

# Geophysical Investigation for Aquifer Potential Assessment and Groundwater Development at EKSU Staff Quarters GRA Ado Ekiti, Southwest Nigeria

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## Abstract

Very-Low Frequency Electromagnetic (VLF-EM) and Electrical resistivity methods for reconnaissance and detailed geophysical studies respectively have been carried out within the Ekiti-State University Staff Quarters at Onigari GRA area of Ado-Ekiti. The study's objectives include amongst others to detect drillable points for groundwater abstraction boreholes in order to frontally address the inherent problem of scarce water supply for uses by the university staff and their families living within the quarters. Seventeen (17) East-West traverses were established along where VLF profiling were conducted at an interval of 10m. The qualitative and quantitative interpretations of the VLF-EM data revealed twenty three (23) positions along the traverses that exhibited significant conductivities which are suggestive of thick and/or fractured overburden which are favourable structures for possible groundwater accumulation, these 23 positions were selected for further detailed investigation using the Vertical Electrical Sounding (VES) technique. The Twenty-three (23) VES stations were thereafter occupied employing the Schlumberger arrangement, with half-electrode spacing (AB/2) varying from 1-150m. The quantitative interpretation of the obtained VES data were carried out using the curve-matching and computer iteration techniques. The 3-layer (A and H); 4-layer (HK, KH, KQ and QH); 5-layer (HKH); 6-layer (AKHK and KHKH) and 7-layer (HKHKH) depth sounding curves were derived from the area. The 4-Layer type curve is predominant with 25% occurrence. The geoelectric sections mapped-out five lithologic units; including the topsoil; the weathered layer; the partly weathered/fractured basement, the fractured basement and the fresh basement. From the integrated consideration of the geoelectric parameters and inferred aquifer characteristics of the study area, it becomes clearer that the following VES positions are recommendable for the development of good yielding groundwater development schemes in order of priority, VES 20, VES 12, VES 18, VES 10, VES 8, VES 7 and VES 15.

**Keywords:** Traverses, Depth Sounding Curves, geoelectric sections, VES stations, aquifer units, boreholes

## 1.0 Introduction

The Staff quarters of Ekiti-State University located at Onigari Government Reservation Area (GRA) have suffered the problem of water scarcity for domestic needs of the residents. This was as a result of non-productive hand-dug wells, failed boreholes and erratic supply from the state government water supply agency in the town. Water is needed in the quarters and adjoining community by members of staff, drivers at the vehicle pool and the University primary school located within the premises. It was observed that most of the buildings in the quarters have erected concrete - structure overhead stands with installed tanks with which the residents purchase water supplies through tanker and trucks to take care of their needs. Since the University is not able to provide sustainable water supplies from other sources, there is need for exploitation of the groundwater resources available in the area. Virtually all the hand-dug wells within the study area are of low yield while others usually dry up during the dry seasons.

In order to address the scarcity problem, a combined geophysical investigation involving the Low Frequency Electromagnetic method (VLF-EM) and electrical resistivity methods were integrated to map the geologic structures such as faults, fractured zones, relief of bedrock and overburden thickness. The VLF-EM method serves as a means of preliminary investigation tool upon which comprehensive study can be carried out (Olorunfemi et al, 2000, Ademilua et al, 2015, Olorunfemi et al 2000).

The application of geophysics in determining productive source for groundwater abstraction has served a lot of purposes in saving time and money, guiding against earth potential problem and provision of adequate information for drillers on safest and quickest means of drilling the appropriate points. The Combined methods of VLF-EM and Electrical resistivity has proved to be a cognizable and referable geophysical investigative tool used in determining the occurrence and reliability of groundwater for the use of water mankind. Electrical geophysical method embroiders basic knowledge derived from VLF-EM results that relays the conductive zones across the study area which serves as suspected points for further detailed study. Electrical resistivity method is versatile in delineating zones of possible groundwater accumulation sources and formations that actually house the groundwater. It is relevant in depth to bedrock estimation, aquifer delineation and structural mapping (Ademilua and Eluwole, 2013, 2014).

VLF-EM and the electrical resistivity methods were used in the study area to delineate the subsurface

geoelectric parameters, identify aquifer units and map geologic structures such as faults and fractured zones, overburden thickness, basement relief e.t.c. which could give room for adequate groundwater accumulation to sustain the immediate needs of the University staff residing within the quarters.

## 2.0 Site Description And Geology

Ekiti State University staff quarters is located within the Ado-Ekiti township. Ado-Ekiti falls within latitudes 7.541 – 7.721 degree North of the equator and Longitudes 5.139 - 5.333 degree East of the Greenwich meridian (Figure 1). Ado-Ekiti, the state capital of Ekiti-State, Nigeria lies within the Precambrian Basement complex of Southwestern Nigeria (Rahaman, 1988). This zone was described to comprise Migmatite Gneiss Quartzite Complex, slightly migmatized to unmigmatized schists and metaigneous rocks; gabbroic and dioritic rocks; and the members of the older Granite suite. The Staff quarters lies within the quartzite region of Ado-Ekiti (Figure 1).

