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Evaluation of Groundwater Potential of Owerri West and Environs, Southeastern Nigeria Using Resistivity Method

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ABSTRACT: *The groundwater in the study area is believed to be shallow and very vulnerable. This research therefore aims at investigating the potential of deeper aquifer system using Vertical Electrical Sounding. The study area covers Owerri west and Ohaji-Egbema LGA, Imo state, Southeastern Nigeria. It is lies between latitude* $5^o20^{'}0^{''}$ *-* $5^o30^{'}0^{''}$ *N and Longitude* $6^o46^{'}0^{''}$ *–* $7^o04^{'}0^{''}$ *E. A total of Twenty two (22) VES was carried out with maximum value of AB =1000m. Zohdy and interplex software were used to produce the resistivity curve. The study area consists of 6-7 geo-electric layer: topsoil, clay, clayey sand, fine sand, medium sand, coarse sand and gravel. The Aquifer resistivity ranges from 2800Ω-m – 9000Ω-m. The depth to potential aquifer across the study area is between shallow to moderate with the deepest aquifer unit around Eziobodo (259m). The aquifer unit is relatively thick with an average thickness of 87m. Longitudinal conductance ranges from 0.02σ/m – 0.034σ/m). Transverse resistance ranges from 0Ωm- 1400000Ωm. Hydraulic conductivity varies from moderate to high. The Transmissitivity ranges from* $1.124539731m^2/day$ *-* $55.78235216m^2/day$*. Using the aquifer geometric parameter Da-zarouk and Hydraulic parameter, the groundwater potential index map was produce and this classified the area into: Moderate and high prolific zone.*

KEY WORD*: Da-zarouk parameter, GWPI, Hydraulic parameter, Schlumberger configuration, VES*

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I. INTRODUCTION

Potable water is the water that is suitable for drinking and sanitary purposes. The accessibility to potable water is an essential matter all over the world and Owerri is no exception. Within the study area groundwater is the most reliable source of water for drinking and irrigation purposes.

Electrical resistivity method has increasingly found it relevance in groundwater exploration owing to the rapid improvement/availability of iterative software. This method implores the sinking of electrical current into the earth and measuring the resultant potential difference. Measurement of earth resistivity gives importantinformationon the measure of water saturation and connectivity of pore space within the rock. A rock containing air in it pore spaces will record a high resistivity while reverse will be observed in soil containing water in its void spaces [1], [2].

Several studies have been carried out to investigate the subsurface within the study area, all in bid to solve hydrological, environmental and geotechnical problems. Some studies such as [3], [4], [5], [6], [7] and [8]have been carried out on some aspects of the hydrogeology of some part of the study area and they all pointed out the that the groundwater system is shallow and vulnerable.

The study area lies within the southern Nigeria sedimentary basin. The areas cover Owerri west and Ohaji-Egbemasituated within Imo state Southeastern Nigeria. It is lies between latitude $5^o20^{'}0^{''}$ - $5^o30^{'}0^{''}$ N and Longitude $6^o46^{'}0^{''}$ – $7^o04^{'}0^{''}$ E.

Rapid urbanization, industrialization and agriculture has led to continuous contamination of the surface water, hence inhabitant of the area rely greatly on groundwater as a better alternative for water supply. And “the so called groundwater” in the study area is a shallow aquifersystem, hence the groundwater is easily contaminated due to the porous nature of the overlaying geologic materials. This research therefor aims at investigating the potential of deeper aquifer system and evaluating the groundwater potential index using parameters (geo-electric, Da-Zarouk and hydraulic parameters) derivedfrom Vertical Electrical Sounding.

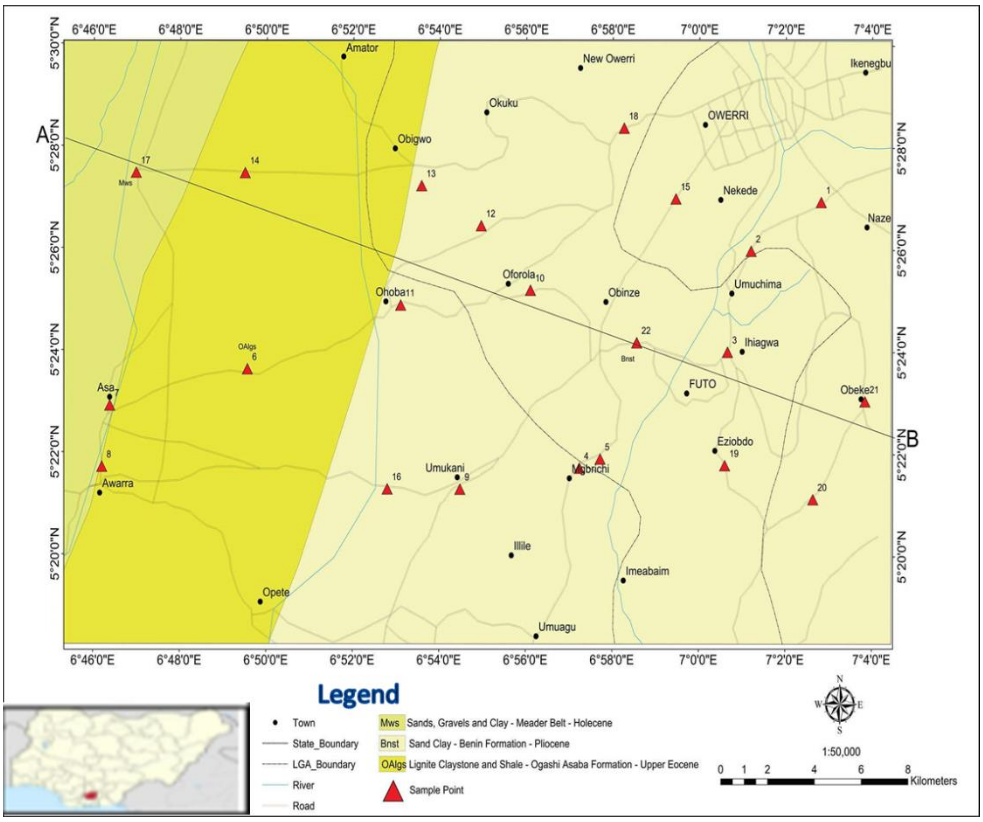


Figure 1: Map showing the geology and VES traverse of the study area

II. Geology

Table 1: Stratigraphic succession in the area (modified after: Adegoke et al, 2017)

Period	Age	Formation	Lithology
Quaternary	Recent	Meander belts	Sand, gravel and clay
Tertiary	Miocene – recent	Benin	Medium- course grain poorly unconsolidated sand with clay lenses and stringers
	Oligocene	Ogwashi- Asaba	Consolidated sands with ignite seams

The study area is composed of both Niger delta basin (Benin Formation) and Anambra basin (Ogwashi/Asaba Formation). This is characterized by three major packages. The Ogwashi/Asaba Formation is observed to be the oldest and is overlain by the Benin Formation. The Benin Formation is overlain by recent Meander sand belts. The stratigraphic succession is shown in Table1above.

