# Combined Use of Electromagnetic and Magnetic Survey for Hydrogeophysical Characterization of Ijapo Housing Estate, Akure.

**Ogungbemi O.S.[1*], Oladapo M.I.[2]**

[1*]*Department of Chemical/Petroleum Engineering, AfeBabalola University, Ado Ekiti.*
[2]*Department of Applied Geophysics, Federal University of Technology, Akure.*

## ABSTRACT

Very Low Frequency Electromagnetic (VLF-EM) and ground magnetic studies were carried out in Ijapo Housing Estate, Akure, with the aim of delineating hydrogeologic associated structures. The area is underlain by the precambrian basement complex rocks of southwestern Nigeria. VLF-EM profiling was undertaken along 19 traverses with lengths ranging from 180 to 1,200 m.Ground magnetic data were acquired along 35 traverses with lengths varying between 120 and 1,060 m. VLF-EM data wereplotted as profiles and also inverted into 2D-sections usingKarous-Hjelt filtering software. Ground magnetic data were reduced and inversed using automatedeuler-deconvolution software to estimate depths to basement. VLF-EM readings vary from – 110.3 to + 99.9 % in the filtered real and imaginary components.VLF-EM depth-structure map enables the classification of the area into zones of shallow and deep fractures. Relative magnetic values vary from -1290.38 to +835.38 nT.Estimated depth to basementfrom the geomagnetic section was used to generatemagnetic depth-structure map which enabled the classification of the study area into shallow and deep fracture zones. Correlations of results show that area classified as deep structure zone from VLF-EM coincide fairly well with that of ground magnetic. This is the high groundwater potential zone. Groundwater development programmewithin crystalline basement complex should be limited to high groundwater potential zone, becauseof the localized nature of its occurrence. Therefore, detailed geophysical survey should be carried out prior to drilling.

*Keywords: Electromagnetic, magnetic, hydrogeology, structures, depths, concealed.*

## 1. INTRODUCTION

The successful exploration and exploitation of groundwater requires a proper understanding of its hydrogeological characteristics [12]. Careful studies that are supported by improved drilling techniques yield very favourable results even in the problematic areas of the basement complex [7]. Geophysical methods are important in investigating near surface formations and modeling of aquifer units for groundwater development. Notable among the methods are the electric resistivity, electromagnetic, seismic refraction and magnetic methods [3].

The aquifer in the basement terrain is not only inhomogeneous but also localized; hence the description of aquifer parameters in this geological terrain may be difficult [6]. In such terrain thorough geophysical investigations must be carried out for optimum siting of viable boreholes for groundwater development.

VLF-EM method is more relevant in the delineation of near surface fractures than in the estimation of overburden thickness, because their anomalies aremore influenced by the conductivity of the overburden (weathered layer) than the thickness [9].Research work has been previously carried out in IjapoHousing Estate Akure to establish geoeletric parameters, the groundwater potential and susceptibility to environmental pollutions [1], [8]. In both studies 30 vertical electrical soundings were carried out across the entire estate. However, in this survey the VLF-EM and ground magnetic methods were adopted.VLF-EM was adopted as a fast reconnaissance tool to map possible linear fractures such as faults and

*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

fractures zones while ground magnetic method was used to investigate prominent magnetic anomalies and provide a structural image of concealed structures.

### 1.1 Geographical and Geological settings of the Study Area

The geology of the study area can be explained within the context of the geology of the Precambrian basement complex of southwestern Nigeria which form a part of thecrystallinebasement complex of Nigeria[11] (Fig. 2).IjapoHousing Estate is situated on a gently undulating terrain with elevation between 330 and 364 m above mean sea level. The area lies in the tropical rain forest with mean annual rainfall of about 1300mm. The annual mean temperature is between 18 and 33℃. River Osisi cut across the estate at the central part and flows south into River Ala.IjapoHousing Estate as at the time of this study is the largest residential estate in OndoState. It is located northeast of Akure town within longitudes 5°12. 307' E and 5°16.552' E and latitudes 7°15.859' N and 7°16. 552' N(Fig. 1). The estate hosts some commercial centers such as petroleum products sales outlets, hotels and guesthouses and shopping mallswhich furtherheightened the demand for portable water within the estate.Residents in the estate depend largely on hand-dug wells and motorized boreholes for domestic and commercial water supply. Hence, there is need to investigate the estate in order to evolveitshydrogeologic setting.