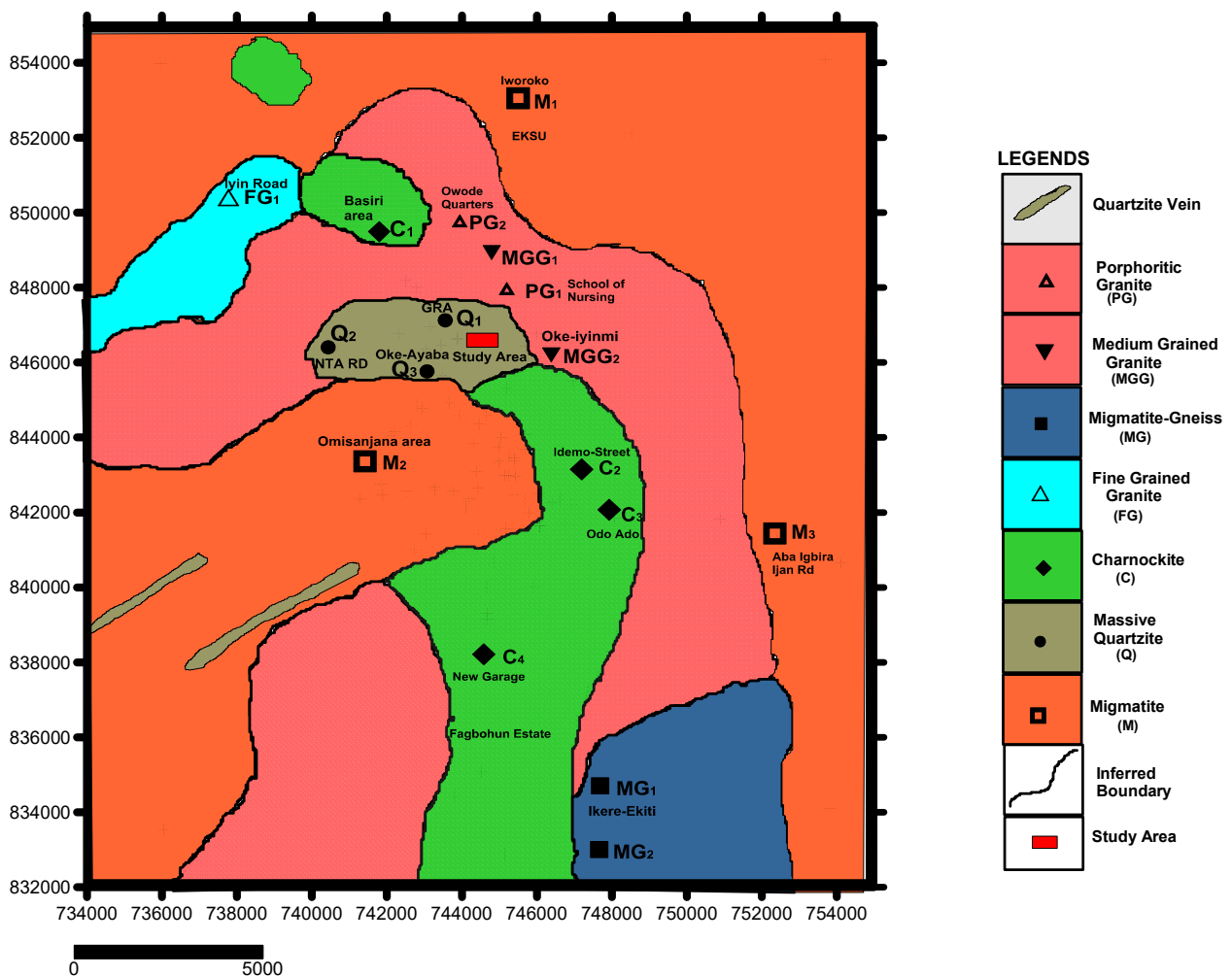


Figure 1: Geological Map of Ado-Ekiti Showing the Study Area (After .... 2012)

## 3.0 Method of Study

The study involved pre-investigation of the environment by studying the geology, topography and the conditions of the available water supply facilities like hand-dug wells within the study area. The area was considered to determine appropriate areas for establishment of traverses. A total of eighteen Traverses were arranged for the study; whereby seventeen traverses were oriented and established in west to east direction; and one was established in north to south direction (Figure 2). The length of the traverses ranged from 160m to 250m with inter-station spacing of 10m; while the inter-traverse spacing ranged from 10m to 40m.

An initial reconnaissance survey involved the use of Very Low Frequency Electromagnetic (VLF-EM) method was applied. This method was used to detect the conductive zones along each of the established traverse lines such as moderate to steeply dipping water filled fractures or fault using military radio signal in the frequency range between 15 to 30KHz range. The VLF-EM data were acquired at an interval of 10m along each

of the traverses with the aid of ABEM WADI VLF-EM instrument. The real and the imaginary components of the induced magnetic field as a ratio of vertical magnetic field to the horizontal magnetic field was measured by the instrument. The data processing involved the use of Microsoft Excel Package/ program. The processed data were interpreted both quantitatively and qualitatively. The raw-real and filtered real data were inspected by identifying point of inflexion and positive peak anomalies respectively; which are good indication for subsurface buried conductors.

Electrical Resistivity method was employed for detailed geophysical study of the area. This was carried out with the aid of SAS 1000 Omega Campus resistivity meter at points initially indicated as conductive zones by the VLF-EM method. The Vertical Electrical Sounding (VES) technique involving Schlumberger array was adopted with half current electrode spacing ( $AB/2$ ) that ranged from 1 to 150m. A total of twenty-three (23) VES stations were occupied. Analytical method of partial curve matching was used to deduce the data quantitatively after plotting the apparent resistivity against half current spacing ( $AB/2$ ) on a bi-log graph. Geoelectric parameters were produced from the curve-matching and smothered with the aid of win resist 1.0 (Vander Velpen, 1988) software.

The parameters were consequently utilized to develop geoelectric sections across the study area. Three sections (GES1,2 and 3) were taken along approximately NW-SE direction, these were followed by two sections (GES 4 and 6) which were taken along approximately N-S direction while the last one other cross-section (GES 5) was taken along approximately NE-SW direction.

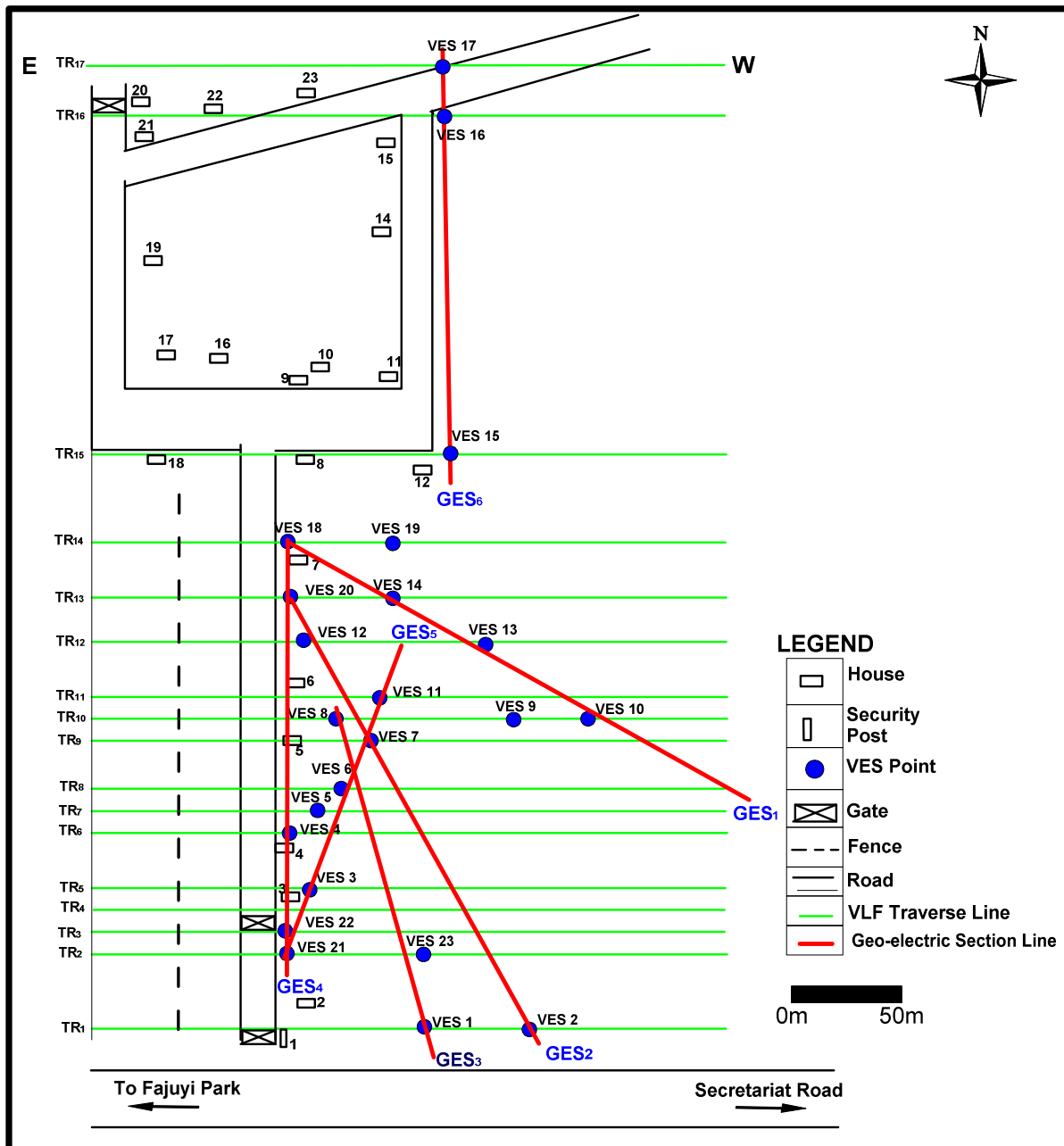
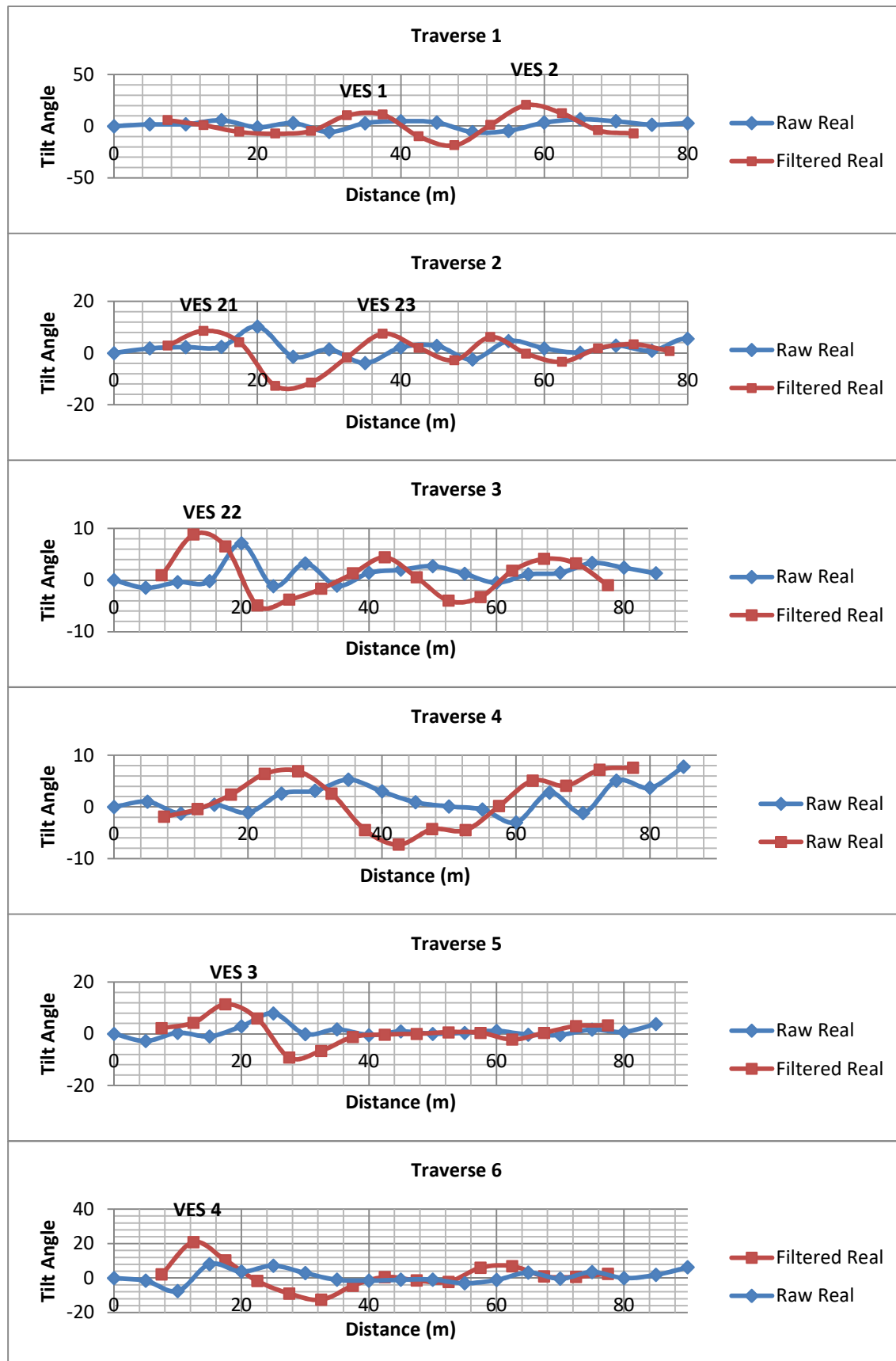


