SEISMIC REFRACTION PROFILING AND VERTICAL ELECTRICAL SOUNDING FOR GROUND WATER STUDY IN OBIARUKU, DELTA STATE NIGERIA

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ABSTRACT

Seismic refraction profiling and Vertical Electrical Sounding (VES) were adopted in Obiaruku, the Head-quarter of Ukwuani local Government Area of Delta State, Nigeria for the purpose of delineating the groundwater potentials in the sedimentary region of the area. The instrument used are the 24 channel Seismograph and Abem Terrameter model SAS 1000AB. The survey carried out with the VES has a maximum current electrode separation of 800m. Three to four distinct geoelectric layers were observed namely topsoil, sand, clay, silt and fine grained sand with resistivities varying from 80.0Ωm to 2500.0Ωm and thickness from 0.8m to 35.7m. The seismic section shows two layers with first layer showing sand while the second layer shows clay or fine grained sand. The results of the survey have enabled the delineation of the groundwater potentials in the area. Viable boreholes for portable groundwater should be sited in locations one, three and five having a fine aquifer at 11.0m respectively.

Keywords: *Vertical Electrical Sounding, Seismic Refraction, aquifer, geoelectric section and first break.*

1. INTRODUCTION

The Seismic method is by far the most important geophysical technique in terms of cost effectiveness, high accuracy, high resolution and great penetration of which the method is capable. Seismic methods is principally use in exploring for petroleum. It is also important in groundwater searches and in civil engineering especially to measure the depth of bedrock in connection with the construction of large buildings, dams, highways and harbour surveys (Telford et al 1974).

Seismic techniques have had relatively limited utilization, due to their relatively high cost and the difficulty of acquiring and interpreting seismic data in strongly faulted and altered igneous terranes, in mineral assessments and exploration at the deposit scale. The refraction method has been used in mineral investigations to map low-velocity alluvial deposits such as those that may contain gold, tin, or sand and gravel.

The information typically required for groundwater studies includes the spatial distribution, quality, and hydraulic properties of subsurface water reserves. Much of these data must be obtained indirectly, using knowledge of the locations of aquifers and their lithological properties, such as porosity, permeability and degree of saturation, acquired from the findings of geophysical surveys (Geissler, 1989). As the population of Abraka and the University community increase, groundwater resource evaluation and management become increasingly important, the requirements of hydro-geologists for detailed and specific geologic information are growing rapidly. The survey is aimed at mapping aquifer sediments directly in order to determine the suitability of the area for a proposed water supply augmentation program involving surface recharge of aquifers outcropping in the area.

Refraction experiments are based on the times of arrival of the initial ground movement generated by a source recorded at a variety of distances. Later-arriving complications in the recorded ground motion are discarded. Thus, the data set derived from refraction experiments consists of a series of times versus distances. These are then interpreted in terms of the depths to subsurface interfaces and the speeds at which motion travels through the subsurface within each layer. These speeds are controlled by a set of physical constants, called elastic parameters that describe the material.

When water infiltrates the ground, gravity pulls the water down through the pores until it reaches a depth in the ground where all of the spaces are filled with water. At this point, the soil or rock becomes saturated, and the water level which results is called the water tables. The water table is not always at the same depth below the land surface. During periods of high precipitation, the water table can rise. Conversely, during periods of low precipitation and high eva-potranspiration, the water table falls. The area below the water in the saturated zone is called groundwater. The area above the water table is the unsaturated zone. Ground water is found in aquifers which consist of soil or rock in the saturated zone that can yield significant amounts of water.

The Vertical Electrical Sounding was equally used for this study because the instrumentation is simple, field logistics are easy and straight forward while the analysis of data is economical and less tedious (Zhody et al, 1974) Vam Verneeren, 1989, Olurunfemi et al 1999, Omosuyi et al 2008, Ayolabi, 2005 and Oladapo et al 2004.

The geophones receive the Seismic waves after a travel time of several milliseconds depending on source, distance and earth conditions. The geophones convert these ground vibrations to electrical signals and pass them to the analog-to-digital converter. Further readings on Seismic profiling could be seen from the work of Camales, 1984, Chase 1992, Yilmazi, 1988 and Aki, 1969.