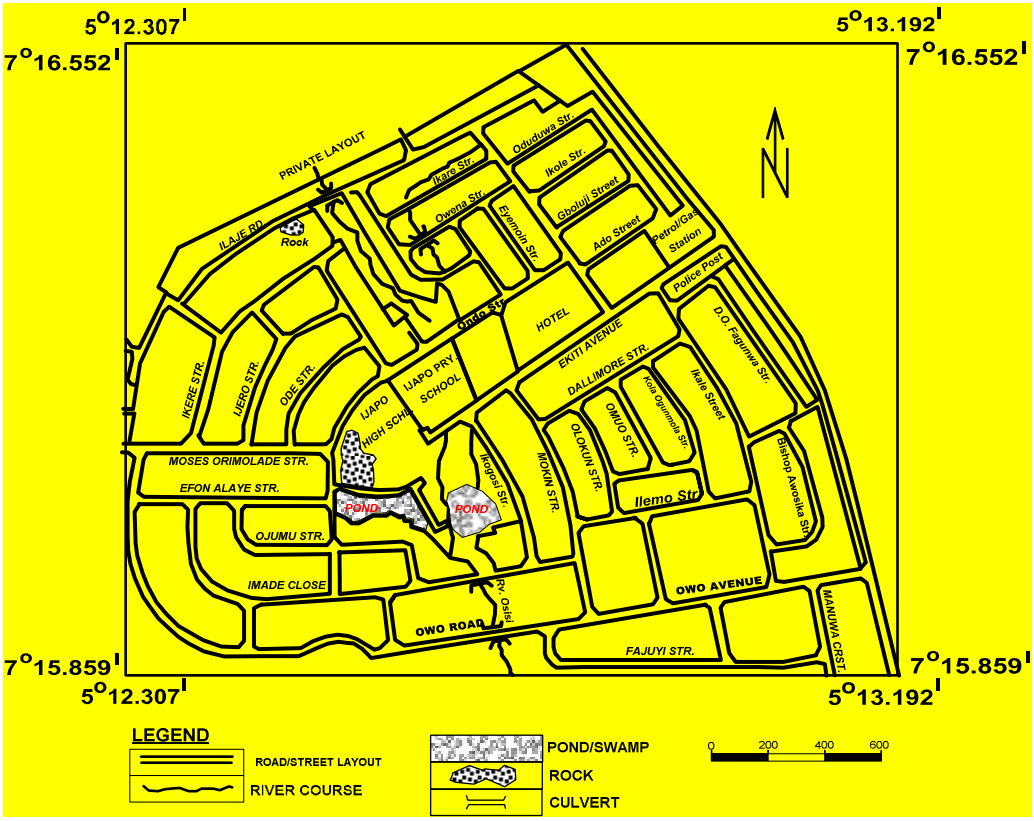


**Fig. 1**: Base map of the study area showing the street layouts.

*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

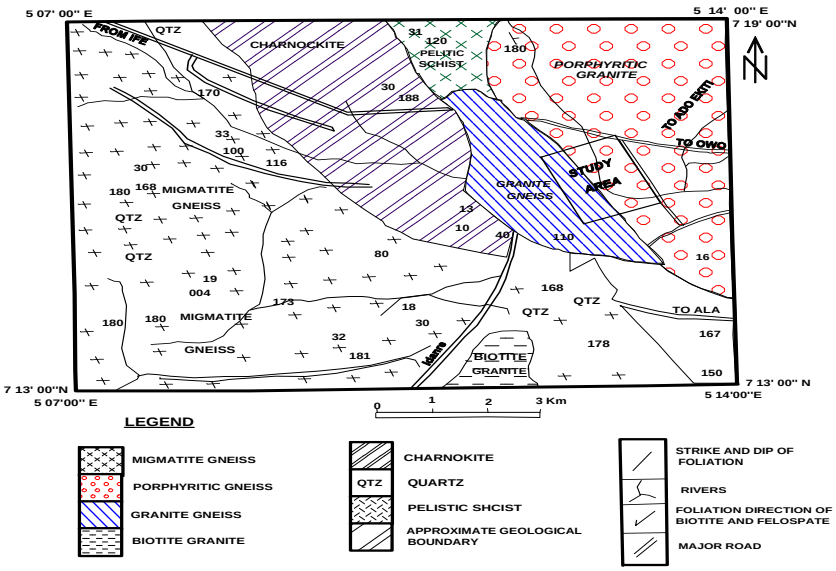


**Fig. 2**: A generalized geological map of Akure (after Owoyemi, 1996)

## 2. MATERIALS AND METHODS

VLF-EM profiling was undertaken at 25 m station interval on 19 traverses. Traverses lengths vary from 180 to 1,200 m. Ground magnetic data were acquired on 35 traverses of lengths ranging from 120 to 1,060 m at 20 m station intervals. ABEM-WADI VLF instrument was utilized for electromagnetic data acquisition while Proton Precision Magnetometer was used for the magnetic data acquisition.VLF-EM data were processed by downloading the filtered real and imaginary components from the AbemWadi VLF-EM equipment. WADI VLF-EM detects the ratio (in percentage) between the vertical and the horizontal components, which is indicative of the degree of inhomogeneity of the subsurface.This instrument measures the field strength and the phase displacement around the fracture zone. VLF-EM data was interpreted and inverted into a 2-D section using the Karous-Hjelt filtering [5]. Groundmagnetic data were drift corrected and presented as profiles of relative magnetic intensity values against distance (Figure7). Automated Euler deconvolution software was used to estimate depth to basement along the traverses.Profiles, sections