Geoelectric Survey for Groundwater Exploration at Sagari Estate, Akure. Southwestern Nigeria.

Abubakar H.O[1], Bayode .S [2].Ige O.O[1] Ajayi C. A[3] and Badmos. A. [2]

[1]Department of Geology and Mineral Sciences, University of Ilorin.

[2] Department of Applied Geophysics, Federal University of Technology Akure.

[3]Department of Geology, Ekiti State University. Ado Ekiti.

Contact: *abubakar.hussainolanrewaju3@gmail.com*

ABSTRACT

Zones favorable for groundwater exploration in the hard rock areas of Shagari Estate in Akure were investigated using VES technique and Werner Array method was used for horizontal profiling measurement at a=15m and a=30m while VES with Schlumberger Array were used to acquire data from 53 stations within the study area. Several boreholes drilled in Shagari Estate were reported to have failed either due to technical inefficiencies, poor handling of projects such as boreholes development and maintenance. Results from this study show static water level of the study area ranges from 0.3m to 4.2m. Four major sub-surfaces were delineated including: Top soil, weathered layer, fractured basement and Fresh basement. Concentration was placed more on zones of low resistivity along HP profiles where 53 VES was conducted to confirm zones of possible fractures in the hard rock environment. The topsoil resistivity values ranges from 32.0Ωm to 257Ωm and overburden thickness values vary from 0.9m to 5.1m. The Weathered layers resistivity values range from 48Ωm to 205Ωm and thickness values vary from 2.1m to 8.4m. Some fractured zones were identified at the deeper depth of about 28-59m, with thickness values ranging from 28m to 59m. The fresh basement has resistivity value ranging between 719Ωm to 64167Ωm. The interpretation of results from the study area reveals that the environment generally is of a favorable groundwater condition provided the fractured zones are fully penetrated within the basement in other to obtain reasonable quantity of water from the area.

KEYWORDS: Resistivity, Vertical Electrical Sounding, Profiling, Delineation, Fractured zones

Introduction

The main use of geophysics in the geosciences is for hydrocarbon exploration typically at depth greater than 1000m. Significant technological advances have been made in industries over the years especially with seismic reflection techniques. In contrast, near surface geophysics for groundwater investigations is usually restricted to depth less than 250m below the surface and developments have not concentrated on one specific geophysical technique. Water is a basic necessity of life. Water constitutes two-third of the whole body of human being, and that of the total earth mass. It constitutes an important resource of supply in drinking water. Virtually, every activities of man require the use of water; whether domestically, industrially, experiments in labs or any other forms. Wells drilled without proper geophysical and hydro geological study often fail to produce groundwater. In hard rock areas, groundwater is found in the cracks and fractures of the local rock (Olorunfemi and Ademilui 2000). Groundwater yield depends on the size of fractures and their interconnectivity. The yield of the groundwater depends on the size of the fractures and their interconnectivity. Groundwater generally occurs in rocks that are permeable enough to allow the accumulation and circulation along the geologic micro-structures.

Generally, the information concerning the lithology, stratigraphic sequence, geologic structures, and hydro-geological characteristics of the subsurface materials can be provided through the application of Electrical resistivity method (Koefoed, 1979). The area of Study is located within Akure north (Shagari Estate), Akure Area in Ondo State. It is situated in the northern part of Akure metropolis. The area lies between longitudes 7º41′400″ E and 7º43′200″ E (UTM) and latitudes 8º05′000″ N and 8º06′250″ N (UTM). The topography is gently undulating. The area is situated within the tropical rain forest region with a climate characterized by dry and wet seasons. Annual rainfall ranges between 100 and 1500mm, with annual temperature varies between 18ºC to 34ºC (Iloese, 1980). The study area is easily accessible through Ilesha-Owo road, tarred roads and un-tarred streets and footpaths connecting them. The study area is underlain by the Precambrian basement complex rocks of South-western Nigeria (Rahaman, 1978). The local lithologic units identified include migmatite-gneiss, biotite, gneiss and granite Biotite-granite was sampled on several locations. They are porphyritic and of medium-coarse-grained texture. The granites occur as intrusive in low-lying outcrops within the biotite gneiss. In basement terrain, groundwater occurs in the weathered basement and the joints, fractures or faults within the bedrock (Ademilua and Olorunfemi, 2000). The rock consists of Precambrian metasediments, migmatites, gneisses, granites and other intrusive igneous rock. As a result the geologic nature of the rock types in this area i.e. non-porous and impermeable at fresh undisturbed form, some geologic processes like faulting, weathering, and fracturing that could be found in them can yield sizeable amount of groundwater.

Materials and Method of Study.