2. GEOLOGY OF NIGER DELTA

Obiaruku is a town in Niger Delta. The Niger Delta is located on the West Africa continent margin where the East trending Equatorial coast turns south towards the Equator. It underlies the coaster plain, continental shelf and slope of Nigeria and Western Cameroon and the Northern Territorial water of Equatorial Guinea, west of Bioko Island. The part of the delta in western Cameroon and Equatorial Guinea is known as the Rio del Rey Basin.

The tertiary delta lies south of the West Africa shield and west of the Oban Massif and Tertiary Cameroon Volcanic trend. The delta is located east of the Benin Basin, and its southern margin is marked by seafloor escarpments that lie over oceanic crust.

The Niger Delta is a coarsening upward regressive sequences of Tertiary classtics that prograded over a passive continental margin sequence of mainly cretaceous sediments. The site of the Niger Delta was established at the initial rift separation of the African and the South American plates from Jurassic to Neocomian times.

The tertiary delta basin is represented by a strong diachromous sequence (Eocene – Recent) the lithologies of the surficial materials show evidence of the variety of depositional environment that include marine, deltaic, estuarine, lacustrine and fluvial (Wright, 1968).

In addition, the entire state is underlain by three lithostratigraphic units, starting with the unconsolidated coastal plain sands (Benin) formation at the top. This is made of contimental sands and gravels with thickness of about 0 – 213m. This is followed by the intervening unit of sandstone and shale called Agbada formation with thickness ranging from 305m to 4572m. Finally, the Akata formation which represents continental, paralic and marine depositional environment is made of marine shales and clays with some turbidite sand bodies having thickness of about 610m to 6096m.

LOCATION

Obiaruku is the headquarters of Ukwuani Local Government Area of Delta State. It lies within latitudes 5^o51^1N and 5^o52^1N and longitudes 6^o12^1E and 6^o18^1E. It is bounded in the north by Obi – Obeti, south by Abraka, east by Utagba-Uno and Amai communities while in the west by River Ethiope. The soil is whitish brown in colour and is very fine in nature. The community obtains water from the Ethiope River about 200 m to 2km from the town depending on the location. They practice subsistence farming.

The area is a hot/wet equatorial climate region made of two main seasons, the wet and dry season. The wet season begins from April and ends in September while dry season begins from October and ends in March. The study area has a direct recharge from rainfall, the rate of infiltration and percolation is very high

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FIELD WORK

The field work was carried out in Obiaruku, Ukwuani Local Government Area of Delta State, Nigeria. The areas surveyed were

Ghana Quarters – Location 1
Amai Road – Location 2
Wire Road – Location 3
Old Agbor-Sapele Road – Location 4
(near Oceanic Bank)
Umuebu Road – Location 5
New Agbor-Sapele Road – Location 6
(by Agip petrol station)

The refraction method involves the use of Abem Seismograph MK6, 24 geophones, seismic cables, 12.0V battery, a heavy sledge hammer and a flat plate. The sledge hammer was used to send sound signal to the ground through the flat plate (wave source) and seismic wave was acquired and recorded through the Seismograph. The first shot was fired 2m outside the geophone (offset). The second fired in between the twelve and thirteen geophone while the third was fired at the last geophone (reverse reading). The data collected with the Seismograph is displayed on the LCD screen and printed out to give the P – wave data sheet.

The instrument used for data acquisition was the Abem 1000SAS Terrameter with an inbuilt booster for greater injection of current into the subsurface. This equipment has the ability of computing and displaying the apparent resistivity of the subsurface with the input data of the current and potential electrode separation (Egbai, 1998). The current electrode spread varied from 1.0m to a maximum of 800.0m

FILTERING APPLICATION

In Seismic acquisition and processing it is conventional to carry out the application of filtering seismic signal from the instrument. It is necessary to filter the seismic signal from geophones or hydrophones before they are in a form useful to the users. This act of filtering is done to reduce or eliminate unwanted variable frequency in form of noise. In this work, sources of unwanted noise could be from generators, shops, road traffic, road construction going on in the town, noise from the field workers, wind induced noise, footsteps etc. The frequencies of these noise generally tend to be above the frequency band of the seismic signal and can be filtered out usually with no loss to the seismic signal (Asokhia, 1984). An electronic filtering device was incorporated in the instrument. The table below shows summary of the result of the field work.