and maps were generated, whichenabled the delineation of concealed geologicalstructures.Integration of results of VLF-EM and ground magnetic survey enabled the hydrogeophysical characterization of the study area.

## 3. RESULTS AND DISCUSSION

### 3.1 VLF-EM Results

Quantitative interpretation of the VLF-EM data involve the generation of VLF-EM sections which allows for estimation of fracture length within the study area.Detailed descriptions of typical profile and sections generated along a selected traverse are given below.VLF-EM profile shows positive peak filtered real values at 100 m, 400 m and 600 m and cross-over points at distance 50 m, 360 m, 700 m and 850 m which revealsconductive zones along the traverse(Fig. 3). Its corresponding 2D-section reveals conductive zones at distance ranging from 60 m to 100 m, 320 m to 400 m and 620 m to 780 m respectively. Depth to the top and bottom of the conductive/fracture zones obtained from the 2D-section is between 20 m and 75 m corresponding to fracture lengths of 45 m, 20 m to 100 m corresponding to fracture length of 80 m and also 20 m to 100 m corresponding to fracture length of 80 m respectively(Fig. 4).2D-inverse models reveal the depth to sources of anomalies which ranges between 37.5 and 100 m. Interpretation of section and profileof VLF-EMalong this traversereveal high degree of fracturingwhich is indicative of occurrence of groundwater.