The materials that were used for this research are: Omega Resistivity Meter, metal electrodes, hammers, connecting cables, measuring tape, compass clinometers, topographic map, and Global Positioning System (GPS) and personal computer software's. The Horizontal Profiling was carried out using wenner array, measurement was taken using electrode spacing (a), a=15m and a=30m. This method was used to delineate the fractured and low resistivity zones which were subsequently investigated using the Vertical Electrical Sounding (VES) technique. Five (5) to nine (9) VES was carried out along the traverses for subsequent correlation with the horizontal profiling technique. The electrode spacing (AB/2) m was varied from 1m to a maximum of 100m. A total number of fifty-three (53) VES was carried out in the study area and serves as a follow up to the preliminary HP-survey conducted in the area. The VES data was interpreted with the use of partial curve matching technique and this technique provided the initial model geoelectric parameters for the computer iteration. The computer iteration was used to refine the geoelectric parameters until the error percentage is less than 10%. The horizontal profiling data was plotted as profiles and inverted into 2-D pseudosection using the RES 2D software. The results are presented as profiles, pseudosections, geoelectric sections, and maps.

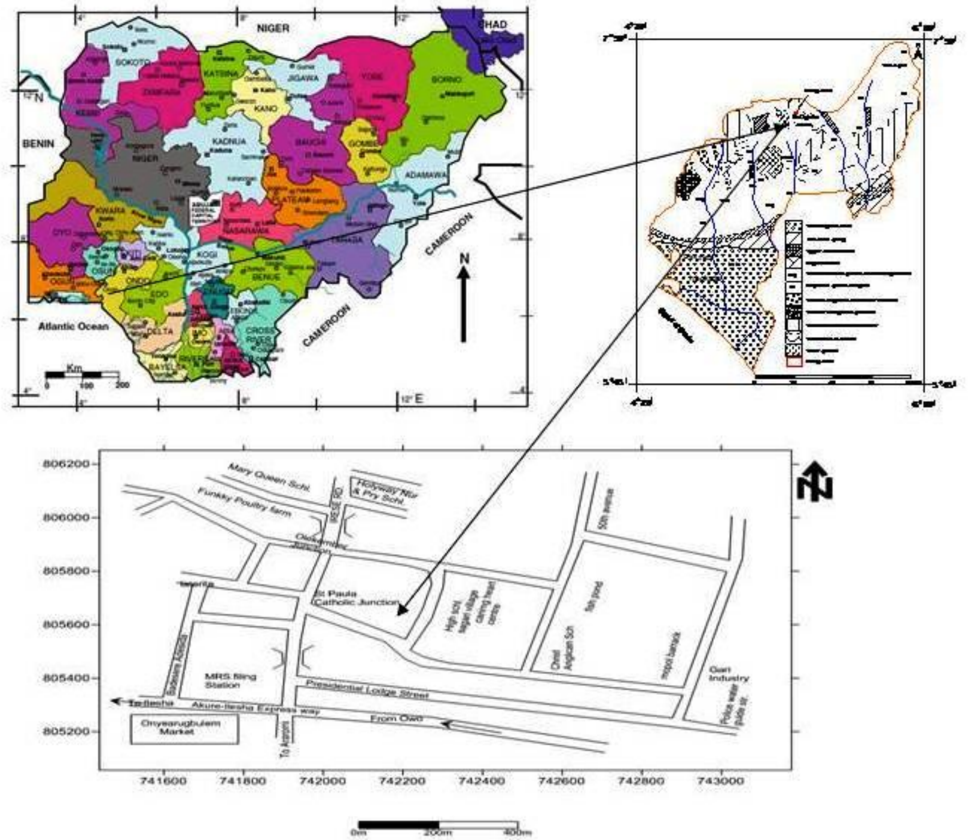


Figure 1: Map of the Study area. (NGSA 1976).

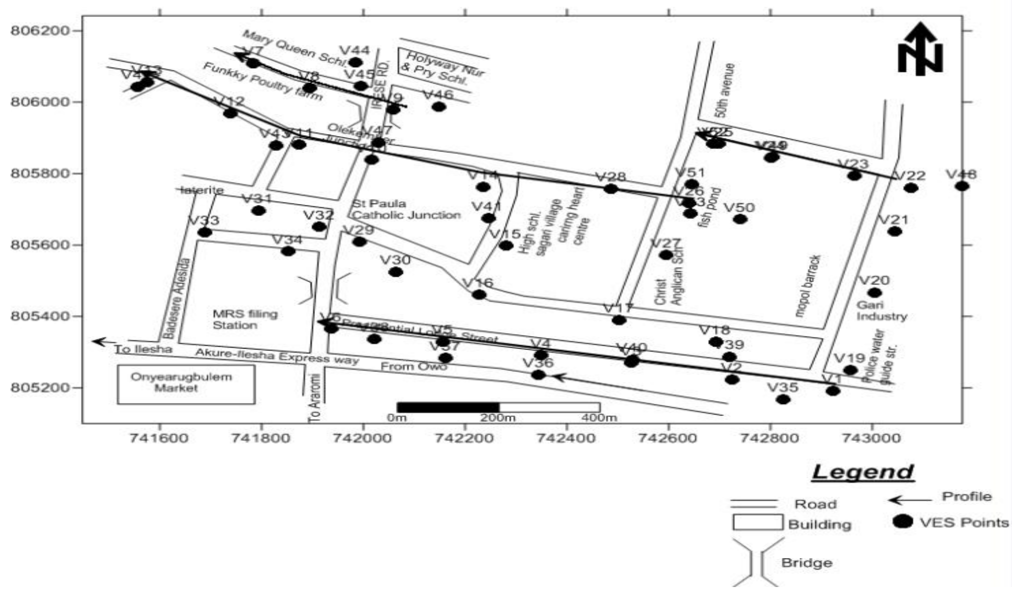


Figure 2: Data Acquisition Map Showing VES stations.