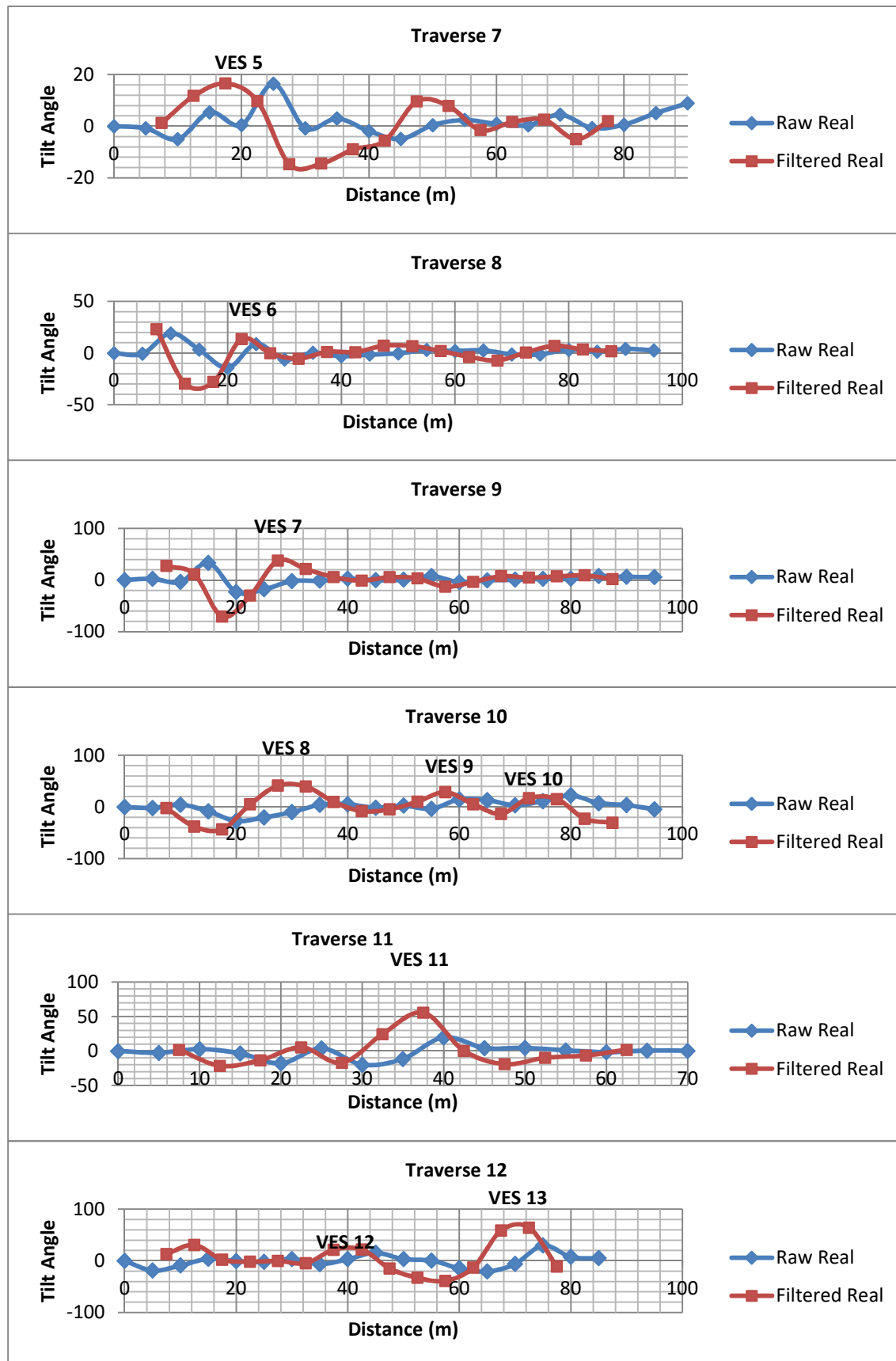
Figure 2: Data Acquisition Map of the Study Area