III. Methodology

A total of 22 VES was carried out using AbemTerrameter SAS 4000 with maximum AB/2 of 500m. This techniqueallows the shooting of electrical current deep into the subsurface through a duo of current electrodes and themeasurement of the subsequent potentials through potential electrodes. Because the current and potential difference is known, the equipment therefore calculates theresistance. Thereafter, the apparent resistivity can be estimated by multiplying the resistance with the geometric factor. The resistivity of any subsurface earth material is influenced by the magnitude of the current, the observed potential difference, and the geometry of the electrode configuration adopted. Likewise, the depth of investigation is influenced by the geometry of the Schlumberger array used and the maximum spread of AB/2. For any electrode configuration adopted the apparent resistivity is given as. The basic equation is:

$$\rho a = 2\pi G\left(\frac{\Delta V}{I}\right) \qquad (1)$$

$$K = \pi\left(\frac{a2}{b} - \frac{b}{4}\right) \qquad (2)$$

Where "a" is the current electrode separation and "b" is the potential electrode separation.

The collected data was plotted on a bi-log graph of apparent resistivity against half current electrode spacing using computer iterative software (Zohdy and interplex 1D).

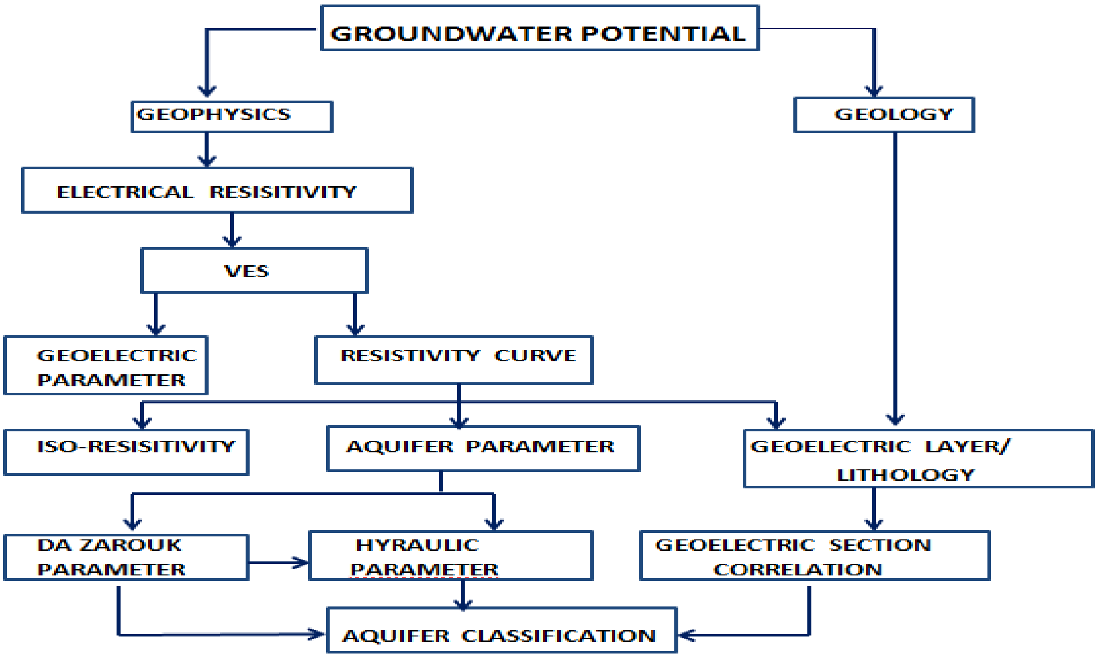


Figure 2: Flow chat of the methodology

3.1Groundwater potential Index

After the careful estimation of Da Zarouk and Hydraulic parameters from the VES data, [10] Groundwater potential index was adopted for classifying the groundwater system, for this to be obtainable the following assumption were made.

3.1.1Assign Weight to parameters

The parameters were assigned different weight (between1-3, see Table 2) taken into account their of degree relevance in groundwater exploration. The most relevant parameters were assigned a weight of 3while the least were assigned a weight of 1. Parameters like aquifer litholgic unit (L) and thickness (b) is assigned 3 because they have a great influence on the porosity and permeability of an aquifer. While depth was assigned the least weight (see Table 2).

3.1.2Ratings/categorization to parameters values

Aquifer parameters were assigned different rating (1-3) depending on their magnitude. For example aquifer unit with thickness of above 100m were assigned a rating of 3 since the thicker the aquifer the better it water potential. Table 3 shows parameters and their ratings.

3.1.3Establish cutoff

To establish the cutoff, the maximum GWPI was first calculated. Since there are six (6) parameters and the GWPI is the cumulative of the product of weight with rating, the maximum GWPI is given as $3^2 * 6 = 56$. 3 classes was therefore established, 25<moderate>30 (since half of 56 lies between 25-30) <25 as low and >30 as high (see Table 4).

3.1.4Estimate GWPI

Groundwater Potential Index is given as the cumulative of the weight and the ratings (3). GWPI was therefore calculated for different areas (different VES point).

$$GWPI = L_w*L_r + b_w*b_r + T_w*T_r + K_w*K_r + \rho_w*\rho r + Z_r*Z_w \qquad (3)$$

Table 2: Summary of GWPI parameter and their assigned weight (modified after Amah et al 2012)

Parameters	Weight
L, b	3
T, K, ρ	2
Z	1

Where w=weight and r= rating for GWPI, k= hydraulic conductivity, b= aquifer thickness, L=aquifer unit, T= hydraulic transimissvity, Z= aquifer depth

Table 3: Summary of GWPI parameter and their rating (modified after Amah et al 2012)

Rating(r)	3	2	1
L	Coarse-medium Sst	Fine Sst	Clayey sand
b	>100	100 – 50	< 50
T	> 5000	500 -5000	<500
P	<5000	5000 - 10000	>10000
Z	>120	120 – 50	<50
K	>0.05	0.05 – 0.03	<0.03

Table 4: Cut off

Cut off	Class
< 25	Low
25 – 30	Moderate
>30	High

IV. Result And Discussion

The Vertical Electrical Sounding (VES) curves are presented (in appendices).The curve type varies ranging from simple: HA, AA, AH to complex type: AKA, HAK, AHAH, AHAK, AAK. The general sequence of the entire curve types indicates a sequence that alternates between resistive to conductive layers. The VES result was compared with geology to infer the geo-electric layers of the study the area. 7- 6 geo-electric layers was identified they include; top soil, clay, clayey sand, fine sand, medium sand, coarse sand, gravel and wet gravel.

4.1 Aquifer geometric parameters (Aquifer depth, thickness and resistivity)

The depth to the potential aquifer ranges from 30m – 259m at VES 12 and VES 19 respectively (see figure 3). The area marked with blue indicates shallow depth to aquifer unit and it can be found at the Northwestern end of the study area. The area marked with red and yellow indicates area of deep aquifer depth which can be seen at the Eastern part of the study area. The depth to the aquiferous unit is generally shallow with an average depth of 36m to the top of the aquifer and 178m to the bottom of the aquifer.

The Aquifer thickness ranges from 20.9m – 145m at VES 13 and VES 16 respectively, with an average thickness of the 87m. The resistivity ranges from 2800Ω-m – 52000Ω-m as seen at VES 18 and VES 2respectively.