Results and Discussion.

Profiles discussion along traverse

Traverse 1 was carried out along the East-West direction of the study area. The resistivity values at shallow depth of 15m spacing range between 141Ωm - 581Ωm. While resistivity values at deeper depth of 30m electrode spacing range between 253Ωm - 1129Ωm. between distance 50m and 150m the resistivity is averagely high. The resistivity values between the distance 150m to 250m the resistivity values is very low at both shallow and deeper investigation. Along distance 250-300m the resistivity value is very high. The resistivity value was very low between distances 300-360m, but between distances 360m and 500m the resistivity values increased uniformly having the highest peak at distance 500m. It was observed that the resistivity value is considerably low between distances 150m and 250m. Traverse 2 is about 400m in distance. This was carried out along the East-West direction of the study area. The resistivity values ranges from 513Ωm to 5519Ωm on the 30m spacing; while that of 15m spacing range from181Ωm to 4981Ωm The resistivity value was very high between the first 50m with both 15m space profiling; while both profiles were low within a distance range of 50m and 110. The resistivity values within 110 and 170m was very high on both profiles. However, the resistivity was very low on both profiles within 170 and 400m distance. Traverse 3 is about 250m long. This was carried out along the East-West direction of the study area. It is located within the Northwestern part of the study area. The resistivity values ranges from 318Ωm to 2961Ωm on the 15m spacing profile; while that of 30m spacing ranges from1211Ωm to 5717Ωm. The resistivity values were averagely low between 0-110m distance lengths and considerably high between 110m and 175m. Traverse 4 is about 220m long. This was carried out along the East-West direction of the study area. The resistivity values ranges from 150'Ωm to 452'Ωm on the 15m spacing profile; while that of 30m spacing ranges from 241'Ωm to 710'Ωm. The resistivity is considerably low between distance 75m and 150m; while it is very high between distance length of 180m and 210m along the profile for both 15m and 30m spacing profiles.

2-D Resistivity Structure along Traverse 1

The raw, theoretical pseudo-section and 2-D resistivity structure are shown in figure:4. Three Geoelectric layers were delineated by the 2-D resistivity structure which is top soil, weathered layer and fresh bedrock. The resistivity of the top soil varies from 40ohm-m to 175ohm-m while resistivity of the weathered layer ranges from 58 to 194ohm-m. The thickness of the top soil varies from 0.5 to 2.3m, and that of the weathered layers range from 2.9 to 13m. Due to the low resistivity values and sizeable thickness of the top soil alongside the weathered layers. The delineated fractures along the traverse between distances 360-380m suggest the zone for groundwater potential.

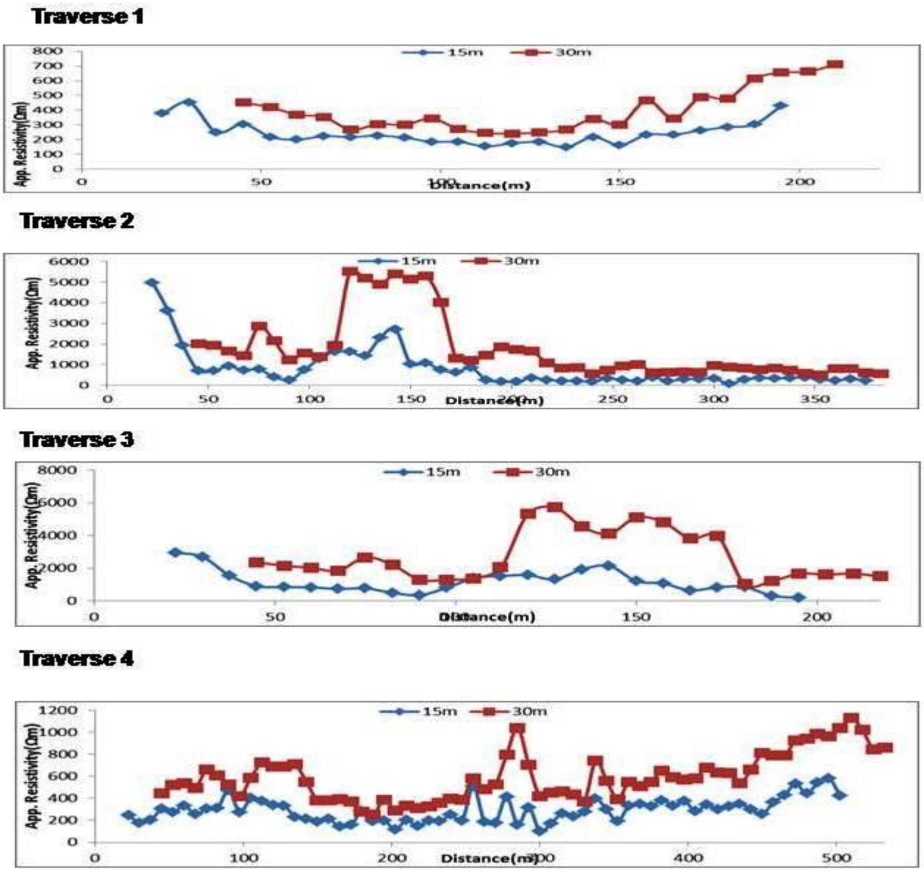


Figure 3: Horizontal Profiling profiles along traverse 1 2 3 &4.

