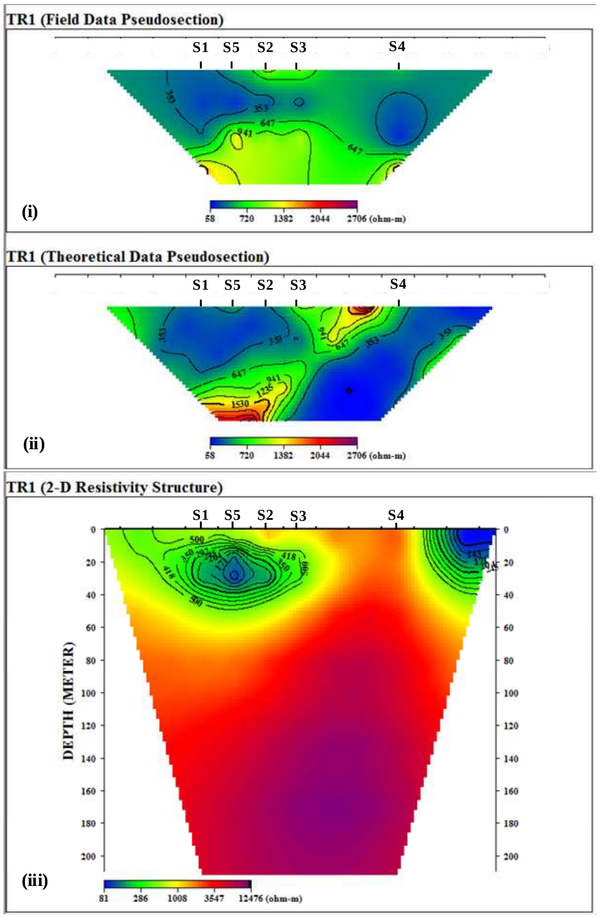

Fig. 10: (i) Field Data Pseudosection(ii) Theoretical Data Pseudosection and (iii) 2-D Resistivity Structure Along Traverse 1 at Owa Otun.

3.0 Results and Discussions

3.1 The VES Curves

The typical VES curves and interpreted geoelectric models are displayed in Figures 7 - 9.The VES interpretation results at Ajelanwa (Fig. 7), indicated fourmajor geologic units: the top soil, the weathered layer, the partly weathered/fractured basement and the highly resistive bedrock.The topsoil is composed of silt, clayey sand and sand with thickness ranging between 1.6 and 11m and resistivity ranging from 40 to 130 Ω-m; the weathered layer is made up of sandy clay/clayey sand with thickness of approx. 15 m while resistivity ranged from 18 to 50 Ω-m; the partly weathered/ fractured basement has a thickness of 15 - 25 m and resistivity of 18 - 20 Ω-m while the fresh basement or bedrock had resistivity ranging from 2000 Ω-m and above. The weathered layer and the partly weathered/fractured basement constitute the main aquifer units and the groundwater potential at VES 1 in the Ajelanwa Community is high.

The VES interpretation resultsat Owa Otun(Fig. 8), indicated four major geologic units: the top soil, the weathered layer, the partly weathered/fractured basement and the highly resistive bedrock.The topsoil is composed of clayey sand and sand, its thickness ranged between 0.5 and 0.8 m while resistivity ranged from 375 to 1,110 Ω-m;the weathered layer is made up of sandy clay/clayey sand, its thickness ranged between 2.3 and 9.9 m while resistivity ranged from 144 to 300 Ω-m; the partly weathered/ fractured basement has a thickness of 8.5 m and resistivity of 345 Ω-m while the fresh basement or bedrock had resistivity ranging from 1120 Ω-m and above. The weathered layer and the partly weathered/fractured basementconstitutethe main aquifer units, however, the partly weathered/ fractured basement is localized beneath VES 1 only and the groundwater potential at this location in Owa Otun Community is low.

The VES interpretation results at Ogga(Fig. 9),indicated four major geologic units: the top soil, the weathered layer, the partly weathered/fractured basement and the highly resistive bedrock. The topsoil is composed of clayey sand, its thickness ranged between 0.6 and 1.1 m while resistivity ranged from 320 to 970 Ω-m; the weathered layer is made up of clay/sandy clay and clayey sand with thickness ranging between 0.9 and 6.2 m while resistivity ranged from 98 to 330 Ω-m; the partly weathered/ fractured basement has thickness ranging from 15.1 to 42.8 m and resistivity ranging from 76 -274 Ω-m while the fresh basement or bedrock had resistivity ranging from 2750 Ω-m and above. The weathered layer and the partly weathered/fractured basement constitute the main aquifer units. The weathered layer is thin and clayey with low permeability but the partly weathered/fractured basement is relatively thick and extensive with high permeability due to high secondary porosity. The groundwater potential at VES 5 in the Ogga Community is of medium level rating.

3.2 The Pseudosections

The pseudosections presented as field and theoretical data pseudosections as well as the 2-D resistivity structure along traverse 1 at Owa Otun study area (Fig. 10) delineated some areas and zones with different resistivities reflecting some subsurface geoelectric characteristics. The areas and zones with low resistivity (e.g. < 300 Ω-m), especially where there are closures are more likely to have highest groundwater potential if the low resistivity is not caused by the presence of excessive clay. These areas are associated with weathered or fractured basement mainly. The zone containing the lobe of low resistivity below VES 1 (Fig. 10) will definitely be a better zone for water prospecting in the area because all the information obtained there show that the lobe constitutes the best prospective area for water exploration.On the other hand, theareas and zones with high resistivity (e.g. > 1000 Ω-m) could be showing un-weathered or un-fractured or fresh basement/ bedrock.

4.0 Conclusions

Geophysical investigation for groundwater exploration in Ajelanwa and Owa Otun Communities in Kwara State and Ogga in Kogi State, in the Basement Complex terrain of the Middle-Belt Region of Nigeria has revealed four major lithologic units. These include: the topsoil, the weathered layer, the partly weathered/fractured basement and the fresh basement.The weathered layer and the partly weathered/fractured basement constitute the main aquifer units.At Ajelanwa, the depth to fresh basement at the VES locationsvary from 6 to 30 mwhile at Owa Otun and Ogga Communities, it vary from 7 to 13 m and 25 to > 60 m respectively along the traverses.

The geoelectric interpretations of the electrical resistivity data obtained in the study areas haveelicitedlobesor areas of low resistivitywhich constitute the prospective zones or areasfor water exploration (e.g. Fig. 10). Basement depression zones which correspond to area with relatively thick overburdenmaterials are priority zones for possible groundwater development most especially when the clay content is low.The study areas have been delineated into prospective high and low groundwater potential zones based on geoelectric characteristics.

5.0 Acknowledgement

The author gracefully acknowledge the contributions of the Lower Niger River Basin Development Authority (LNRBDA) for making available the VES data on Ajelanwa and Owa Otun Communities in Kwara State and Ogga Community in Kogi State of Nigeria.

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