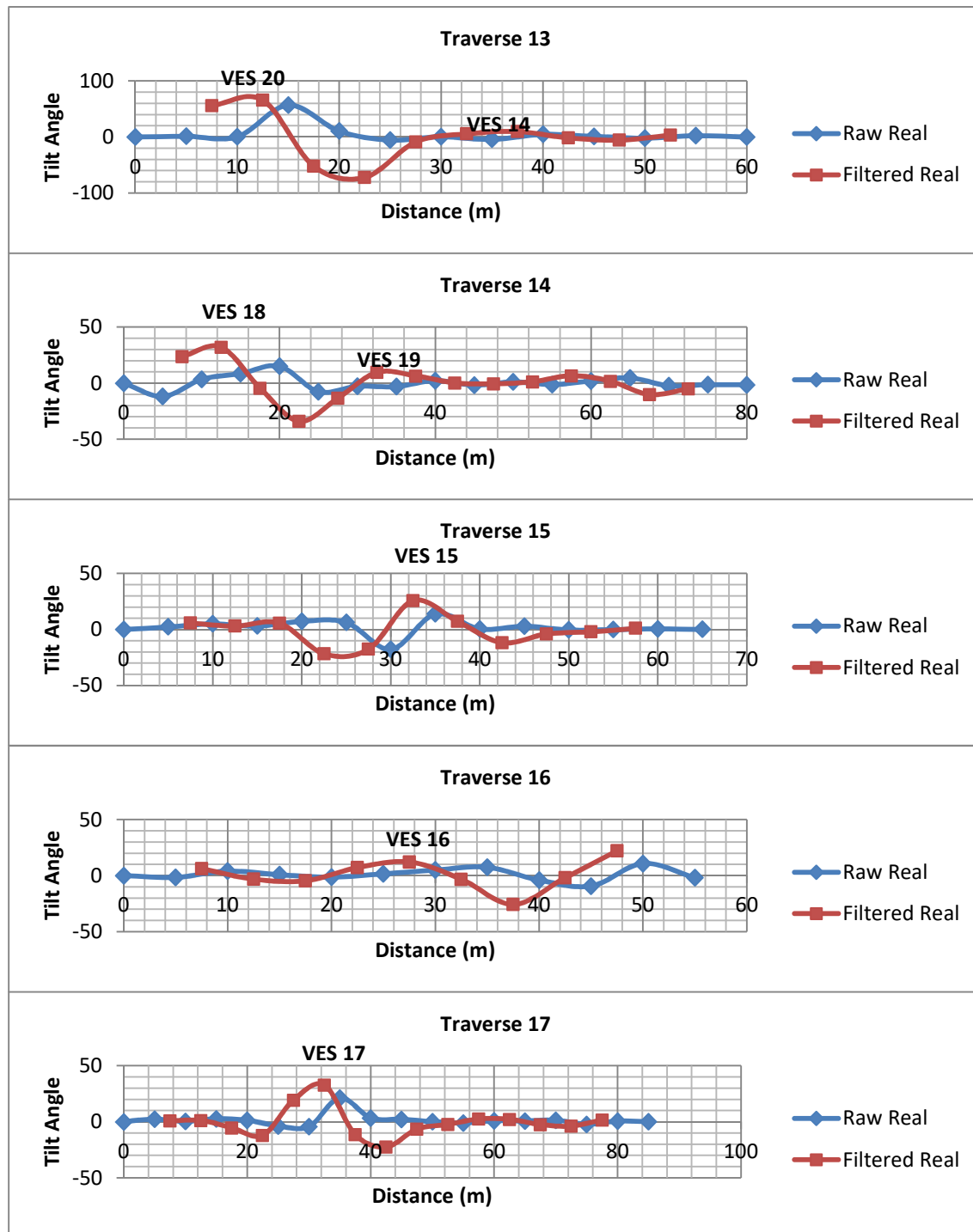
#### 4.0 Results And Discussion

##### 4.1 The VLF-EM Profiles

On each figure, the blue coloured profile represents the raw-real, while the red colour is the filtered-real profile. Each of the figures was carefully examined for characteristic delineation of positions where the point of inflection of the S-shaped anomaly on the raw-real coincides directly with the peak positive amplitude anomaly on the filtered-real profile which is presumed to coincide with a conductive subsurface structure ((Ademilua and Eluwole, (2013), (2014)). The factors ( direct coincidence of the point of inflection of the S-shaped anomaly on the raw-real with the peak positive amplitude anomaly on the filtered-real profile) are diagnostic of the presence of subsurface structures (fractures, faults, thick and conductive overburden) that are favourable to groundwater accumulation were carefully examined, and those that possess satisfactory lateral and depth extents were selected for further investigations. A total of twenty-three (23) of such stations/points represented as VES1-VES 23 on figures 3a-p were generated in the study area.







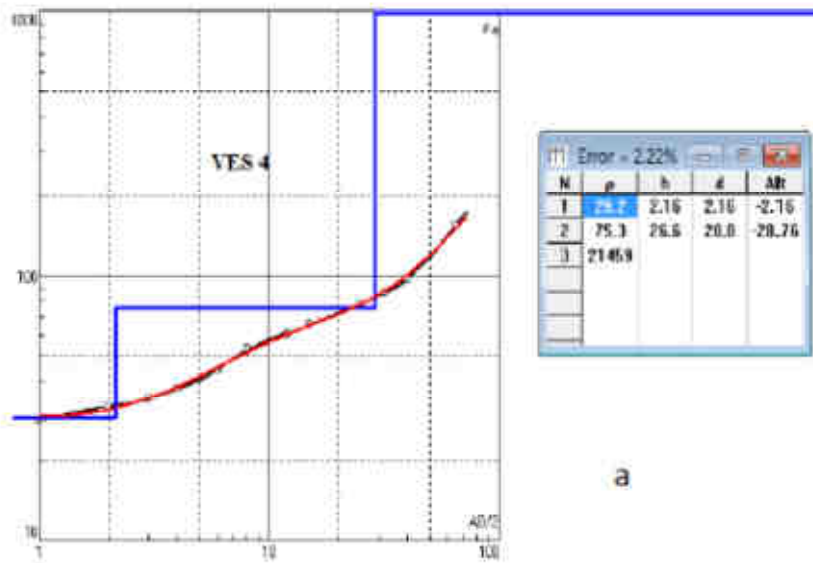
**Figure 3. The VLF-EM Profiles along Traverses 1-17 Showing the VES points  
 The VES Curves**

Five classes of resistivity sounding curves were observed in the study area, these include the 3-layer (A and H) curves (Figures 4a and 4b); the 4-layer (HK, KH, QH and KQ) curves (Figures 4c-f); 5-layer (HKH) curve (Figure 4g); 6-layer (KHKH and AKHK) curves (Figures 4h and 4i); and 7-layer (HKHKH) curve (Figure 4j). The 3-layer curve type has 18% occurrence with A and H curves having 9% each. The 4-layer categories have 35% with HK, KH, QH and KQ having 9%, 13%, 9% and 4% respectively. The 5-layer curve type which is HKH curve type has only 25% level of abundance. Also, 6-layer curve type is having 13% with KHKH and AKHK having 9% and 4% respectively. The 7-layer curve type which is HKHKH has only 9% of the total curve (Table 1).