Traverse 2 in fig.4 shows raw and theoretical pseudo section and resistivity structure. The 2-D resistivity structure delineated three geo-electric sequence; top soil, weathered layer and fresh bedrock. The top soil and the weathered layer resistivity range from 35 to 63ohm-m.and 85 to 100ohm-m respectively. The 2-D resistivity structure revealed the thickness of the top soil and weathered layer as ranges from 0.5 to 2.1m and 2.3 to7.8m. The zone of low resistivity at 19m depth below is between distance 300m and 360m along the traverse. The 2-D resistivity structure along traverse 3 delineated three geo-electric/geologic sequences, the top soil, weathered layer and fresh bedrock. The top soil and the weathered layer resistivity range 59.3 to 237ohm-m and72.3 to415.1ohm-m. The thickness of the top soil also ranges from 0.5m to1.1m.and that of the weathered layer varies from 4.6m to7.2m. The fractures revealed by the 2-D resistivity structure were of high significant between distances 40m and 65m.The measured apparent/ raw and the calculated apparent/ theoretical pseudosection and the inverse model resistivity section along traverse 4 shows that, the top soil layer thickness ranges from 0.5m to o.8m and that of the weathered layer varies from 2.5m to 3.7m. The resistivity of the weathered layer varies from 64.2 to184ohm-m and that of the top soil ranges from38.5to131.8ohm-m.

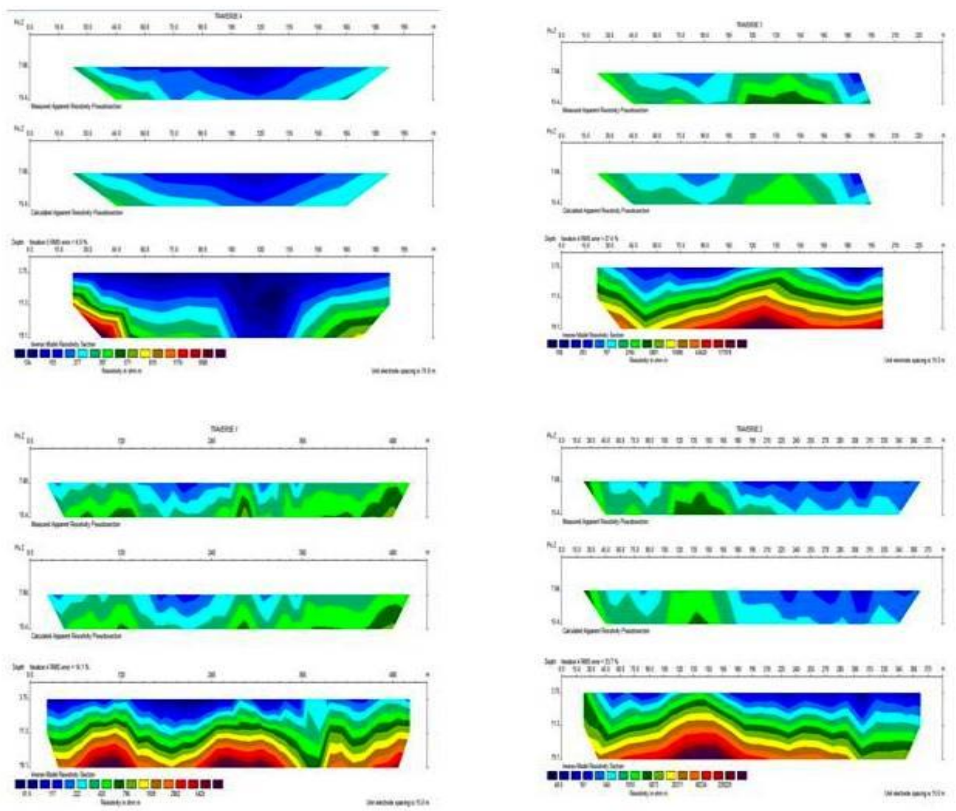


Figure 4: 2-D Inverse Model Resistivity Section of Wenner along traverse 1, 2, 3

Electrical Resistivity Method

The interpretation of field resistivity data are in terms of resistivity, depth to the bedrock and the interfaces across which a strong electrical contrast exists which can be interpreted as the geological strata. The electrical resistivity varies between different geological materials, depending mainly on variation in water contents and dissolved ions in the water. The analysis and interpretation of the survey data showed different geoelectric layers. The layers been accessed in the study consist of the topsoil as the first layer which consist of material like clay, clayey sand, sandy clay and laterites; the next is the weathered layer, while the third layer is the fractured/weathered layer or fresh basement; while the fourth is fresh basement which is in the bottom part of the section surveyed. The fresh basement rock is highly resistive and cannot accommodate groundwater accumulation. The curve types generated vary from three layers A-type, K-type and H-type to four layer KH, HK, and HA curve type, to five layer HKH and AKH type.