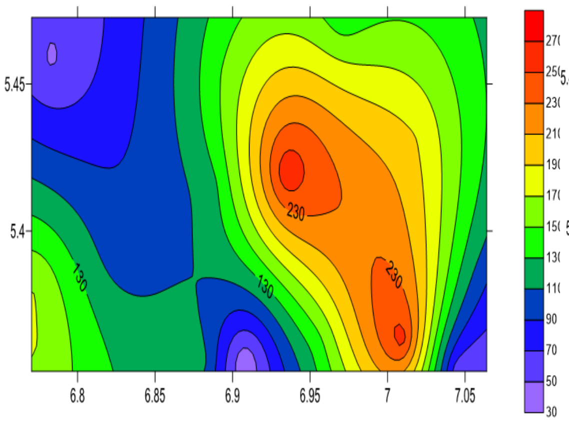


Figure 3: Aquifer depth map Depth

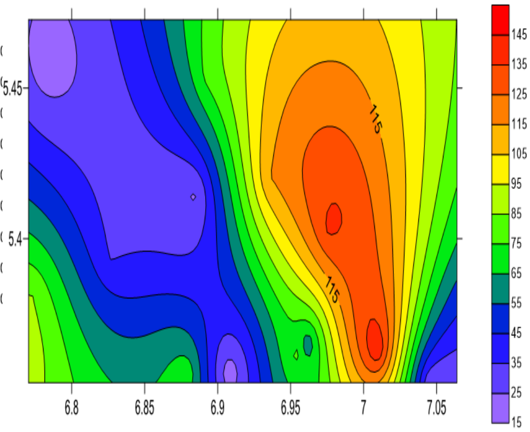


Figure 4: Aquifer thickness map

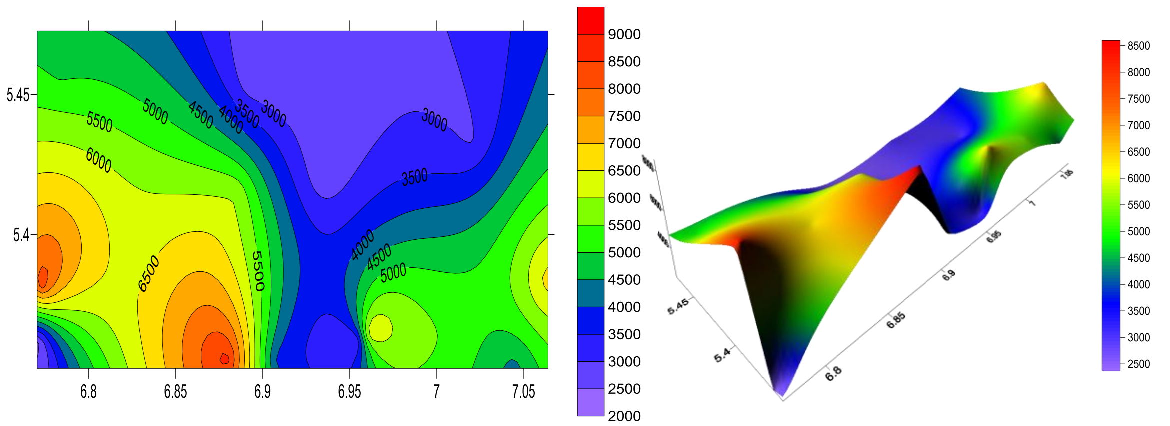
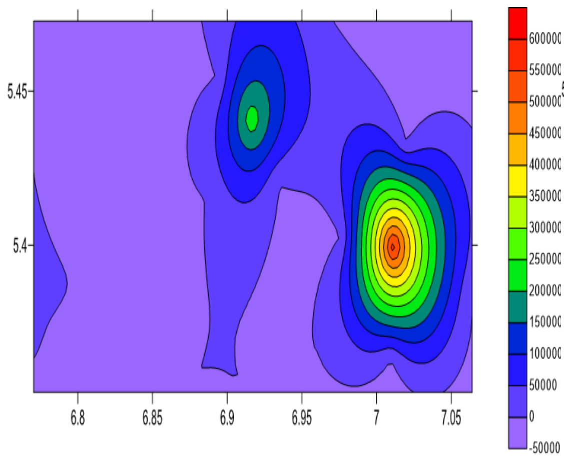


Figure 5: 2-D/3-D model of Aquifer resistivity (Ω-m) of the study area

4.3 Dar-Zarrouk parameters (Transverse resistivity and longitudinal conductance)

The transverse resistance (t_r) was obtained by simply taking into account the product of both the aquifer resistivity and aquifer thickness, while the longitudinal conductance (S) was estimated by dividing the aquifer thickness by the aquifer apparent resistivity. Fig 6 and 7 above showed similar distribution trend of both the transverse resistance and the longitudinal conductance. Relatively low values of t_r and S were seen at the western part of the study area while the Southeastern parts houses relatively high t_r and S.



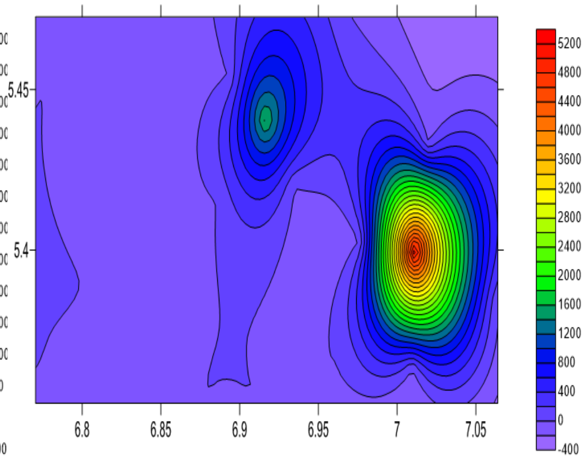


Figure 6: Aquifer transverse resistance map **Figure 7**: Aquifer longitudinal conductance (σ/m)

4.4Hydraulic parameter (Hydraulic conductivity and transmmissivity)

The hydraulic conductivity is used to describe the ability of a material to conduct fluid under a unit hydraulic gradient [11]. The Hydraulic conductivity is usually estimated from pump test of the borehole around the area. However, in this research work, it is pertinent to note that the hydraulic conductivity was estimated using Heighold method [12]

$H= 386.4R^{-0.93283}= k$ (4)

Where R= resistivity of the aquiferous unit

K = hydraulic conductivity

$T=K\sigma t_r =KS/\sigma =Kb$ (5)

Hydraulic conductivity was estimated using (5) above. T is the aquifer transmissivity, K is the hydraulic conductivity, b is the aquifer thickness, t_r is the transverse resistance of the aquifer, and S is the longitudinal conductance. S andt_r are often referred to as the Dar-Zarrouk parameters the above (5) was established using [13]. The calculated aquifer hydraulic parameters from Dar-Zarrouk parameters are shown in Fig 8 and 9 below.

The transmmissivity values varies from one location (VES point) to another although the study due to the variation in the geologic Formation of the area (Benin Formation and OgwashiAsaba formation).This also implies variations in the groundwater potential of the study area. High transmissivity and hydraulic conductivity is observed in the middle of the study area which is an indication of good groundwater yielding proficiency. The transmissitivty of the study area ranges from (1.124539731m^2/day - 55.78235216m^2/day) as seen at VES11 and VES 18 respectively.