3. DATA ANALYSIS

The data collected from the field were tabulated with their corresponding time (ms) – distance (m) graph as shown. The travel times are determined from the first breaks of the traces represented on the monitors. The first breaks are also known as first arrivals.

From the graph, direct wave slope, $1/V_1$ and the refracted wave slope, $1/V_2$ were drawn (V_1 and V_2 correspond to velocities of upper and lower layer earth respectively). The depth or thickness of each layer earth can be obtained by taking the average velocities of the forward and reverse curves (V_1 and V_2 respectively) and the intercept time (t_o). If these values are substituted into the equation below, the value of the thickness Z can be calculated

$$Z = \frac{t_0 V_1 V_2}{2(V_2^2 - V_1^2)^{1/2}}$$

t_o = intercept time in millisecond (ms)

V_1 and V_2 = velocities of layer 1 and 2 in metres per second (m/s).

Knowing V_1 and V_2 the angle of dip θ and the critical angle φc can be deduced from the formulae. The results of the seismic section are as shown in table 1 and 2.

$$\theta = \frac{1}{2}\left\{\sin^{-1}\frac{V_1}{V_2} + \sin^{-1}\frac{V_1}{V_2}\right\}$$

$$\varphi c = \frac{1}{2}\left\{\sin^{-1}\frac{V_1}{V_2} + \sin^{-1}\frac{V_1}{V_2}\right\}$$

The apparent resistivity ρ_a could be calculated by applying the formulae shown below

$$\rho_a = \frac{2\pi\Delta V}{I} \quad \frac{1}{[1/r_A - 1/r_B] - [1/R_A - 1/R_B]}$$

Thus $\rho_a = K \times R$

where $R = \frac{\Delta V}{I}$

$$K = \frac{2\pi}{(1/r_A - 1/r_B) - (1/R_A - 1/R_B)}$$

where

K = geometric factor

V = the potential difference

I = the current generated at the subsurface

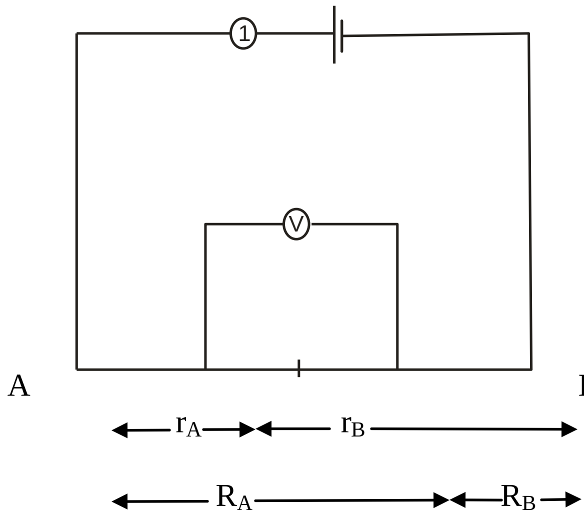


Figure 1: Schlumberger configuration

The observed field data were used to produce depth sounding curves. The quantitative interpretation of field sounding curves were subjected firstly by curve matching before iteration using the resist software (Vander Velpen, 1988)

The results are as shown in table 3

Table 1: Summary of Seismic Refraction result

Nos.	Locations	Layer	Velocity (m/s)	Depth (m)	Angle of Dip (Θ)	Critical Angle (ρc)
1	Ghana	1	425.69	4.24	56.69	3.65
	Quarter	2	510.42			
	Ghana Quarter	1	306.80	2.79	24.30	-21.25
	(Split spread)	2	488.09			
2	Amai Road	1	430.41	2.75	61.27	10.98
		2	500.00			
	Amai Road	1	430.40	5.0	71.93	-18.07
	(Split spread)	2	476.20			
3	Wire Road	1	378.57	2.39	51.36	5.77
		2	488.1			
	Wire Road	1	361.40	2.49	49.9	7.20
	(Split spread)	2	476.19			
4	Old Agbor-Sapele Road	1	425.69	3.25	58.42	1.98
	Old Agbor-Sapele Road	2	500.00			
	(Split spread)	1	303.03	2.03	41.79	0
		2	454.60			
5	Umuebu Road	1	409.69	2.45	57.14	3.28
		2	488.09			
	Umuebu Road	1	434.78	6.22	63.18	-2.76
	(Split spread)	2	488.10			
6	New Agbor-Sapele Road	1	455.48	5.25	66.33	5.92
	(G.S.)	2	500.00			
		1	455.49	2.23	75.21	14.80
		2	488.09			