Geoelectric Section

Curves types identified ranges from A,K, H, KH, HK, HA to HKH and AKH curve type varying between three to five geoelectric layers along the four traverses. The H curve type dominates, constituting 41% of the totals while the A constitutes 20.8%, HKH constitute 17%, KH and HK constitutes 7.5% each while HA, K and AKH constitute 1.9% each. Traverse 1 shows the geoelectric section in Eastern-Western direction. The VES stations along this traverse include VES, 35, 36, 38, 39 and 40. Five subsurface layers were delineated; these include the topsoil, the weathered basement, fractured basement and the fresh basement. The first layer is the topsoil with resistivity values ranging from 92 to 302 Ώm. and the thickness ranges from 0.4m to 4.2m. The top soil is made up of clayey sand, clay, sandy-clay and laterite. The second layer is the weathered basement which has resistivity values that range from 52 to 205Ώm and thicknesses ranging from 2.6-5.5m. The Third layer delineated was a fresh basement with resistivity values ranging from 719-1411Ώm and thickness values that range from 13.6-49.5m. The fourth layer is a fractured basement with resistivity values ranging from 82-602Ώm and thickness values that range from 28-54m. The fifth layer is the fresh basement which is characterized by high resistivity values ranging from 2184Ώm to 16167Ώm. Traverse 2 shows the geoelectric section in East to West direction. The VES stations along include VES 41, 42 and 43. Five subsurface layers were delineated; these include the topsoil, the weathered basement, fractured basement and the fresh basement. The first layer is the topsoil with resistivity values ranging from 43 to 73Ώm. and the thickness ranges from 0.3m to 1.5m. The top soil is made up of clayey sand, clay and laterite. The second layer is the weathered basement which has resistivity values that range from 44 to 94Ώm and thicknesses ranging from 2.2-5.5m. The Third layer delineated was a fresh basement with resistivity values ranging from 1114-1351Ώm and thickness values that range from 27.6-54.6m.The fourth layer is a fractured basement with resistivity values ranging from 371-602Ώm and thickness values that range from 28.7-65.6m. The fifth layer is the fresh basement which is characterized by high resistivity values ranging from 1958Ώm to 8769Ώm.mTraverse 3 shows the geoelectric section in North-Western direction.

The VES stations along include VES 44, 45, 46 and 47. Five subsurface layers were delineated; these include the topsoil, the weathered basement, fractured basement and the fresh basement. The first layer is the topsoil with resistivity values ranging from 83 to 184 Ωm. and the thickness ranges from 0.5m to 2.2m. The top soil is made up of clayey sand, clay, sandy-clay and basement with resistivity values ranging from 94-570Ωm and thickness values that range from 24-43m. The second layer is the weathered basement which has resistivity values that range from 41 to 73Ωm and thicknesses ranging from 4.6-8.4m. The Third layer delineated was a fresh basement with resistivity values ranging from 284-2382Ωm and thickness values that range from 46.1- 48m. The fourth layer is a fractured. The fifth layer is the fresh basement which is characterized by high resistivity values ranging from 1938Ωm to 2389Ωm. While Traverse 4 shows the geoelectric section in East-western direction. The VES stations along include VES 48, 49, 50, 51, 52 and 53. Five subsurface layers were delineated; these include the topsoil, the weathered basement, fractured basement and the fresh basement. The first layer is the topsoil with resistivity values ranging from 68 to 143Ωm. and the thickness ranges from 0.5m to 5.1m. The top soil is made up of clayey sand, clay, sandy-clay and laterite. The second layer is the weathered basement which has resistivity values that range from 48 to 90Ωm and thicknesses ranging from 3.7-4.7m. The Third layer delineated was a fresh basement with resistivity values ranging from 582-1436Ωm and thickness values that range from 34-56m. The fourth layer is a fractured basement with resistivity values ranging from 340-547Ωm and thickness values that range from 34-38m. The fifth layer is the fresh basement which is characterized by high resistivity values ranging from 2335Ωm to ∞.

Hydrogeological Static Data Interpretation

The hydrological static data was obtained from the study area. The Static level ranges from 0.3m to 4.2m. The static level was very deep around the eastern and western part of the study area. The static level was very shallow around the North-Western part of the study area. An average water static level was found around the Northern and the Southern part of the study area.