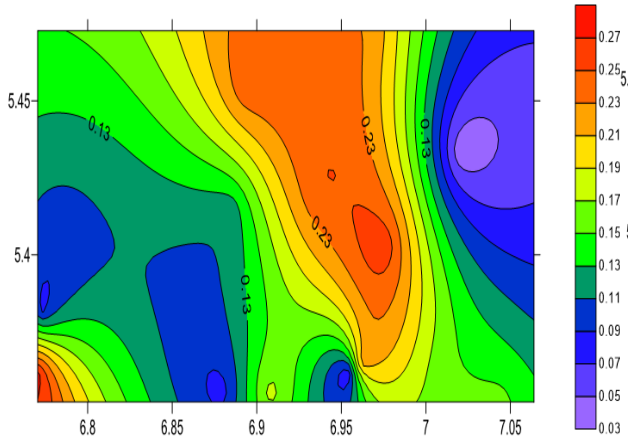


Figure 8: Map of aquifer hydraulic conductivity

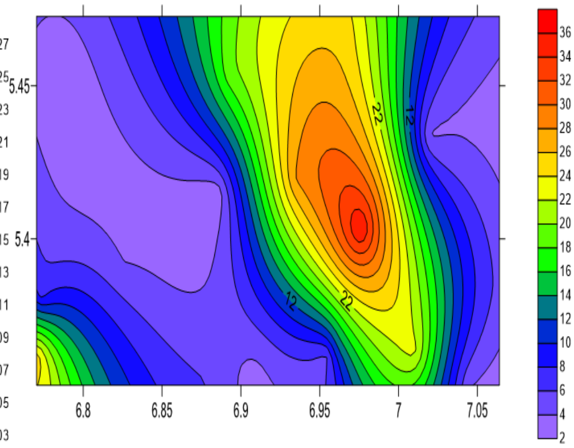
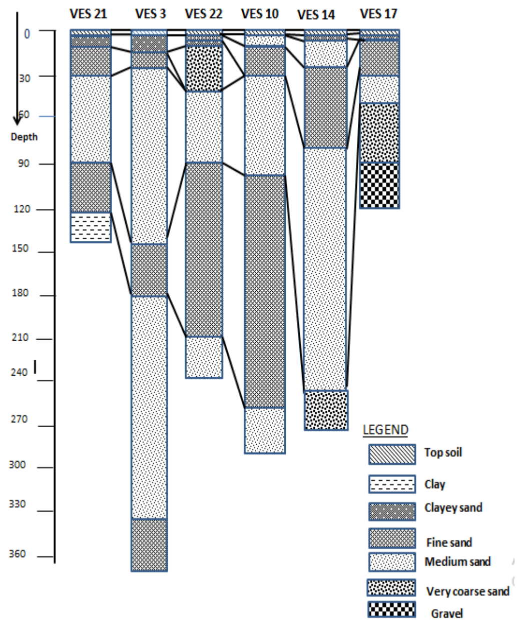


Figure 9: Map of aquifertransmissitivity

4.5 Geo-electric layers and correlation

The profile section (A-B)established in the study area runs through the Southwest-Northeast direction and it traverses through VES 21, VES3, VES 22, VES10, VES14 and VES 17. The VES in this profile consist of 6-7 layers made up of: top soil, clay, clayey sand, fine sand, medium sand, coarse sand and gravel. The clay ranges from 18.5Ωm- 73.2Ωm, clayey sand ranges from 202Ωm- 970Ωm, fine sand ranges from 1120Ωm-2880Ωm, medium sand ranges from 3345Ωm- 9700Ωm, coarse sand ranges from 12,100Ωm- 24,600Ωm and gravel ranges from 30,000Ωm – 52,00Ωm. The Aquifer unit of this profile is medium-coarse sand and the aquifer depth are relatively shallow expect for VES 14. The aquifer across the profile is thick enough to yield prolific water and VES 14 has the thickest aquifer unit.



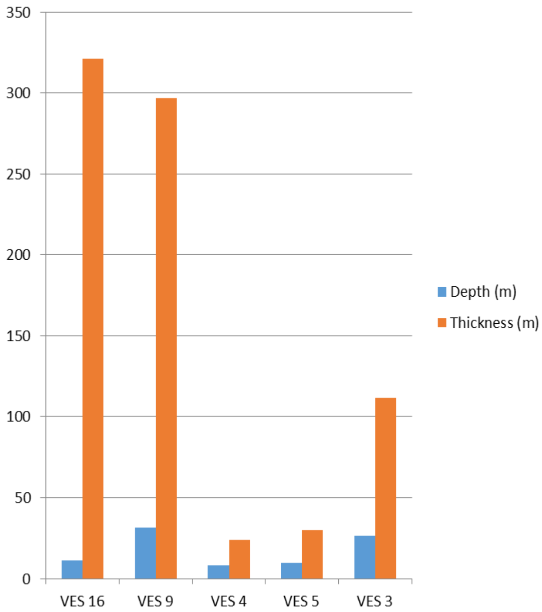


Figure 10: Geo-electriccorrelationfor A-B **Figure11**: Aquifer thickness-depth plot for A-B

4.6 Iso-resistivity model across the area

Table 3: Summarized tableof Iso-resistivity data of the study area

VES NO	LOCATIONS	LONGITUDE (E)	LATITUDE (N)	AB/2 =10	AB/2 =20	AB/2 =30	AB/2 =50	AB/2 =75	AB/2 =100	AB/2 =160	AB/2 =220	AB/2 =280	AB/2 =370	AB/2 =450	AB/2 =500
1	NAZE	7.047	5.449194	384.4	1500	2000	2700	3200	3100	2800	3192	3191.5	3409.7	3000	2459.0
2	NEKEDE	7.019917	5.433444	91.1	200	300	400	620	800	1200	1800	2726.6	2800	3000	4582.5
3	IHIAGWA	7.011028	5.399600	198.6	226.8	360	570	860	1100	1300	1760	2049.4	3177.9	2600	2346.2
4	MGERICHI	6.954111	5.361806	285	505	940	1780	2000	2200	2600	30000	2066.2	2884.1	6000	9840
5	PH/OWERRI	6.961667	5.365167	1018.1	1200	1780	1934	2061.5	2200	1944	1240	1705	2265	2300	2435.8
6	AWARRA-OHOBA	6.826389	5.393528	2561.3	4000	4998.8	4841	4724	5000	3598	8851	8775	17076	20000	30598
7	ASA	6.772944	5.381806	780	1200	2300	3547	3800	4200	4235	5800	4919	8897	8500	8279
8	AWARRA	6.770444	5.361611	1087	1300	1900	2700	3600	4300	6000	7000	4735	5373	4000	4295.6
9	UMUOKANNE	6.907861	5.355222	102	1500	200	400	770	800	1137	1493	2200	3425	3600	4000
10	OFOROLA	6.934611	5.419722	2126	3100	2907	3044	3000	2900	2781	3100	2720	3000	30040	3092
11	OHOBA	6.885389	5.414944	380	600	900	1300	2617	2800	4426	4500	8368	9964	9850	9647
12	OBOSIMA OHAJI	6.916167	5.4405	180	340	554	766	767	883	885	710	1580	1673	1270	441
13	OBIGWE	6.892528	5.454083	945	1200	1830	2532	2513	2774	2750	2709	2876	3342	3400	3431
14	ADA PALM-AMAFOR	6.825	5.458222	1200	1850	2678	3119	3180	2888	3000	3003	3000	3986	4100	4550
15	AVU-JUNCTION	6.991	5.449833	818	1300	1672	2700	3606	4000	4883	4993	4707	7184	9000	26980
16	UMUOKANE-AWARA	6.879611	5.355472	2659	2900	3700	4300	4851	6279	7000	7951	9679	7378	8000	9176
17	ETEKWURU	6.783194	5.457556	480	750	1076	1400	1447	2500	2677	6383	6239	7884	10000	25558
18	UMUGUMA	6.970722	5.472694	230	400	761	828	1000	1250	1992	2124	2029	1955	1700	1679
19	EZI OBODO	7.009722	5.362944	1200	1800	2412	3150	3732	3934	3499	3473	3059	4578	4430	3231
20	EZI OBODO-OGBEKE	7.044472	5.352222	4000	5300	6176	6639	7280	8000	10789	13908	23260	11235	1145	11663
21	OGBEKE	7.063944	5.383639	688	800	1205	1370	1502	1800	2054	2543	2097	1589	1200	656
22	OBINZE-FUTO	6.975944	5.402972	1354	2000	3007	4000	4970	5500	7000	6700	3499	4137	4800	4920