*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

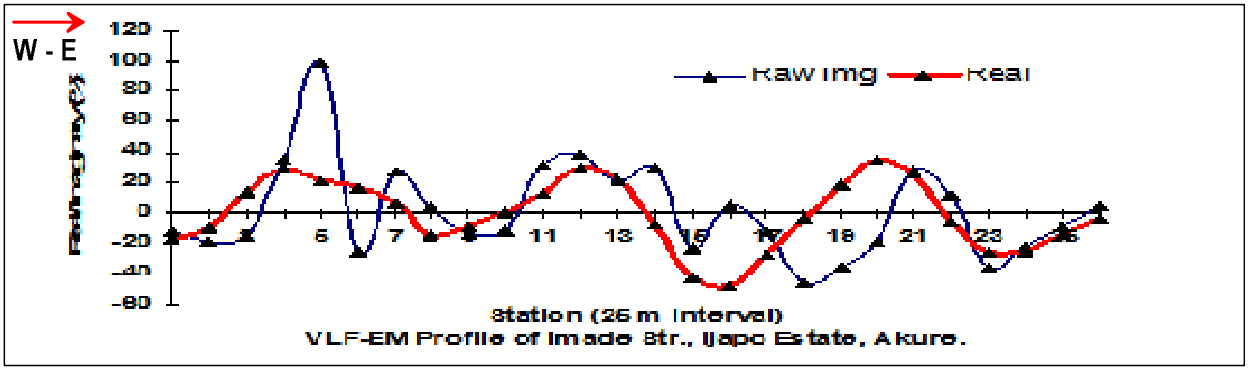


Fig. 3: VLF-EM Profile of Imade Street, Ijapo Estate, Akure.

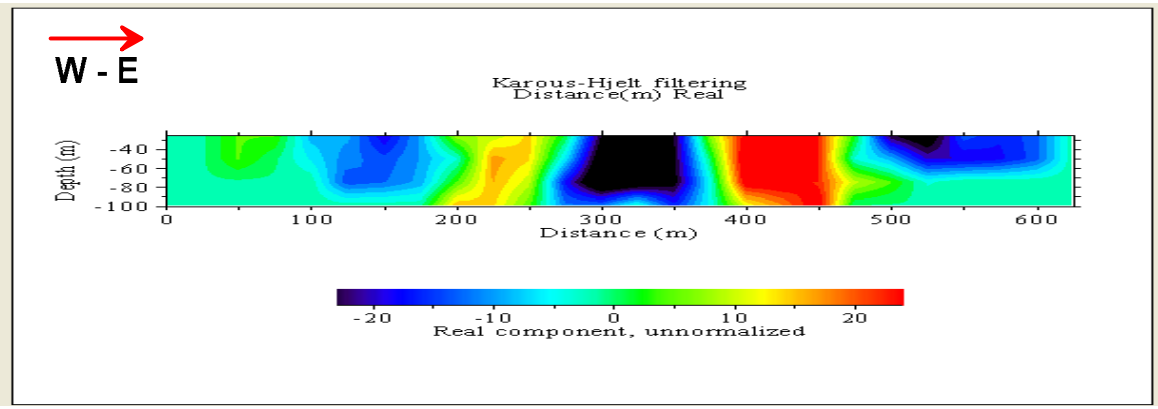


Fig. 4: 2D-inverse model of Imade Street, Ijapo Estate, Akure.

Real component readings were also plotted as a contour map of the study area (Fig. 5). The map is characterized with zone of positive and negative anomaly, the readings range between - 50 to +35 %. Zones with positive anomaly occur as patches and are more prominent around the western part, also around the central region and the northern flank. VLF-EM anomalies were delineated at twenty-nine locations within the study area.Statistics show a number offairly-conductive, conductive and highly-conductive response at different locations across the study area.This indicates that these areas have concealed geological structureswhich are suspected to be linear steeply-dipping fractures that can favourgroundwater accumulate.