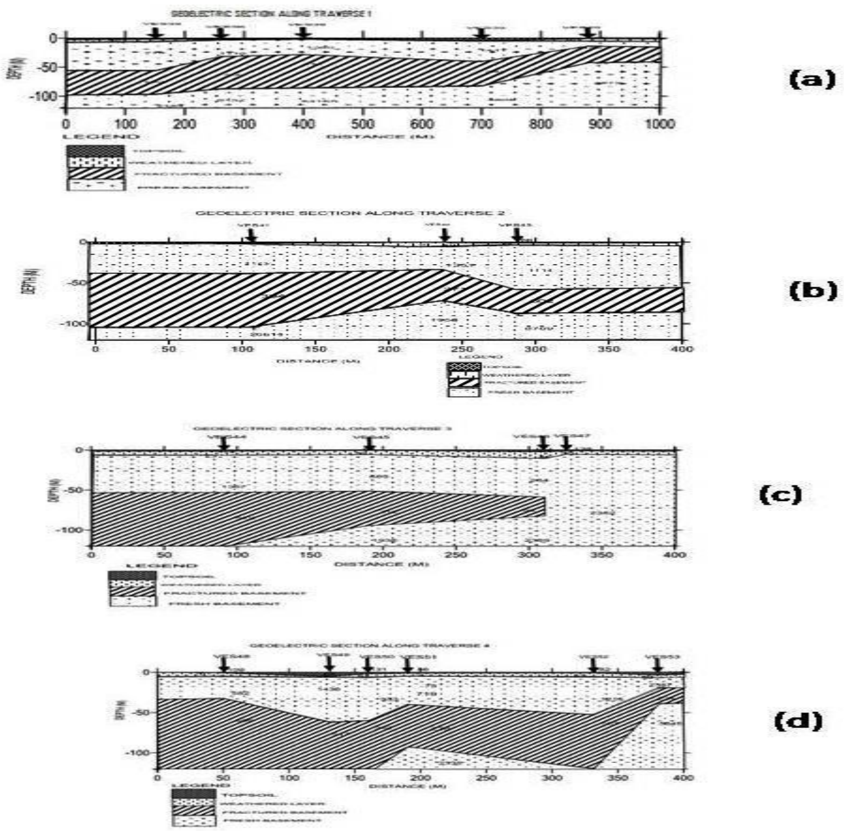


Figure 5: Geoelectric Section Along Traverses

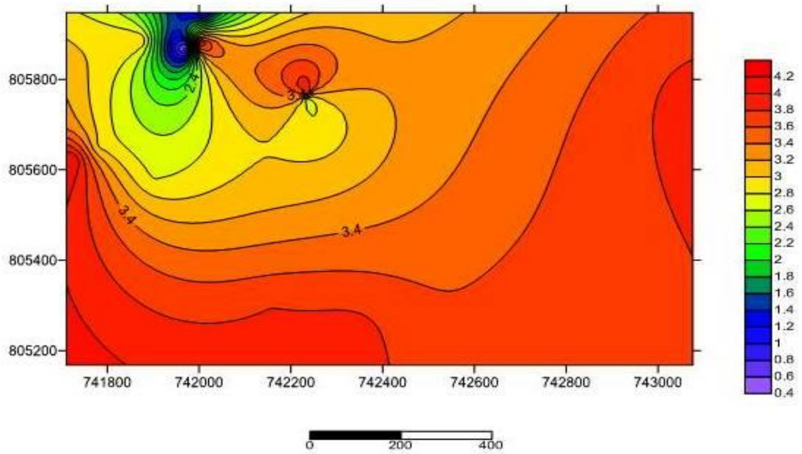


Figure 6: Hydrogeology (Static-Level) Data Map

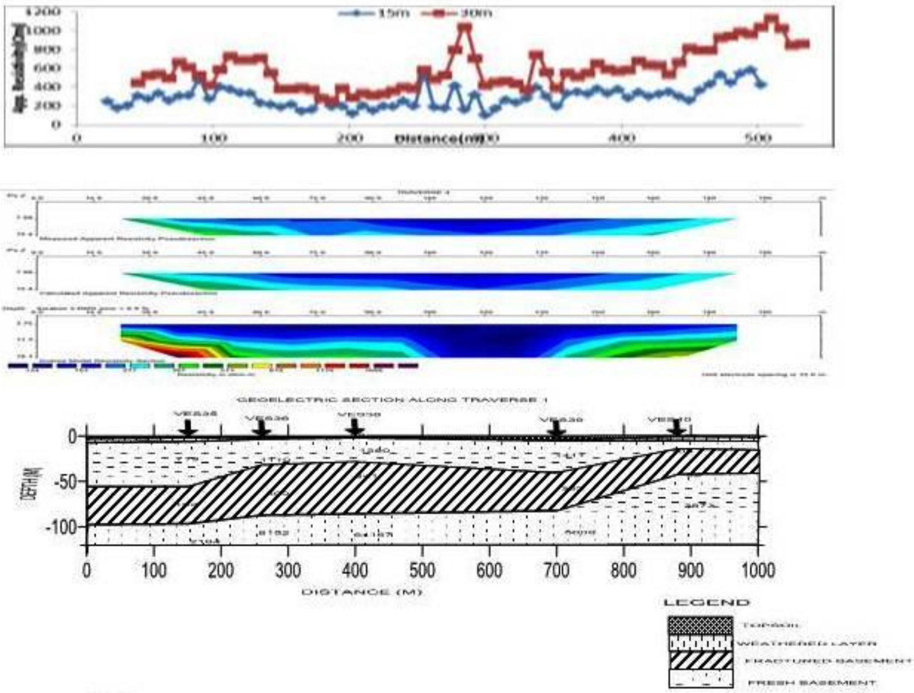
Correlation between horizontal profiling 2d-inverse model resistivity section, profiles and the geoelectric section along the four traverses.