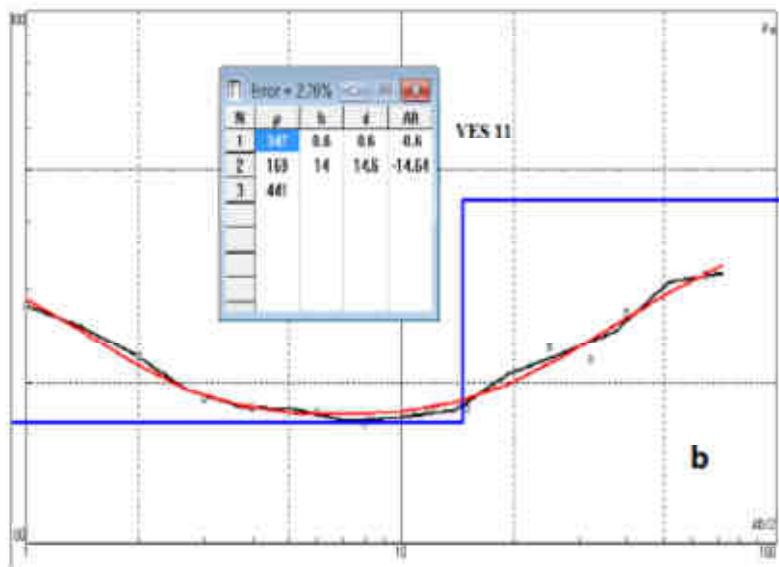
**Table 1:** Summary of Distribution of the different Curves-Types in the Study Area

S/N	CURVE TYPE	RESISTIVITY MODEL	YES NUMBER	FREQUENCY	% ABUNDANCE
1	A	$\rho_1 < \rho_2 < \rho_3$	4,5	2	9
2	H	$\rho_1 > \rho_2 < \rho_3$	2,11	2	9
3	HK	$\rho_1 > \rho_2 < \rho_3 > \rho_4$	9, 21	2	9
4	KH	$\rho_1 < \rho_2 > \rho_3 < \rho_4$	17,18,23	3	13
5	KQ	$\rho_1 < \rho_2 > \rho_3 > \rho_4$	12	1	4
6	QH	$\rho_1 > \rho_2 > \rho_3 < \rho_4$	1, 3	2	9
7	HKH	$\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5$	6, 8, 14, 19, 20, 22	6	25
8	AKHK	$\rho_1 < \rho_2 < \rho_3 > \rho_4 < \rho_5 > \rho_6$	15	1	4
9	KHKH	$\rho_1 < \rho_2 > \rho_3 < \rho_4 > \rho_5 < \rho_6$	13, 16	2	9
10	HKHKH	$\rho_1 > \rho_2 < \rho_3 > \rho_4 < \rho_5 > \rho_6 < \rho_7$	10	2	9
				23	100