Table 1 could be put in the form as shown in table 2

Table 2: Summary of Seismic Refraction result

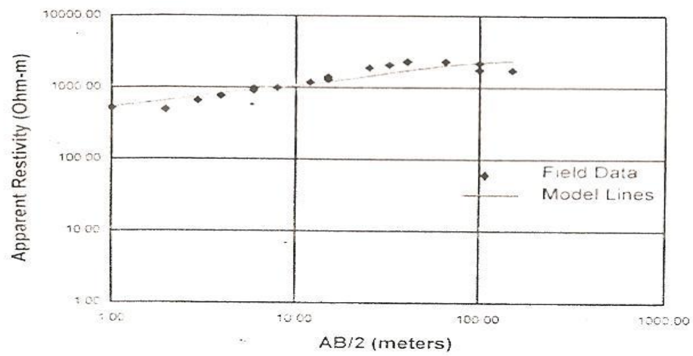
Nos.	Locations	V1 (m/s)	V2 (m/s)	T (m)	T x 10-3 (s)	Θ (degree)	φ (Degree)
1	(Forward) (Reverse)	425.69 306.78	510.42 488.09	4.24 2.79	11.0 10.0	56.69 24.34	3.65 -21.25
2	(Forward) (Reverse)	430.41 430.40	500.00 476.20	2.75 5.03	6.5 10.0	61.27 71.93	10.98 -18.07
3	(Forward) (Reverse)	378.57 361.40	488.10 476.19	2.39 2.49	8.0 9.0	51.36 49.90	5.77 7.25
4	(Forward) (Reverse)	425.69 303.03	500.00 454.60	3.25 2.03	8.0 1.0	58.42 41.79	1.98 0
5	(Forward) (Reverse)	409.69 434.78	488.09 488.10	2.45 6.22	6.5 13.0	57.14 63.18	3.28 2.76
6	(Forward) (Reverse)	455.48 455.49	500.00 488.09	5.25 2.23	9.5 11.0	66.33 75.21	5.92 14.80

Table 3: Summary of Iteration Results and lithology of the locations

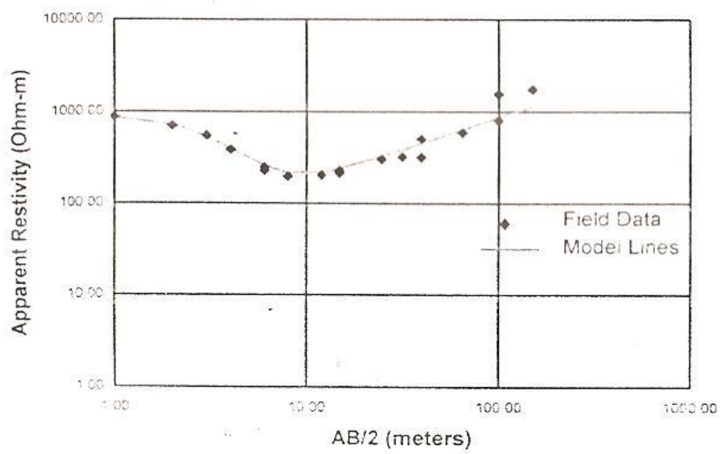
Location	Layer	Thickness (m)	Depth (m)	Resistivity (Ωm)	Lithology	Curve types	% error
1	1 2 3	1.0 10.0	1 11	300.0 1400.0 1500.0	Top soil Sand Fine coarse sand	$\rho_1<\rho_2<\rho_3$ A	5.50
2	1 2 3 4	15.0 10.0 20	1.5 11.5 31.5	900.0 175.0 800.0 2500.0	Top soil Clay Sily sand Fine coarse sand	$\rho_1>\rho_2<\rho_3<\rho_4$ HA	8.94
3	1 2 3	1.0 10.0	1.0 11.0	500.0 1100.0 2500.0	Top soil Sand Fine coarse sand	$\rho_1<\rho_2<\rho_3$ A	7.89
4	1 2 3	1.0 11.0	1.0 12.0	215.0 80.0 2000.0	Top soil Clay Coarse sand	$\rho_1>\rho_2<\rho_3$ H	7.35
5	1 2 3	1.0 10.0	1.0 11.0	1000.0 1200.0 2000.0	Top soil Sand Fine coarse sand	$\rho_1<\rho_2<\rho_3$ A	5.92
6	1 2 3 4	0.8 3.0 35.7	0.8 3.8 39.5	172.8 707.0 424.3 733.3	Top soil Sand Clay Clayey sand	$\rho_1<\rho_2>\rho_3<\rho_4$ KA	3.5