*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

**Fig. 5:** Filtered real component map of the study area

VLF-EM depth-structure map was obtained by computing the depths and locations of fractures delineated by VLF-EM 2D-sections across the entire study area. This map enables the classification of the study area into two; based on the depth of the delineated fractures i.e. the shallow and the deep fractures (Fig. 6). Western and eastern flanks of the study area are classified as shallow fracture zone; it covers Ikere, Ijero and Ode Street on the western flank and Dallimore, D.O. Fagunwa and Ikale and Kola Ogunmola Streets on the eastern flank. The central part of the study areais classified as fairly deep-fracture zone; it covers Ondo Road, Mokin Street, Ilemo Street, EfonAlaye Street and Ode Street. Its northern and southern flanks are classified as deep-fracture zone. Most of the deep fractures delineated fall within the central region.

**Fig. 6:** VLF-EM depth-structure map of Ijapo Housing Estate, Akure

*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

## 3.2 GROUND MAGNETIC SURVEY RESULTS

### 3.2.1 Geomagnetic Profile and Section

Ground magnetic profile and section were produced from data acquired through the ground magnetic survey.Qualitative interpretation of ground magnetic survey reveals that varying amplitude of the anomaly signaturesand low magnetic intensity on the magnetic profilessuggest possible fracture zones. Any zone with high number of networks of fractures is believed to be zones of high groundwater potential.Quantitatively, magnetic profiles were interpreted one by one using the automated freeware euler-deconvolution techniques.

Figure 7is atypical profile and section of ground magnetic survey along Imade Street. The length oftraverse is about 1,000 m and is oriented W – E. Low magnetic intensity values were observed at distance ranging from 5 to about 100 m and then from 300 to 800 m. Magnetic intensity contrast were observed between + 29.1 and – 14.5 nTat distance between 150 and 220 m, - 25.1 and + 13.5 nT at distance ranging from 250 to 280 m and + 29.1 and – 29.1 nT at distance between 850 and 950 m respectively. These identified zones of low magnetic intensities and magnetic intensity contrast are the probable fracture zones, and aresuspected to have high groundwater potential. This geomagnetic sectiondelineatedfive probable fracture zones with estimated depth of 19 m at distance 250 m, 20 m at distance 400 m, 20 m at distance 425 m, 20 m at distance 700 m and 21 m at distance 900 m respectively. The probable fracture zones all occurred within the granite gneiss.

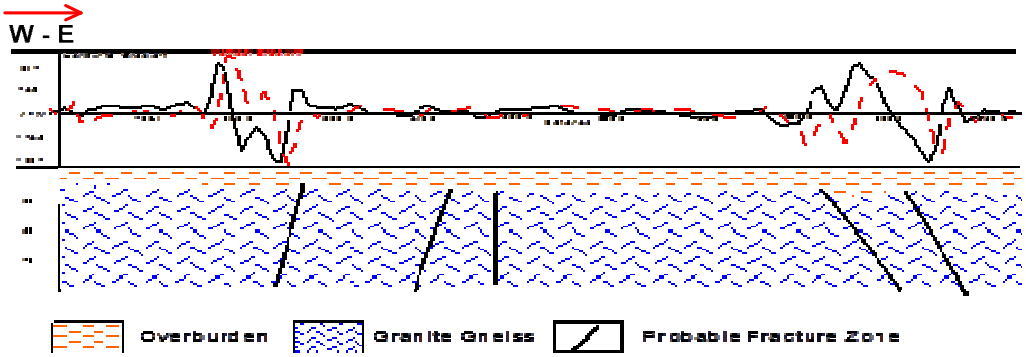


**Fig. 7:** Ground magnetic profile and section.

Magnetic depth-structure map was obtained by computing the depth and location of source of magnetic anomalies across the entire study area. Close observations of the map enable the characterization of the study area based on the depth of occurrence of the identified structures. Low magnetic intensity zones which were delineated produced a steeply dipping interface and are noted as probable fracture zones for groundwater accumulation. Zone with concealed shallow features covers a major part of the study area, underlining Ojumu Crescent, EfonAlaye Street, Akoko Avenue, D.O. Fagunwa Street, Owo Avenue, Ondo Road, Mokin Street, Henry Fajemirokun 1, Ekiti Avenue, Eyemoin Street and Olokun Street. The remaining part of the study area i.e. region around Owo Avenue, Fajuyi Crescent, Henry Fajemirokun Street 2, Ilaje Road, parts of Imade Street, Moses Orimolade Street, Ondo Road, Ode Street, Ikole Street, Dallimore Street, Ikale Street and Owena and northern part of Ondo Road are all classified as zones with deep-fractures (Fig. 8). Magnetic anomalies were delineated at one hundred and seventy-one locations from the ground magnetic profiles.The deep structures are oriented NW – SE.