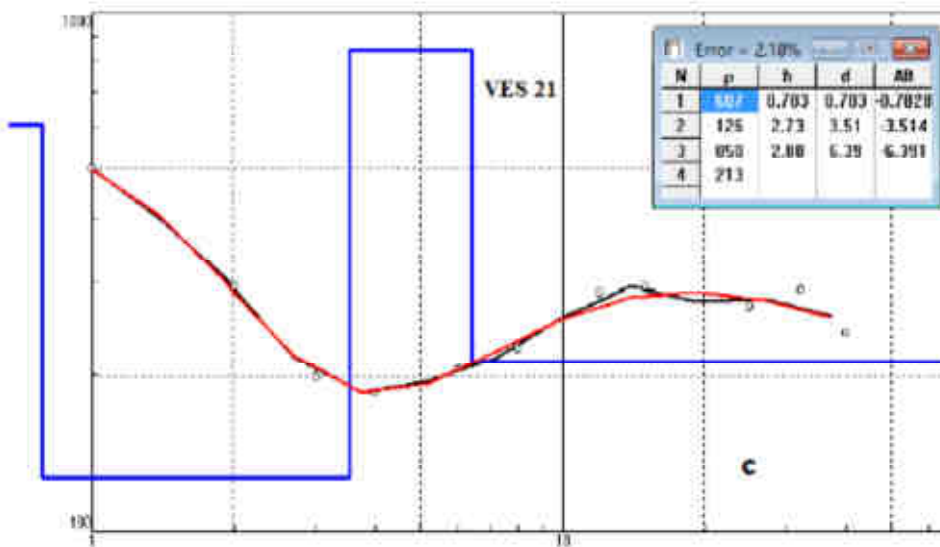




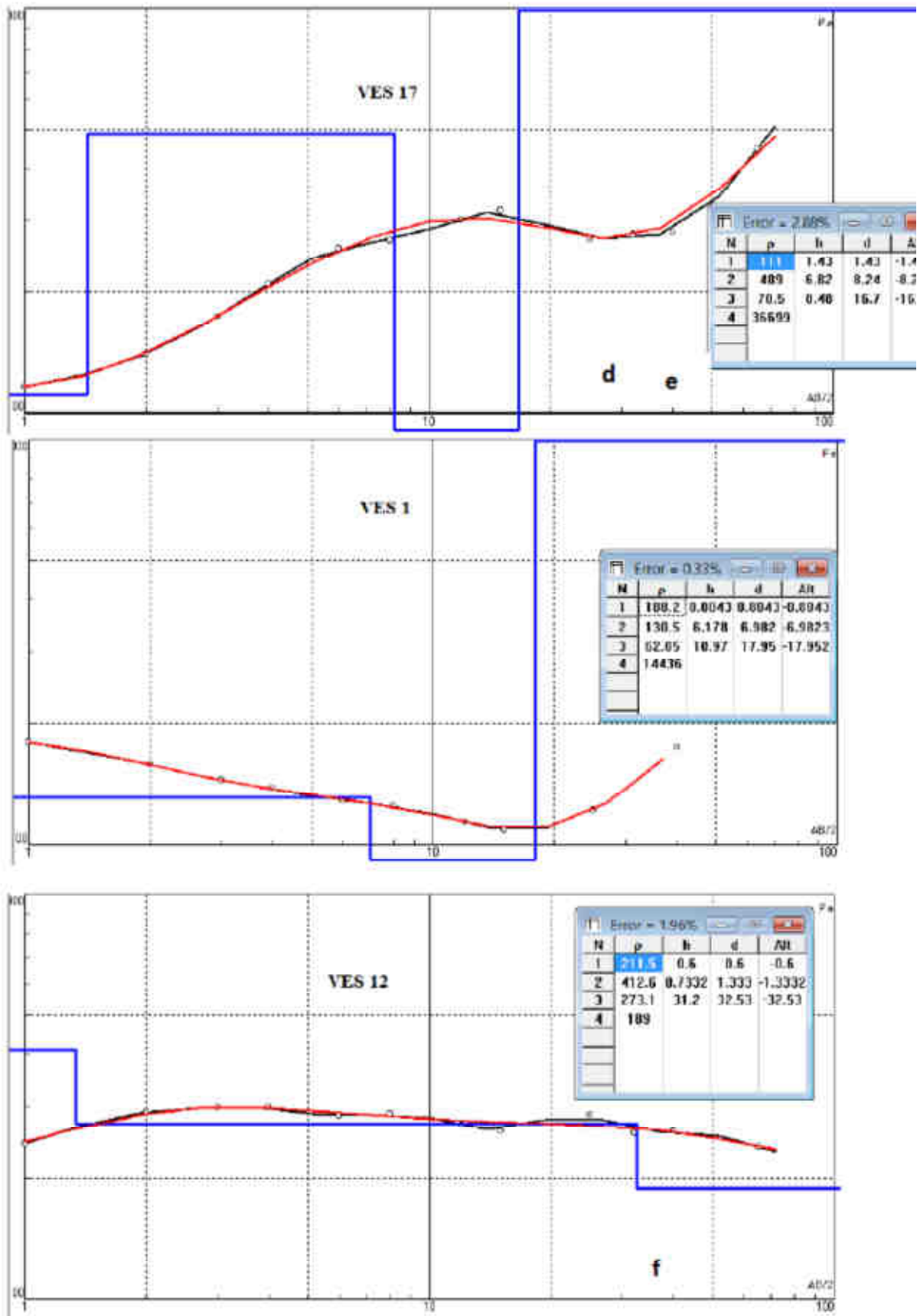
a

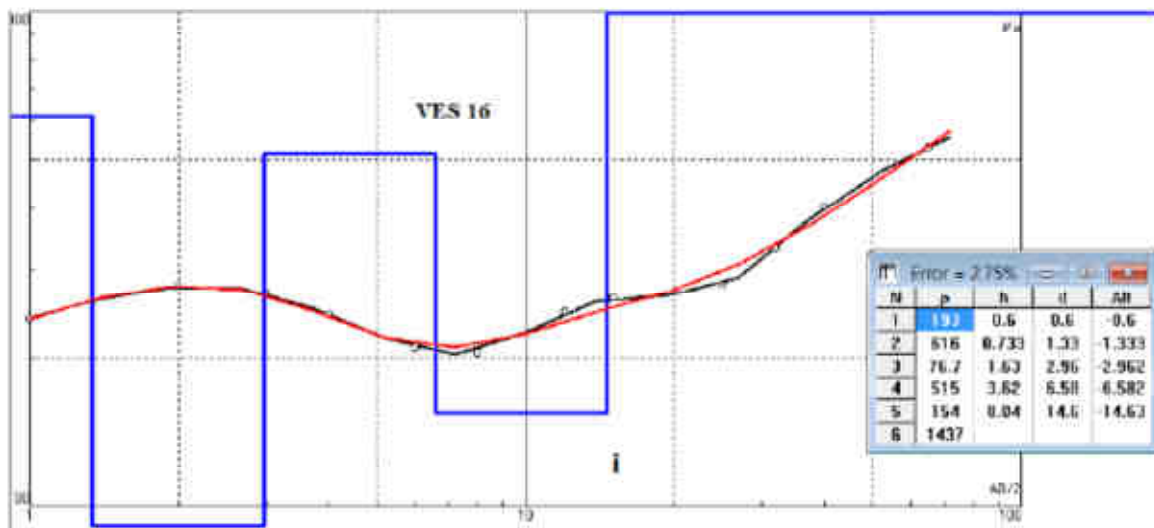
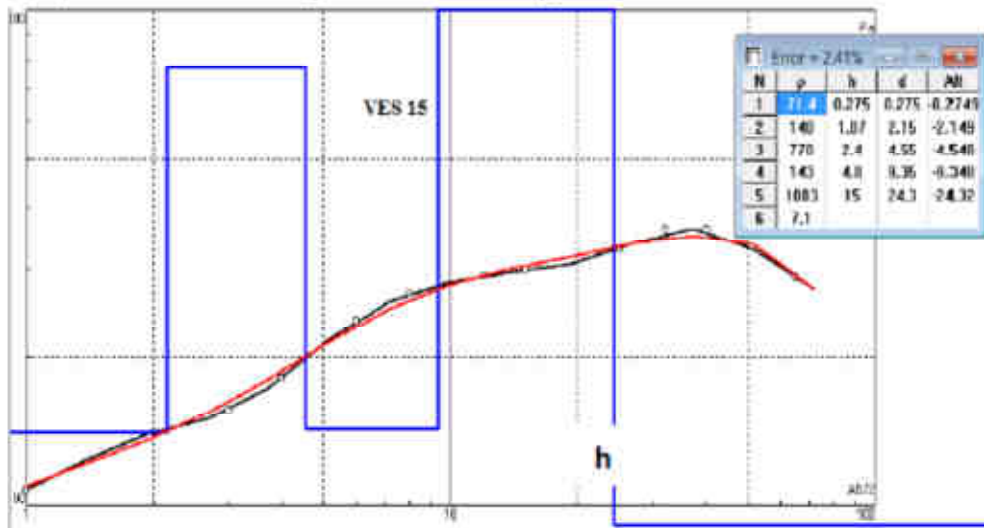
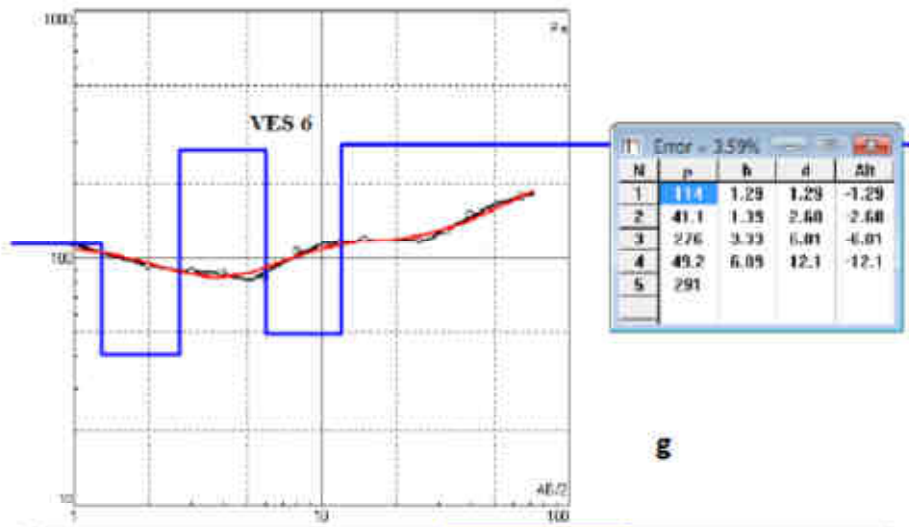


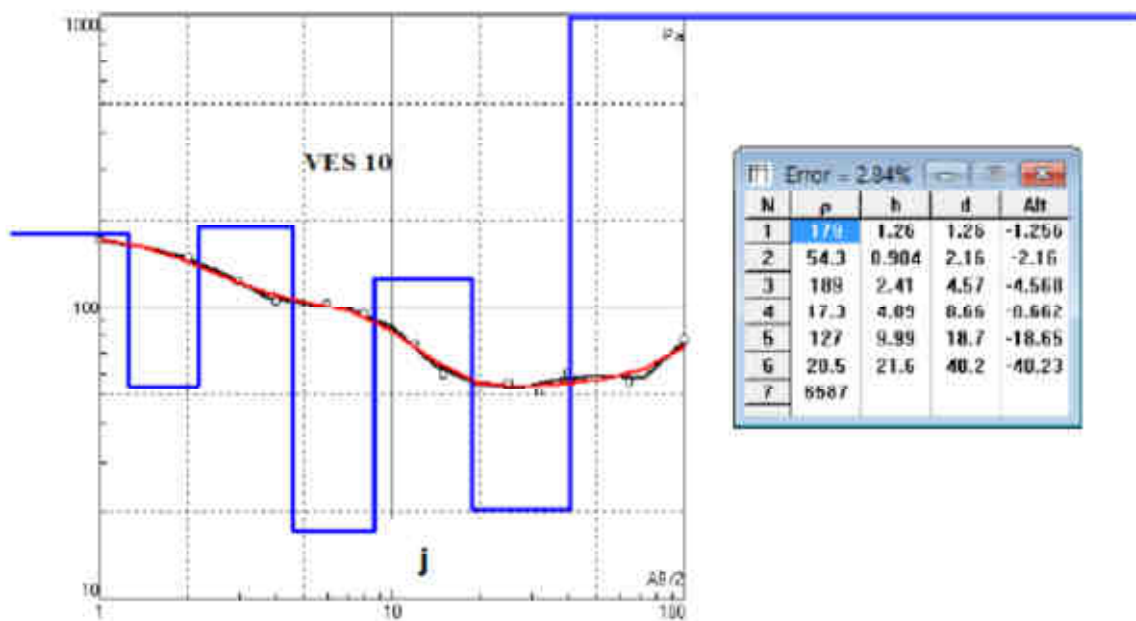
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c