The low resistivity section of the 2D-inverse model section along the a=15m and a=30m HP profiles of traverse 1 between the distances 280m- 400m and 750m-800m indicates the presence of fracture at about 20m deep. This was confirmed by the geoelectric section with the fracture been detected at shallow depth. The high thickness of the third layer of the traverse (which is the basement complex) ranging from 5m to 50m at shallow depth as indicated by the geoelectric section is also confirmed by the high resistivity profile of the HP between the distances 50m and 200m and the shallow basement section indicated by the 2D-inverse model section of HP. Along traverse 3 between the distance 230m and 300m, the high resistivity profile as indicated by the 2D-inverse model section at about 20m deep is been confirmed by the geoelectric section with a very high thickness of the third layer basement complex between the range of 7m and 52m. The 2D-inverse model section indicates the presence of fracture between the distances 155m and 250m at about 20m deep. The HP profile also shows low ranges of resistivity along both profiles (a=15m & a=30m). This was confirmed by the geoelectric section with the fracture been detected at closer range to the surface and the basement complex thickness been averagely thin at a depth of about 30m.

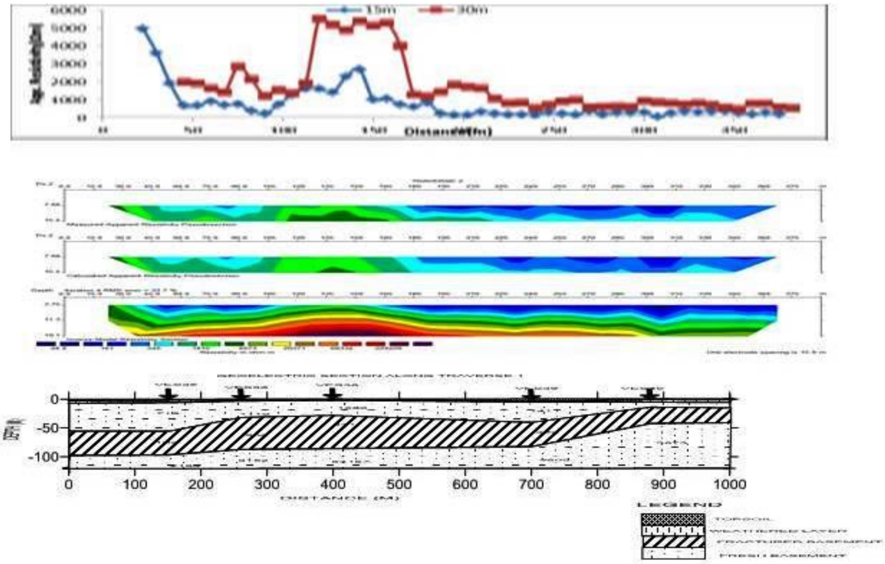
Table 1: Summary of Hydrogeological Data

S/N	Features	Northing	Easting	Altitude (m)	Static water level (m)	Remark
1	MTN MAST	741948	805588	362.2	-	In use
2	HDW	741898	805579	361	2.8	In use has dry season effect
3	HDW	741778	805650	365	3	In use has no dry season effect
4	HDW	741727	805625	376	4.2	In use has no dry season effect
5	HDW (Mosque)	741711	805690	384	3.4	In use has no dry season effect
6	HDW (TR2)	741878	805886	355.9	2.96	In use has no dry season effect
7	HDW (GFM) (TR2)	741976	805870	343.8	0.3	Filled to the surface, little effect during dry season
8	HDW	742012	805948	330.9	0.9	Filled to the surface, little effect during dry season
9	HDW (CC)	741878	805767	359	-	Abandoned no information about it
10	HDW (ESTATE HIGH SCH)	741998	805877	363	4.2	In use & has dry season effect
11	HDW (BGB SCH)	742801	805846	390	3.5	In use & has dry season effect
12	HDW (TR4)	743076	805766	389	3.9	In use & has dry season effect
13	HDW (TR4)	742236	805768	387	4	In use & has dry season

						effect
14	HDW (NGI)	742237	805765	366	2.7	In use & has dry season effect
15	HDW (TR1)	742920	805170	364	3.7	In use & has dry season effect
16	HDW(TR1)	742726	805168	367	3.8	In use & has dry season effect
17	HDW (TR1)	742530	805180	365	3.6	In use & has dry season effect
18	HDW (T1R1)	742342	805240	366	3.9	In use & has dry season effect
19	HDW (TR1)	741875	805882	378	-	Abandoned, not effective, dry off during dry season
20	HDW	742158	805295	360	3.8	In use
21	B.HOLE	742008	805861	361		Fully in use
22	B.HOLE (TR4) OMG	741885	805892	360		In use
23	B.HOLE	741577	806060	371		Fully in use
24	BH (MOPOL BARRACK)	742022	805336	368		Little effect at dry season