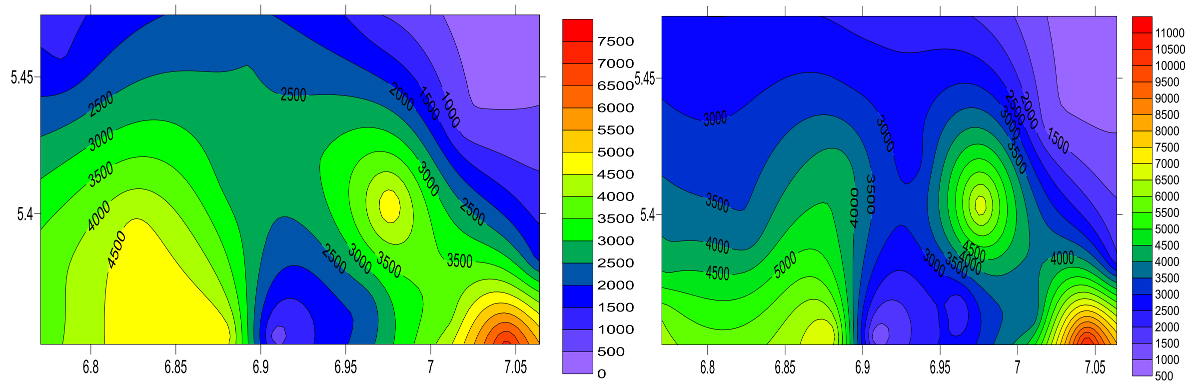


Figure 12: Iso-resistivity map at AB/2 = 75m and 160m

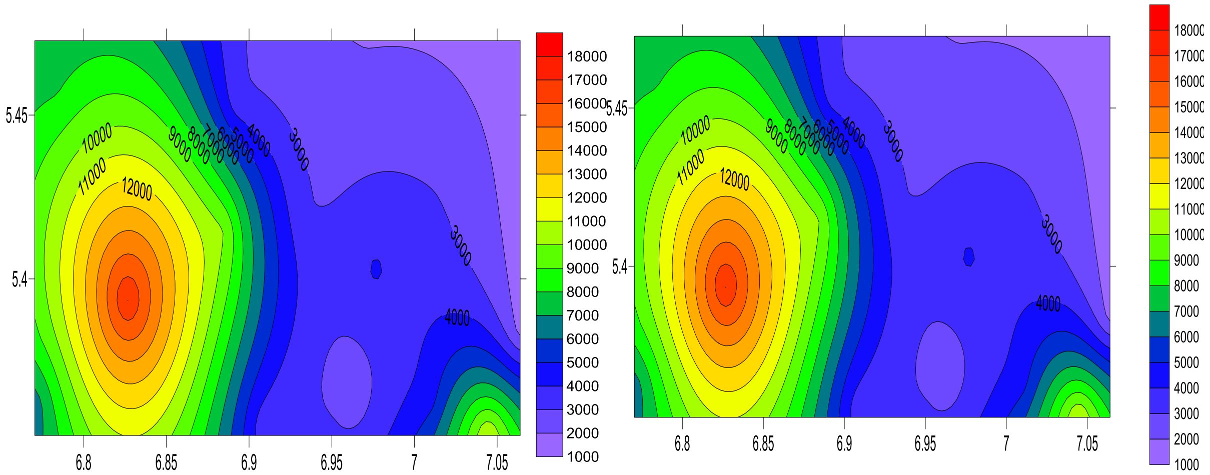


Figure 13: Iso-resistivity image map at AB/2 = 370m and 500m

From the iso-resistivity map above it could be seen that the resistivity is relatively moderate at shallow depth (AB/2=75 and 160m) and highest along the Southeastern and Southwestern end. And with deeper depth resistivity values across the area increased significantly (AB/2= 370m and 500m) with the highest values around the West ward section.

4.7 Groundwater Potential Index (GWPI)

This GWPI was estimated using aquifer geometric, Da Zarouk and Hydraulic parameters. And this categorically divided the investigated area into two (high and moderate) based on their estimated GWPI. High groundwater potential zone includes: VES 13,VES12, VES22, VES 5, VES 4, VES 19, VES 20, VES 10,VES 3,VES 2, and VES15, while the moderate prolific zone are: VES 17, VES 14, VEX 11, VES 6, VES 9, VES 8, VES 16, VES 20, VES 21 and VES 1.

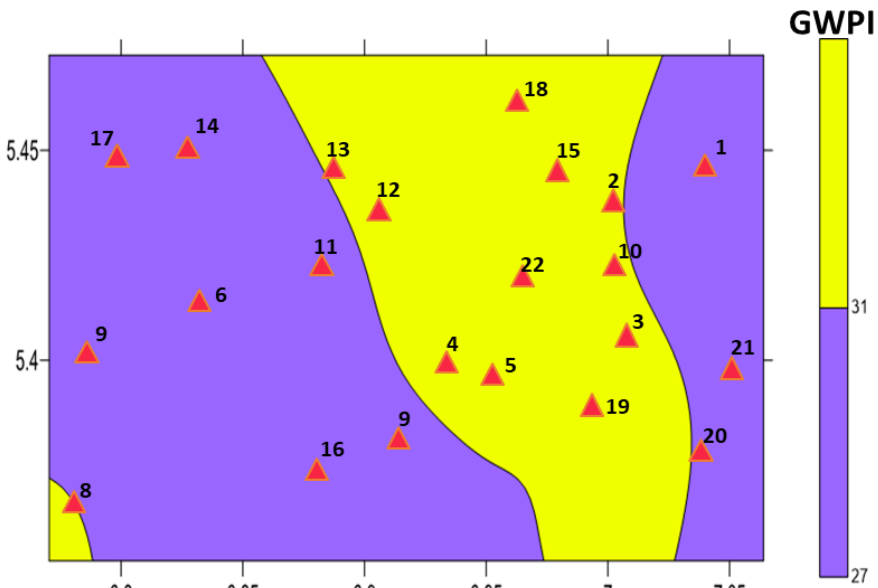


Figure 14: GWPI map of the study area

V. Conclusion And Recommendations

5.1 Conclusion

The results show that the study area is dominated by sand and clay packages within the Benin Formation. And clay with sand and silt packages within the Ogwashi-Asaba Formation. The iso-apparent resistivity maps show that these lithologic units occur at varying thicknesses as different pockets of resistivity were recorded. The Groundwater Potential index map showed that the Groundwater Potential of the area is between high – moderate with the highly prolific zone coinciding with the Benin Formation and the Moderate prolific zone coinciding with the Ogwasi-Asaba Formation.

5.2 Recommendations

Having carefully carried out this research, the following recommendation can be made:

1. The design of the casing system of those shallow aquiferous areas must be carefully completed and properly grouted to avoid contamination of the groundwater system.
2. Since the aquifer unit of the study area is majorly shallow, the use of filters and treatment plant are encouraged.
3. For areas with multiple aquiferous units, deep aquifer should be targeted in other to avert the chances of tapping the contaminated water.

References

[1]. A.S.Ogungbe, J.A.Olowofela, O.O.Oresanya, and A.A. Alabi, Archives of Applied Science Research, 2(2),(2010), 24-3.