Some of the curves produced from the iterated results are as shown in fig. 2
The lithology as well as the model parameter are as shown in table 3. Figure 3 show the seismic monitor where the first break were deduced. Figure 4 is the split spread graph while figure 5 is the forward and reverse graph for location 1

VES for Location 1



VES for Location 2



VES for Location 3

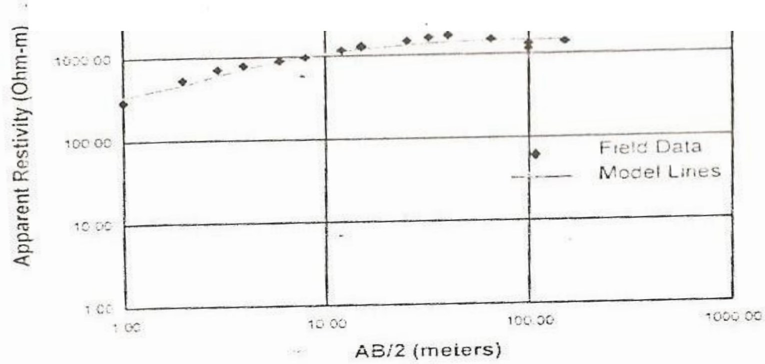


Figure 2: VES for some Locations

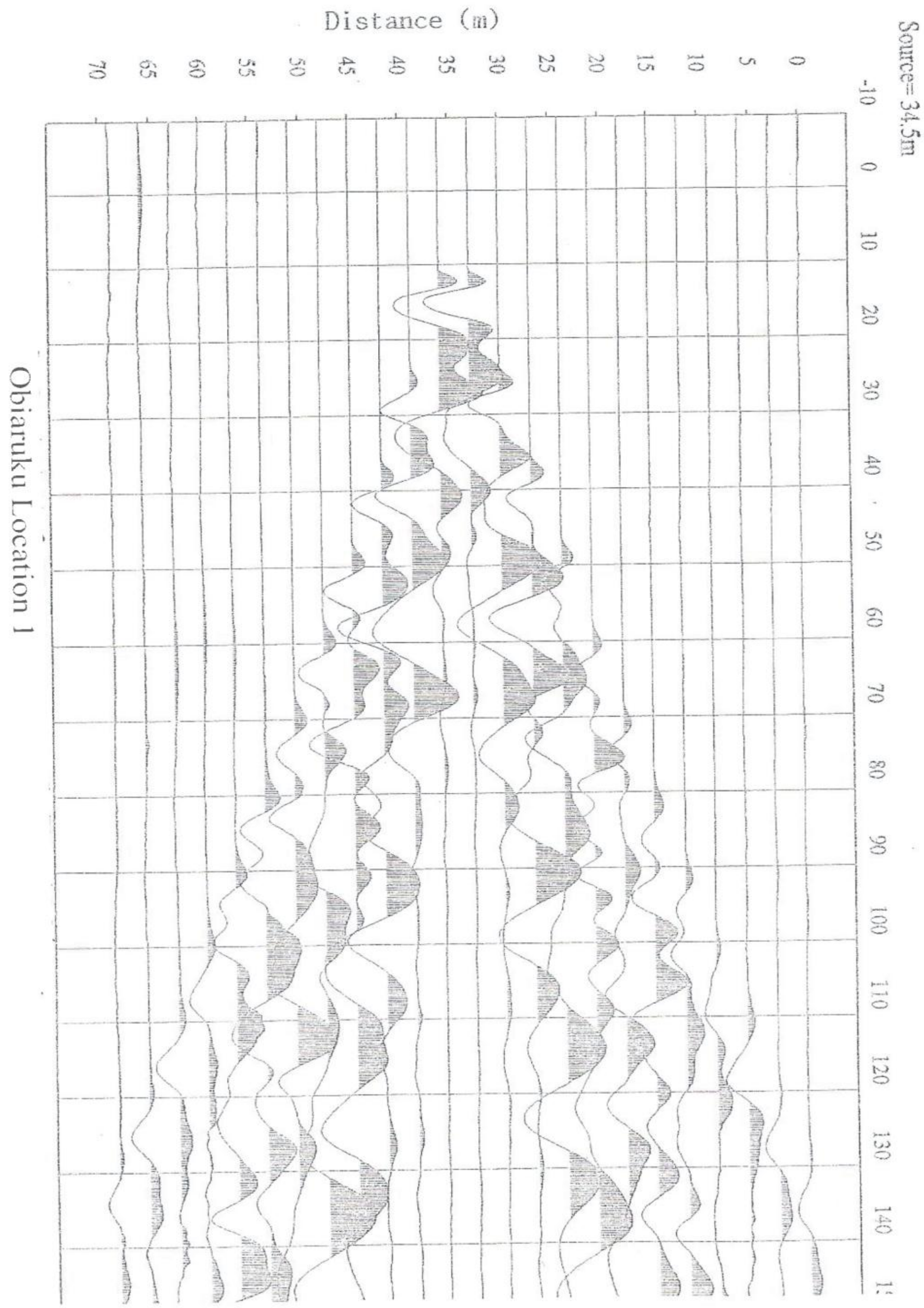


Figure 3: Seismic monitor for first break

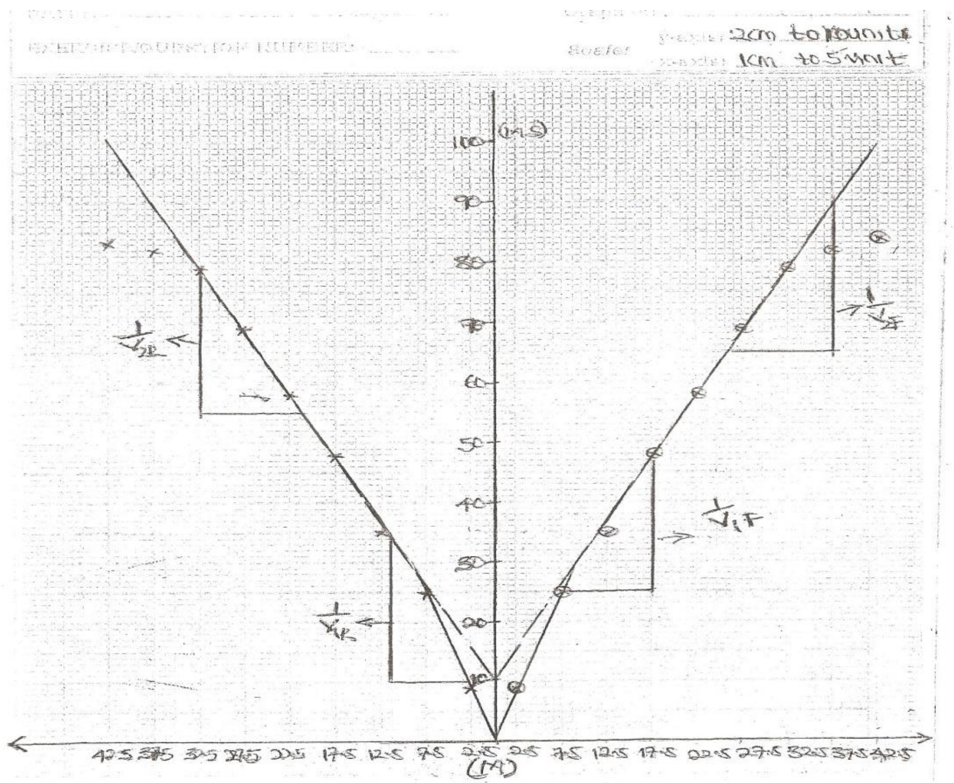


Figure 4: Split spread graph

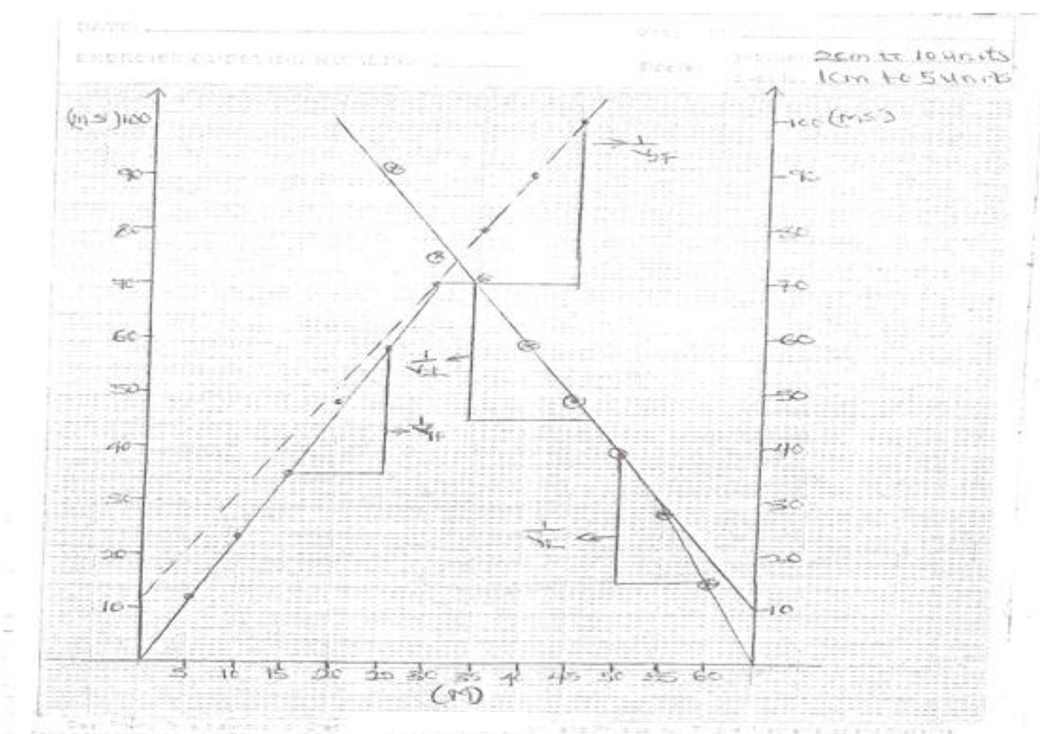


Figure 5: Forward and Reverse graph