*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

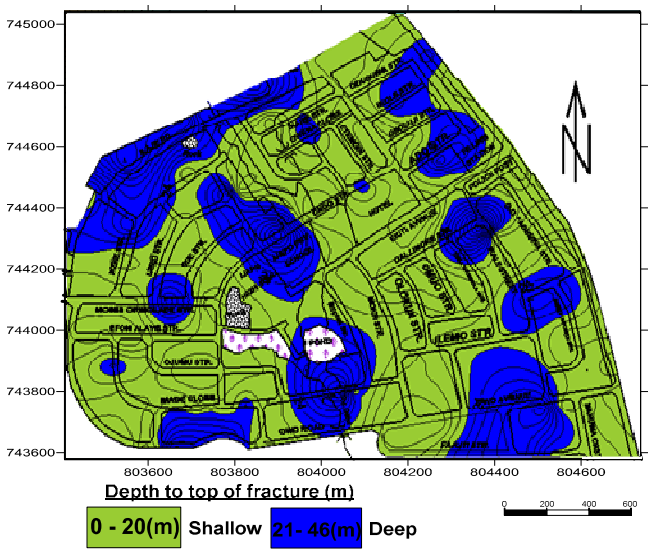


**Fig. 8:** Magnetic depth-structure map of the study area.

### 3.3. Hydrogeophysical Characterization of the study area

The integration of VLF-EM andground magneticdata(Table 1)(Fig. 9) enabled the hydrogeophysical characterization of the study area. VLF-EM depth-structure map is characterized by zones of shallow and deep-seated fractures, thus classified as the low and moderately-high water bearing potential zones. Western and the eastern flanks are marked by high altitudes which also coincide with zones of shallow fractures. Depth to top of structures within these zones is below 40 m. Shallow buried structures may be due to the presence of ridges or/and thin overburden layers which may not favour groundwater accumulation within these zones. On the other hand, the northern, southern and the central regions are characterized by low altitude and deepstructures and relatively thick overburden, thus forming the groundwater collection center within the study area.Ground magnetic depth-structure map is characterized by zones of high and low water bearing potential as a result of the deep and shallow fractures delineated within the study area (Fig. 9). Deep structures are oriented NW – SE coinciding with the trend of the water course within the study area.Shallow structures are buried within 20 m below the ground surface while structures buried within 21 – 46 m are classified as deep structures. Deep structures occur at regions with depression, thick-overburden and river course thereby forming groundwater collection centers of the study area.It is observed that delineated structuresoccurred at the basement-overburden interface. VLF-EM serves as a good reconnaissance tool for ground magnetic survey. Most of the deep structures delineated with groundmagnetic method fall within zones classified as deep-fractured from VLF-EM.