[2]. A.R.Zohdy, Application of Surface geophysics (electricalmethods to groundwater investigations) in techniques for water resources investigations in the United States. Section D, Book 2:1976, 5–55.

[3]. R. E.Iduma, and T, K. S.Abam,Groundwater exploration in parts of Afikpo Town, Southeastern Nigeria using GeoelectricalSounding.Water Resources, Journ of Nig. Assoc of Hydrogeologists, 20(2),2010, 29-42.

[4]. C.A Ahiarakwem,and O. G. Ejimadu, Geochemical properties of Groundwater in Orlu Area of Imo State, Southeastern Nigeria. Water Resources Journal of Nigerian Assoc. of Hydrogeologists (NAH), 13 (1),2002, pp1-22.

[5]. N.A.Akpoborie, A.A.Nfor,I.Etobor,and S. Odagwe, Aspects of the Geology and groundwater conditions of Asaba, Nigeria. Arch. Appl. Sci. Res. 3(2), 2011, 537-550.

[6]. A.C. Ekwe, and A.I.Opara, Aquifer transmissivity from surface geoelectrical data: a case study of Owerri and Environs, Southeastern Nigeria. J GeolSoc India.2012,355–378.

[7]. A.Usman, U.A.Ojonugwa, O.K.Iheme, C.A Ifeanyi, O.F.Onyekwelu, and O.C. Chukwunonso, Hydrogeological Implications of Environmental Devastation in Orlu and Its Evirons South Eastern, Nigeria. Journal of Environment and Earth Science.Vol.4(1), 2014,216-224.

[8]. I. Ibeneme, C.N.Okereke, C.Iroegbu, E.O.Etiefe, Vertical Electrical Sounding for Aquifer Characterization around the Lower Orashi River Sub-Basin Southeastern Nigeria. Journal of Communications in Applied Sciences.ISSN 2201-7372. 2(1),2014, 36-51.

[9]. O.Adegoke, A.Oyebamji, J.Edet,O. Ulu, and P.Osterloff, Cenozoic Foraminifera and Calcareous Nannofossil Biostratigraphy of the Niger Delta.2017. 25-66.

[10]. E.A.Amah,A. N. Ugbaja,, and E. O. Esu,, Evaluation of Groundwater Potentials of the Calabar Coastal Aquifers.Journal of Geography and Geology.4 (3),2012, 130-141.

[11]. C.W. Fetter, Applied Hydrogeology, 3rd ed.: Macmillan College Publishing, Inc., New York, 1994. 616-623.

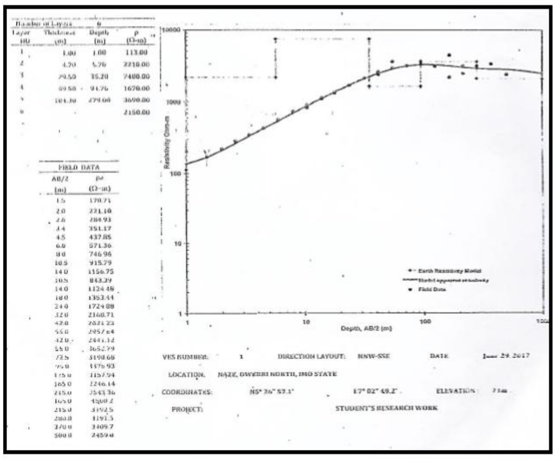
[12]. P. C.Heigold, R. H.Gilkeson, K. Cartwright, and P. C. Reed, Aquifer transmissivity from surficial electrical methods. Ground Water 17(4),1979, 338- 345.

[13]. S.Niwas, D.C. Singhal, 1. Estimation of aquifer transmissivity from Darzarrouk parameters I a porous media. Journal of Mining and Geology, 20(1),1981, 131-146.