4. RESULTS AND DISCUSSION

As a result of the geologic investigation carried out at Obiaruku, the qualitative interpretation shows that location 1 is an A type curve ($\rho_1<\rho_2<\rho_3$) with resistivity varying from 300Ωm to 1500Ωm and layers thickness ranging from 1.0m to 10.0m with root mean square error of about 5.5 indicating a three layer earth. The seismic record for this location shows velocities ranging from 306.78m/s to 510.42m/s with thickness varying from 2.79m to 4.24m for forward and reverse records. The lithology of this location is of top soil, sand and fine coarse sand. The aquifer is located within the third layer.

The second location shows evidence of HA type curve ($\rho_1>\rho_2<\rho_3<\rho_4$) with resistivity varying from 900Ωm to 2500Ωm with thickness ranging from 1.5m to 30.0m with root mean square error of 8.94, showing a four layer earth. The seismic records show layer velocities ranging from 430.40m/s to 500.00m/s with thickness varying from 2.75m to 5.03m, the lithology is of top soil, clay, silt sand, and fine coarse sand.

Locations 3 and 5 is similar to location 1 having 3 layer earth with A types curve ($\rho_1<\rho_2<\rho_3$). The velocities resistivities, thickness, root mean square error as well as their lithology are as shown in tables 2 and 3. The aquifers in these locations are within the third layer. The lithology are mainly top soil, sand and fine coarse sand.