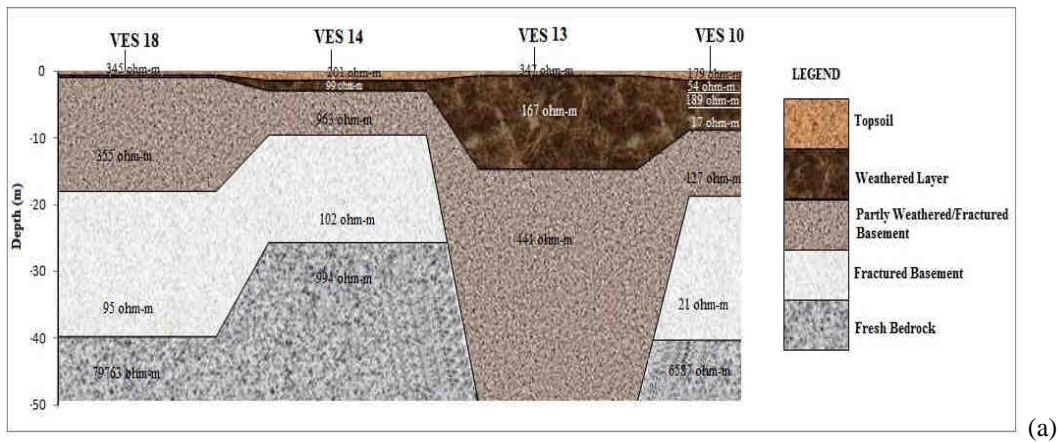
**Figure 3:** Typical Resistivity Sounding Curves obtained in the study area. (a) A-Type, (b) H-Type, (c) HK-Type, (d) KH-Type, (e) KQ-Type, (f) QH-Type, (g) HKH-Type, (h) AKHK-Type, (i) KHKH-Type, (j) HKHKH-Type

### 4.3. The Geoelectric Sections

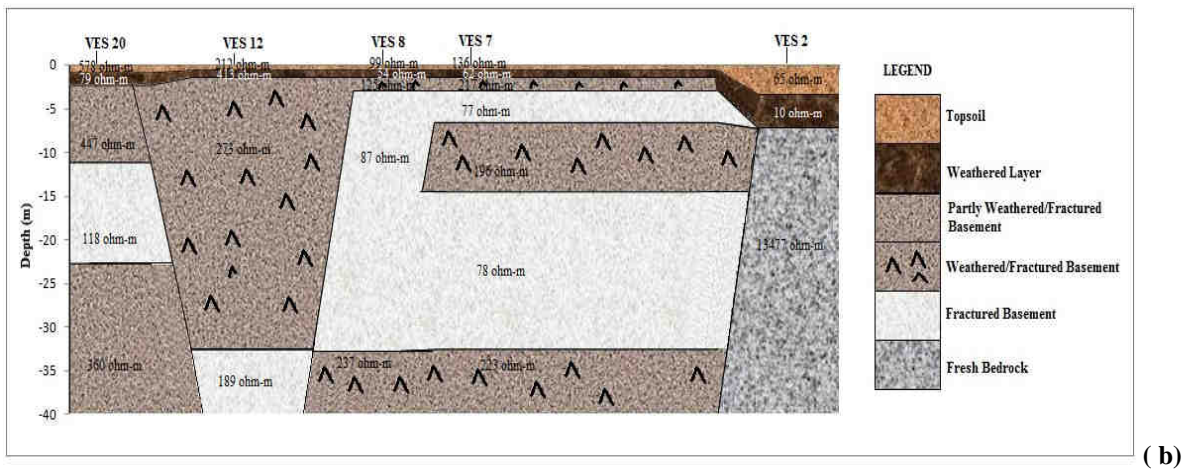
The 2-D geoelectric sections across the VES points were developed from the resistivity and thickness parameters generated from the depth sounding curves to correlate the sounding points within the study area. Six (6) geoelectric sections were generated, these include GES1, GES2, GES3, GES4, GES5 and GES6 (Figure 4a-f). GES1 correlates VES 18,14,13 and 10; GES2 correlates VES 20, 12, 8, 7 and 2; GES3 correlates VES 8, 6, 23 and 1; GES4 correlates VES 18, 20, 4, 22 and 21; GES5 correlates VES 11, 7, 6, 3 and 21; while GES6 correlates VES 15, 16 and 17. GES1 (Figure 5a) reveals a total of five (5) geoelectric layers under the section. Virtually all the VES points have common layers except VES 13; and they all occur with five layers which are; the topsoil with resistivity and thickness values ranging between 179ohm-m and 347ohm-m, and 0.2m and 0.6m respectively; weathered layer characterised with lateritic soil filled with quartzite rubbles having relatively high resistivity and thickness values at VES 13 and VES10. The partly weathered/fractured basement layer is characterized with the resistivity values that range from 127ohm-m to 963ohm-m. The fractured basement with relatively low resistivity values ranging between 21ohm-m and 102ohm-m and high thickness between 15m and 22m represent a few of the considerable instances that could be promising for good groundwater accumulation in a typical basement complex terrain. This layer is common to all the sounding points along GES1 except in VES13. VES 18 can be considered to be most promising of all the VES points along this section considering the thickness of the aquiferous unit of 22m and comparatively low resistivity value. The depression towards the fractured basement layer beneath VES 18 from VES 20 could be substantially favourable for accumulation of water within the aquifer setting along the section (Olorunfemi 2009, Olorunfemi et al 2000, Obasi et al, 2013,Ademilua and Olorunfemi, 2011). Furthermore, GES 2, 3, 4, 5 and 6 revealed five (5) geoelectric layers like that of GES1. From these, VES12, 8 and 7 were found to have geoelectric and geologic conditions that are favourable for highly productive aquifer settings considering the occurrence of faults, low resistivity and high thickness values which characterised the geoelectric layerings along these GES sections in the study area. In the same vein, a careful consideration of VES8 is revealing of its prospects to be more efficient and prolific with very high thickness of 33m and a resistivity value as low as 87ohm-m which are diagnostic of a high yielding aquifer setting along GES3 section. Considering the section GES5, VES7 is evidently the most appropriate point with reasonably high thickness of fractured basement of about 32m and low resistivity value of 78ohm-m. All the VES points along GES 6 are characterized by parameters that are considerable, moreso given the incidence of the thick fractured zone which straddle the section, which would be highly complementary to the weathered layer if well penetrated(Olorunfemi and Fasuyi, 1993, Olorunfemi, 2009, Ademilua and Eluwole, 2013, 2014). Succintly put, the occurrence of the uniquely continuous sequence of the fractured basement makes VES 15 along GES 6 considerable as the most appropriate of all along this section having a system of two fractured layers confined within fresh basement with the second fractured layer occurring at the greatest depths of all the three sounding points along the section. From the aforementioned criteria and analyses, it becomes clearer that the following VES positions are recommendable for the development of good yielding groundwater development

schemes in order of priority, VES 20 , VES 12 , VES 18 , VES 10 , VES 8 , VES 7 and VES 15.