(a)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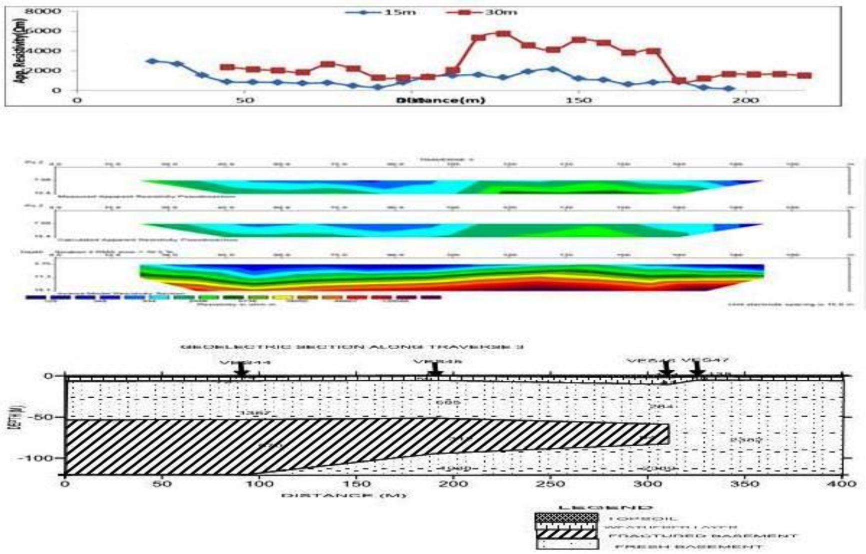
b)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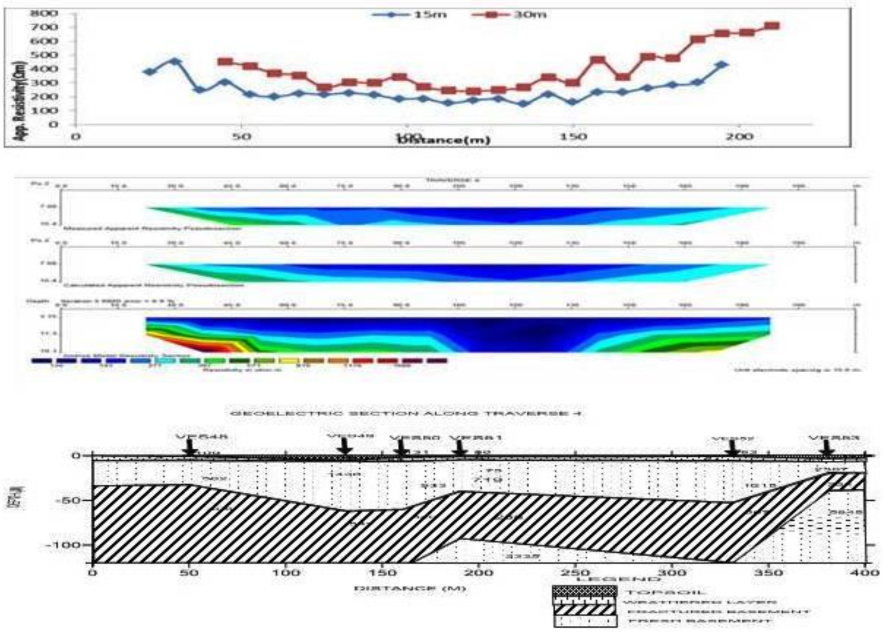
(c)



(d)

Figure 7(a-d): Correlation between the HP profile, 2D-inverse Model and Geoelectric Sections along traverse1, 2, 3&4.

Conclusion

The results of the interpretation of the data obtained from geoelectric exploration for favorable groundwater conditions in hard rock environment of Federal Housing Estate, Akure are presented in this study. Horizontal Profiling (Wenner Array) was carried out along the four established traverse stations using a=15m and a=30m, and a maximum of five subsurface geologic layers were delineated from the 19 Vertical Electrical Sounding stations along the four traverses established (where fractured zones were under probe based on zones of low resistivity values identified by the HP). These include the topsoil, clayey-sand or sandy-clay, weathered layer, fractured basement and fresh basement. Also, another 34 Vertical Electrical Sounding was carried out randomly to have the basic knowledge of the lithologic characteristics of the environment under study. The topsoil resistivity values ranges from 32.0Ωm to 257Ωm and overburden thickness values vary from 0.9m to 5.1m. The weathered layers resistivity values range from 48Ωm to 205 Ωm and thickness values vary from 2.1m to 8.4m. The fractured zones were identified at the deeper depth ranging from 28m to 59m across the four traverse stations. The fracture thickness ranges from 28m to 54m. The fresh basement has resistivity value ranging between 719Ωm to 64167Ωm.The correlation of the results of the HP profiles, HP 2D-Inverse Model Section, Geoelectric section, overburden thickness map, hydrogeological data map and the weathered layer thickness shows that the study area is characterized by good groundwater potential within the hard rock formation. Also, the north-western part of the study area is of favorable groundwater condition for any hand-dug well as a result of the low depth of water static level.

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