*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

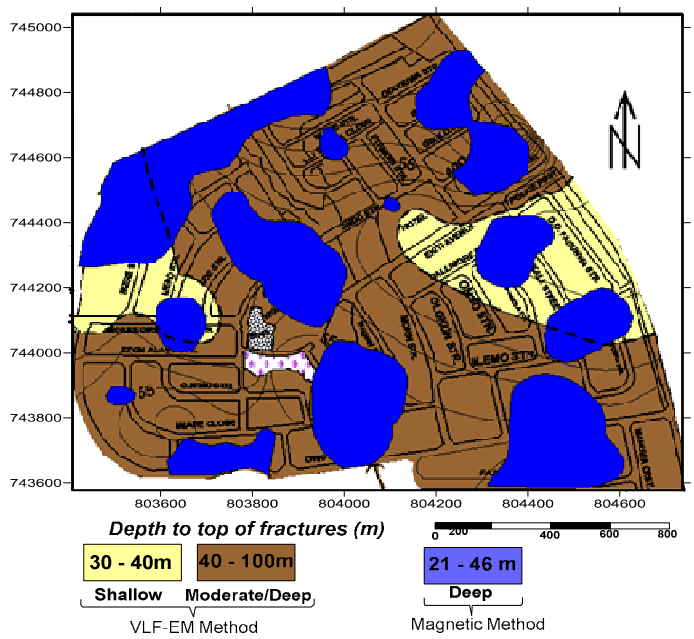


**Fig. 9:** Integrated Magnetic and Electromagnetic mapof the study area

**Table 1: Summary of integrated ground magnetic and VLF-EM results**

| Traverses | Traverse Length (m) | Traverse Orientation | Geophysical Method Adopted | Location of Fracture (m) | Depth Top of Fracture (m) | Geology of the area |
|---|---|---|---|---|---|---|
| Dallimore Street | 375 | SW – NE | Ground Magnetic | 75*<br>245<br>275<br>360 | 25<br>30<br>25<br>19 | Porphyritic Gneiss |
| | | | VLF-EM | 75*<br>275* | 25<br>25 | |
| Imade Street | 1,000 | W – E | Ground Magnetic | 250<br>400*<br>425<br>700*<br>900 | 19<br>20<br>20<br>20<br>21 | Granite Gneiss |
| | | | VLF-EM | 100<br>400*<br>700*<br>850 | 20<br>20<br>20<br>20 | |
| Fajuyi Street | 450 | W – E | Ground Magnetic | 100*<br>225<br>275<br>405* | 25<br>30<br>25<br>25 | Porphyritic Gneiss |
| | | | VLF-EM | 105*<br>300<br>420* | 25<br>25<br>25 | |
| Owo Avenue | 1,100 | W – E | Ground Magnetic | 260<br>550<br>620*<br>660<br>885<br>975 | 15<br>24<br>26<br>30<br>19<br>16 | Granite Gneiss & Porphyritic Gneiss |

*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | VLF-EM | 325<br>625*<br>875<br>1,025 | 25<br>25<br>25<br>25 | |
| Ondo Road | 900 | SW – NE | Ground Magnetic<br><br><br><br><br><br><br>VLF-EM | 50*<br>200*<br>410*<br>480<br>650<br>700<br>775<br>50*<br>200*<br>400*<br>775 | 15<br>14.5<br>41.6<br>16.7<br>23.5<br>23.5<br>16.7<br>25<br>25<br>25<br>25 | Granite Gneiss & Porphyritic Gneiss |

**Note:** ***Locations where fractures are delineated by the two methods.***

## 4. CONCLUSION AND RECOMMENDATIONS

This integrated geophysical technique has proved very successful and cost effective indelineatinghydrogeological structures suspected to be steeply dipping linear conductors that are of varying length within the study area. Profiles and sections generated revealedconductive zones within the study area.VLF-EM and ground magnetic methods give an estimate of depth to top of fractures which enable the classification of the area as shallowand deep structure zone. Integration of methods enabled the hydrogeophysical characterization of the estate.This estate is highly fractured; as observed from the results. The trends of the identified fracture zones are mostly in the NW-SE, the orientation of the structures agree with the physical trend of the river course and bedrock structures. Groundwater occurrence in this terrainis structurally controlledand highly localized. Therefore, groundwater development programme should be restricted to the high groundwater potential (deep-fractured) zone while scrupulous geophysical survey should be carried out prior to drilling.

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*Tel:+23 480 30402302 E-mail: seungbemi77@yahoo.com

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