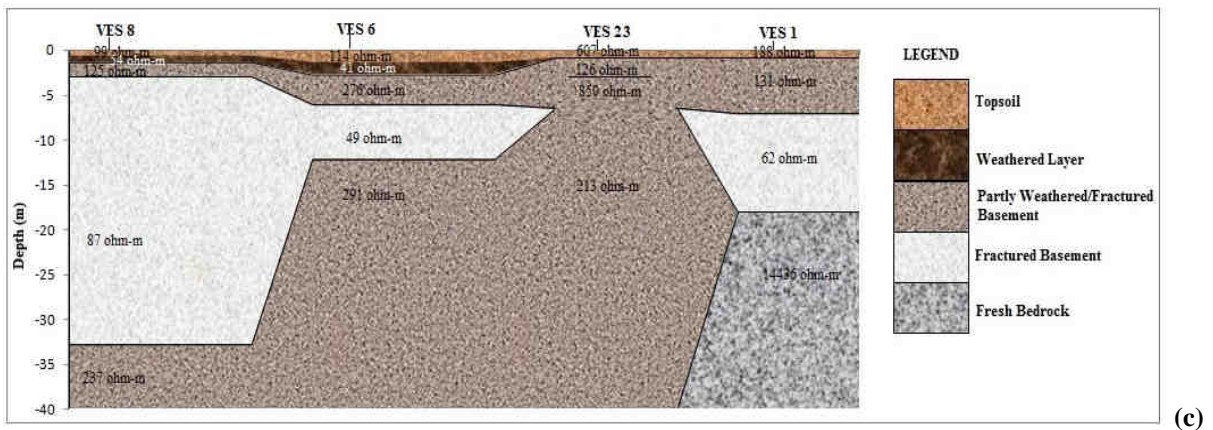
**GES 1**



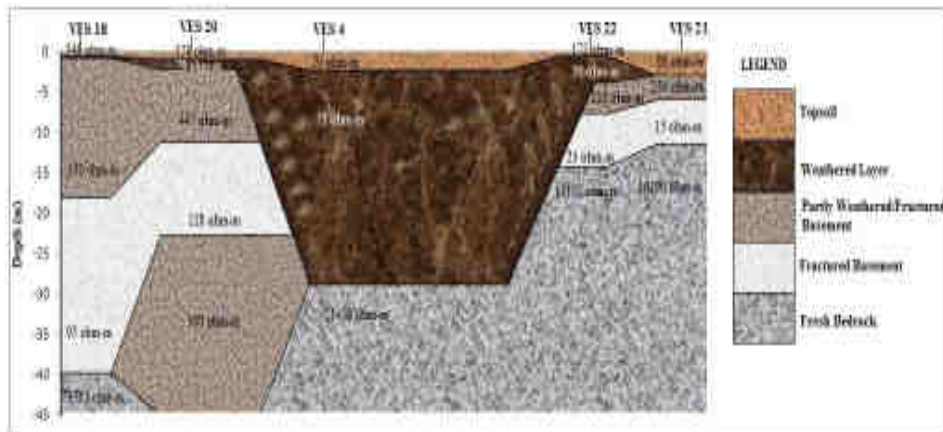
**GES 2**



**GES 3**

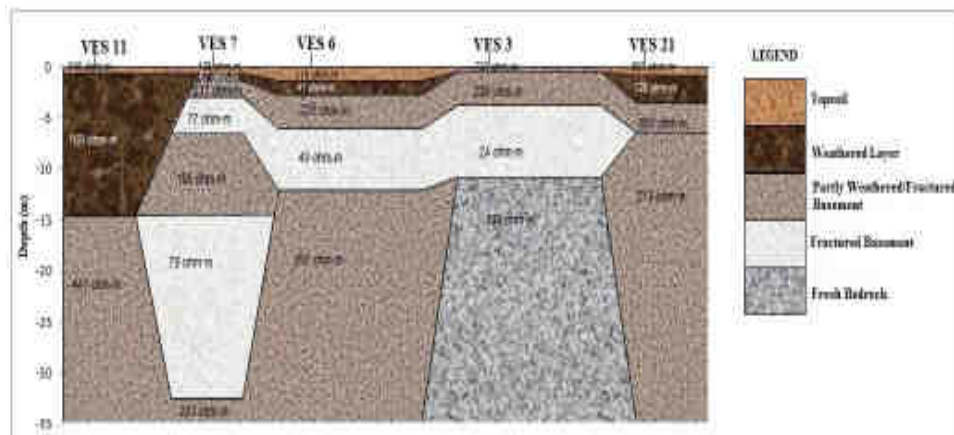


**GES 4**



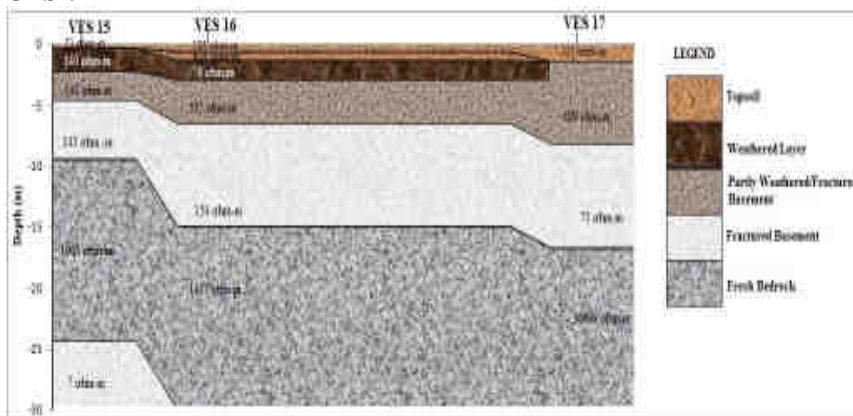
(d)

**GES 5**



(e)

**GES 6**



(f)

**Figure 4(a-f):** Goelectric Sections Beneath Selected VES Points. (a) GES 1, (b) GES 2, (c) GES 3, (d) GES 4, (e) GES 5 and (f) GES 6

**5.0 Conclusion**

The study revealed that the environment is having a high potential for groundwater accumulation. The result showed that the environment is generally underlain by five lithologic units which include the topsoil, weathered basement, partly weathered/fractured basement, fractured basement and the fresh basement. Three of the five lithologic units are favourable enough for groundwater accumulation having been examined geologically and in terms of the resistivity and thickness of the layers. These are the weathered layer, partly weathered/fractured basement and the fractured basement. The aquifer units are generally below 18m thick except that of VES 18, 10 and 8. The overburden is generally thin in all the goelectric sections with an exception of GES 4 with

considerable thickness of about 26m. Others possess overburden thickness that are less than 15m. Considering all the factors that actually determine high potential groundwater formation for borehole development. The occurrence of continuous sequence of the fractured basement in conjunction with a thick sequence of weathered layer compels a consideration as appropriate positions along the geoelectric sections for the siting and location of a good and sustainable groundwater development borehole. From the aforementioned criteria and analyses, it becomes clearer that the following VES positions are recommendable for the development of good yielding groundwater development schemes in order of priority, VES 20 , VES 12 , VES 18 , VES 10 , VES 8 , VES 7 and VES 15.

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