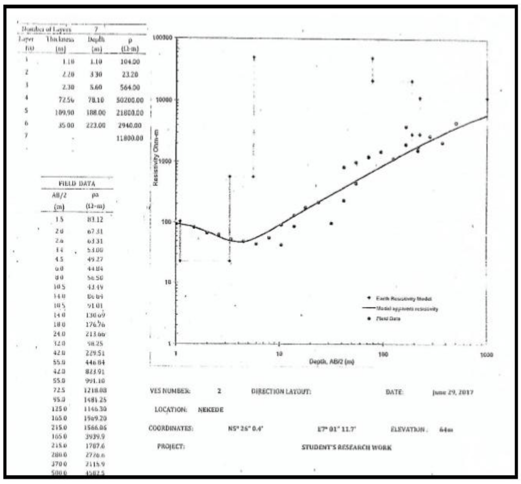
APPENDIX

MODELED GEOELECTRIC FIELD CURVES

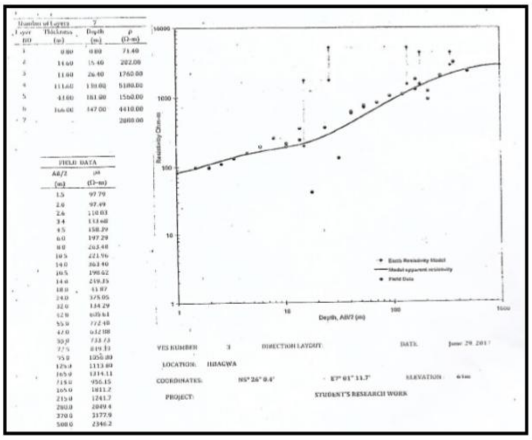
VES 1- NAZE



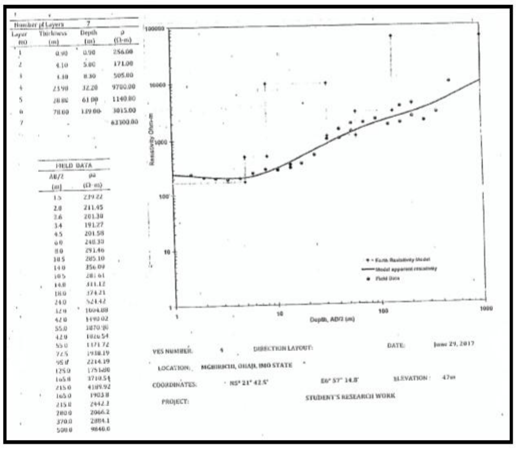
VES 2- NEKEDE, OWERRI



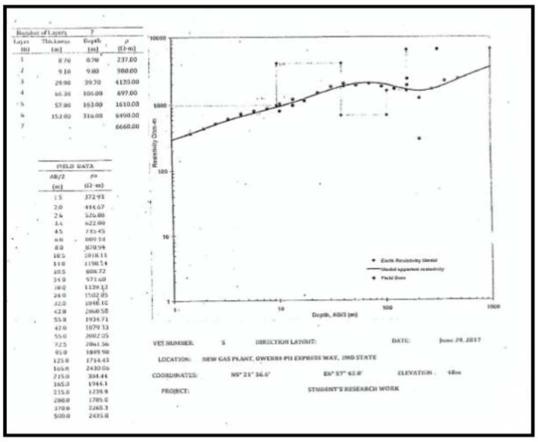
VES 3 – IHIAGWA, OWERRI



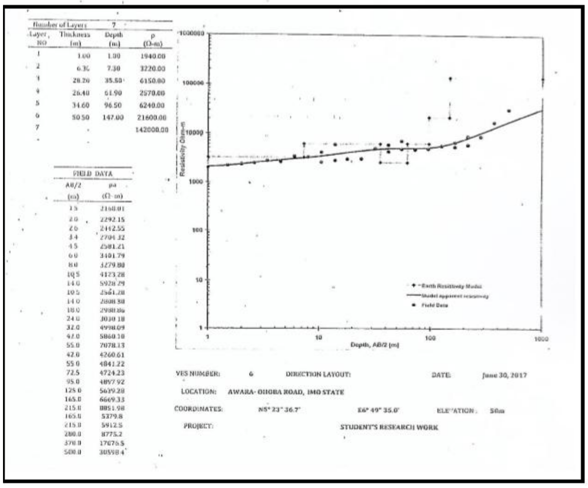
VES 4 – MGBIRICHI, OHAJI



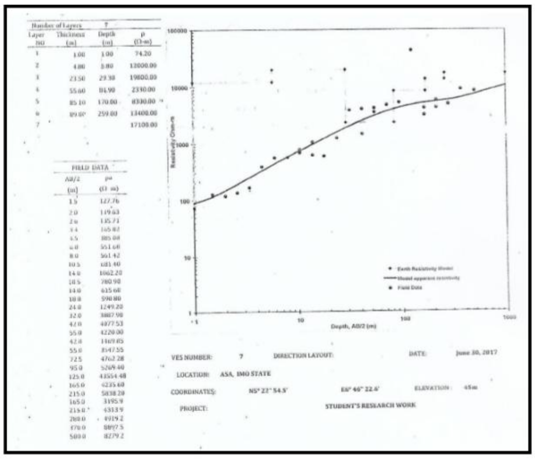
VES 5 –NEW GAS PLANT, OWERRI-PH EXPRESSWAY



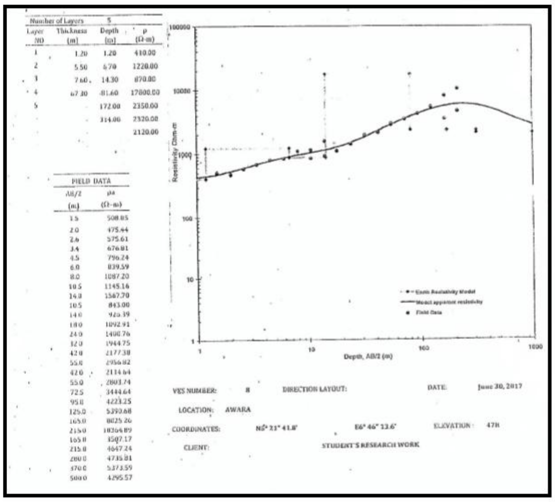
VES 6- AWARA-OHOBA ROAD



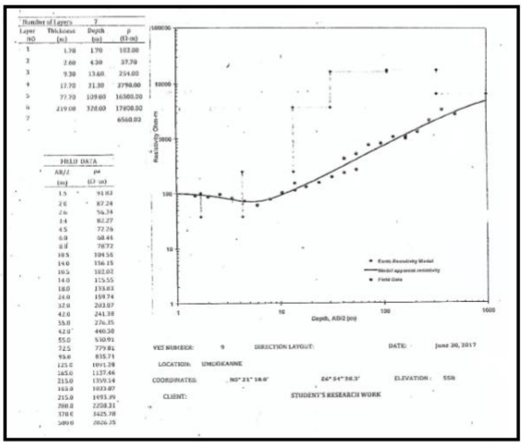
VES 7- ASA, OHAJI



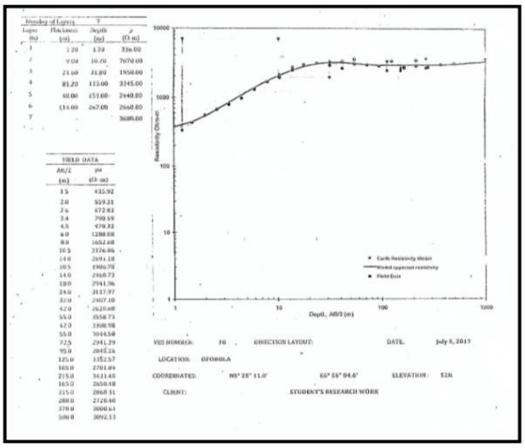
VES 8- AWARA, OHAJI



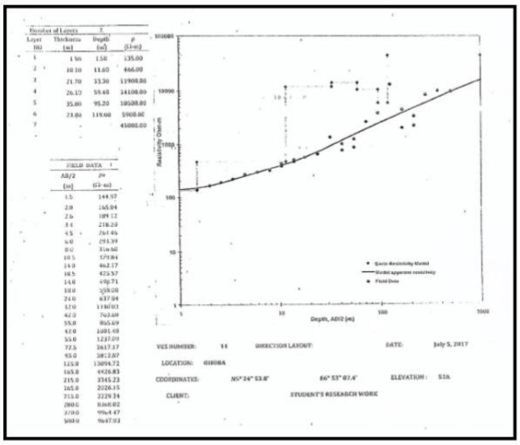
VES 9- UMUOKANNE



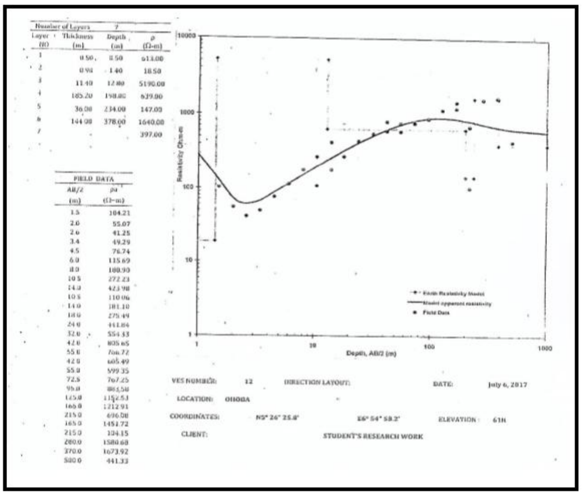
VES 10 – OFOROLA



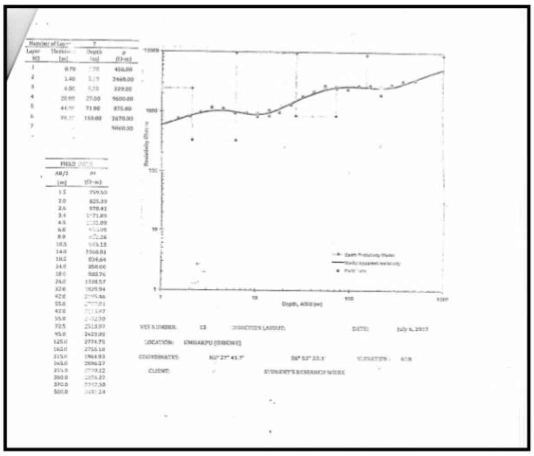
VES 11- OHOBA



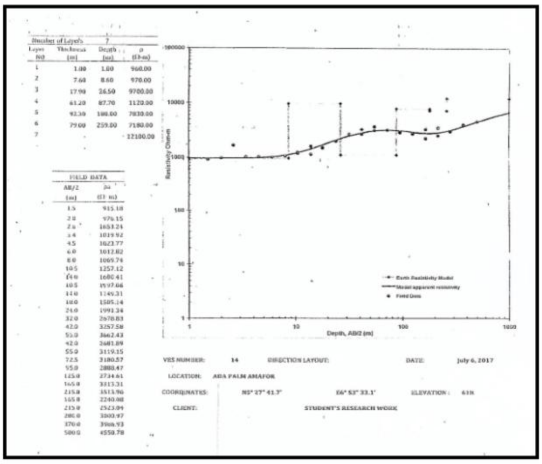
VES 12 – OBOSIMA, OHAJI



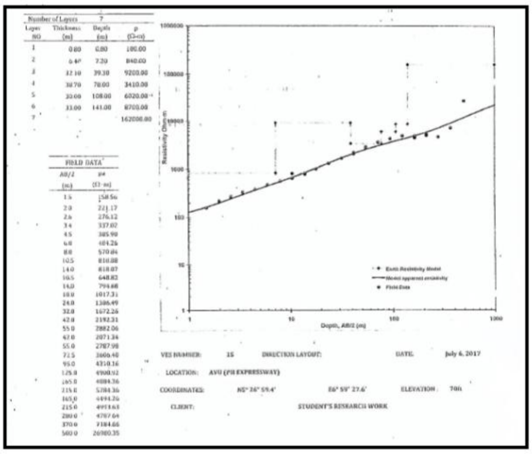
VES 13 – UMUAKPU (OBIGWE)



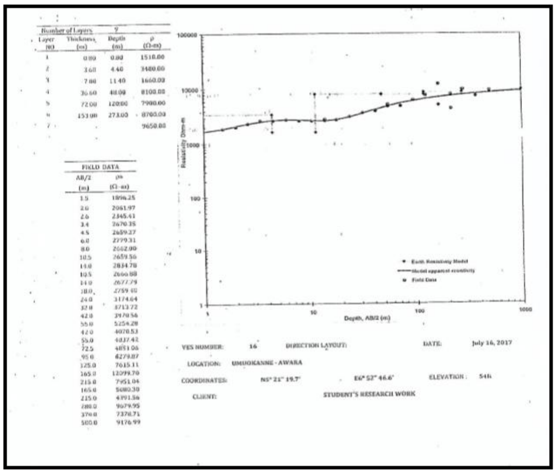
VES 14 – ADA PALM AMAFOR



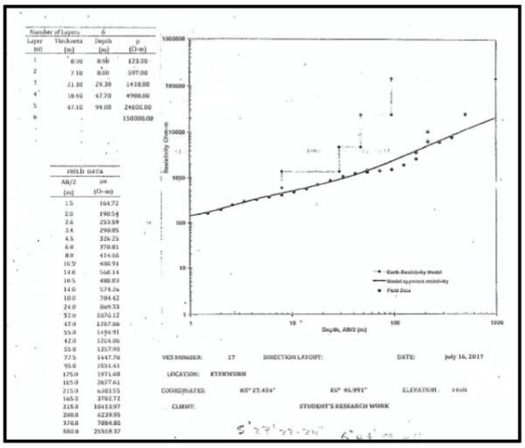
VES 15 – AVU (PH EXPRESSWAY)



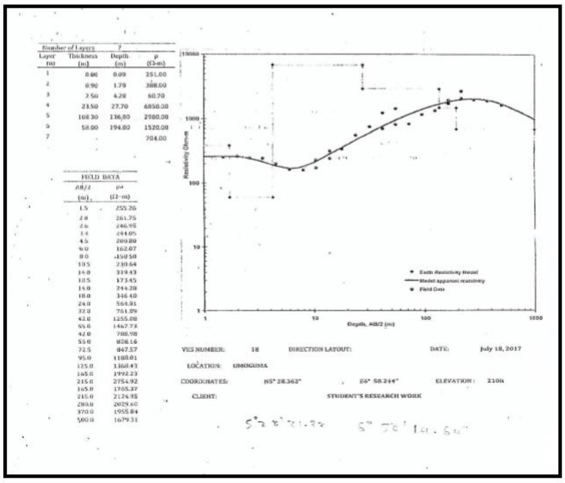
VES 16 – UMUOKANNE AWARA



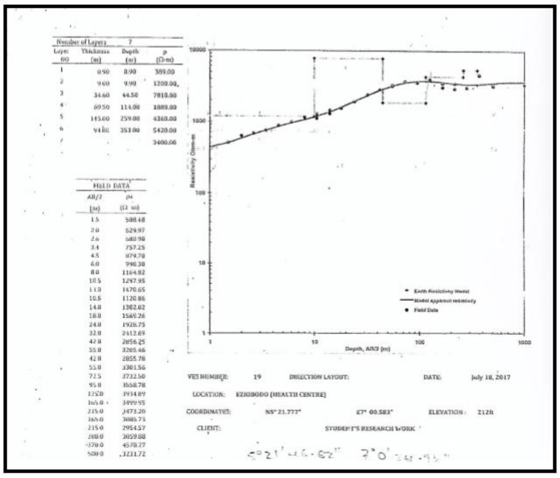
VES 17- ETEKWURU



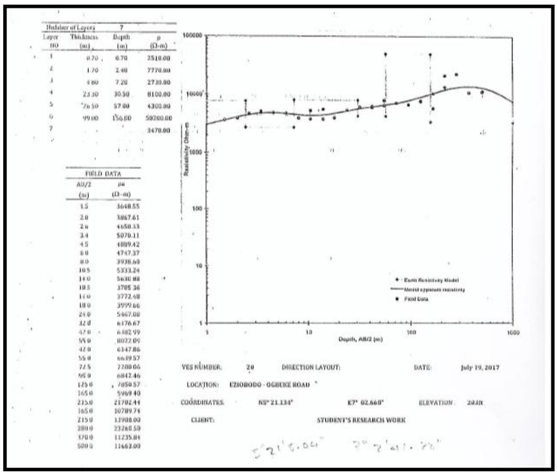
VES 18 – UMUGUMA



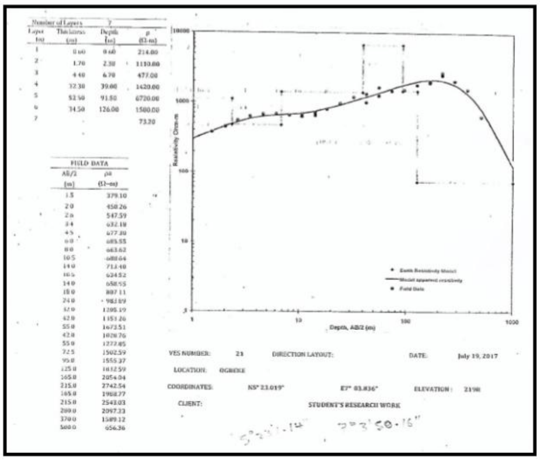
VES 19 – EZIOBODO HEALTH CENTER



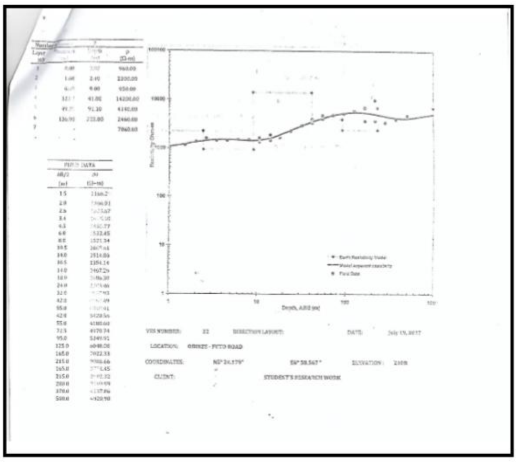
VES 20 – EZIOBODO-OGBEKE ROAD



VES 21 – OGBEKE



VES 22 – OBINZE FUTO-ROAD



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