Location 4 is characterized by H- type ($\rho_1>\rho_2<\rho_3$) curve consisting of three layers with resistivity ranging from 80.0Ωm to 2000Ωm and thickness varying from 1.0m to 11.0m with root mean square percentage error of 7.35. The lithology is made of top soil, clay and coarse sand. The seismic refraction result for this location show velocities of 425.69m/s and 500.00m/s for first and second layer for the forward records while velocities of 303.03m/s and 454.60m/s for the reverse records. The thickness for the forward and reverse records are respectively 3.25m and 2.03m

Location 6 shows evidence of KA($\rho_1<\rho_2>\rho_3<\rho_4$) type curve consisting of four layers with resistivities varying from 172.8Ωm to 733.3Ωm with thickness ranging from 0.8m to 35.7m and root mean square percentage error 3.5. The lithology of this location is made of top soil, sand, clay and clayey sand. The seismic section shows velocities of 455.48m/s and 500.00m/s for first and second layer respectively for the forward records while 455.49m/s and 488.09m/s for first and second layers respectively for the reverse records. The thickness of forward and reverse records are 5.25m and 2.23m respectively. The aquifer is located in the fourth layer.

Location one, Ghana quarters close to River Ethiope has the aquiferous layer in the second layer at a depth of 11.0m. This is a good aquifer and borehole could be sited here. This is applicable to locations three and five having aquifer in the second layer with depth of 11.0m each.

Locations two, four and six may not be good for sitting boreholes because of the presence of clay especially location 2 having clay and silt. Boreholes within this area could contain mineralized water (Selemo et al 1995). This location is therefore not recommended for sitting boreholes.

5. CONCLUSION

This paper describes the use of seismic profiling and vertical electrical sounding (VES) surveys in delineating groundwater potentials in the sedimentary area of Obiaruku, the local government headquarter of Ukwuani. The result of the survey shows three to four distinct geoelectric layers namely top soil, sand, clay, silt and fine grained sand with resistivities varying from 80.0Ωm to 2500.0Ωm and thickness from 0.8m to 35.7m

The result obtained from both VES and seismic surveys in Obiaruku, clearly indicates that the aquifer is about 11.0m and above depending on the location. Comparing seismic with VES data, it could be observed that the velocity of the seismic ranges from 330.03m/s to 510.42m/s while the VES ranges from three to four layers with apparent resistivities and thickness clearly summarized and properly interpreted.

Reliable borehole for good portable water should be sited at locations one, three and five having a fine aquifers at a depth of 11.0m respectively.

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7. REFERENCES

[1]. Aki, K., 1969, Analysis of the seismic code of local earthquakes as scattered waves: J, Geophysics Res., 74, 615 – 631

[2]. Asokhia, M.B., 1984, Profile shooting and Data corrections in Dipping Beds at Akoka. Nigerian inst. Phys. Bull, vol. 6

[3]. Ayolabi, E.A, 2005, Geoelectric elevation of groundwater potential: A case study of Alagba Primary School, Akure south-west Nigeria, Journal of Geological society of India, 66 pp 491 – 495

[4]. Canales, L.L., 1984, Random noise reduction: 54th Ann. Internat. Mtg, Soc. Expl. Geophys., Expanded Abstracts, 525 – 527.

[5]. Chase, M.K., 1992, Random noise reduction by 3-D spatial prediction filtering: 62nd Ann. Internat. Mtg., Soc. Expl. Geophys., Expanded Abstracts, 1152 – 1153.

[6]. Egbai, J.C. and Asokhia, M.B. 1998, Correlation between Electrical Resistivity survey and well logging in Delta State. J. MPAN vol. 2 pp. 163 – 175

[7]. Geissler, P.E. 1989, Seismic reflection profiling for groundwater studies in Victoria, Australia Geophysics, vol. 54, No. 1 pp. 31 – 37

[8]. Oladapo, M.I., Mohammed, M.Z., Adeoye, O.O., and Adetola, B.A., 2004, Geoelectrical investigation of the Ondo State Housing Cooperation Estate, Ijapo Akure, Nigeria. J. of mining and geology 40 (1), pp. 41 – 48

[9]. Olorunfemi, M.O., Ojo, J.S., Akintunde O.M., 1999, Hydro-geophysical evaluation of groundwater potentials of Akure metropolis, Southern Nigeria J. Mining and Geology, 35 (2): 207 – 228.

[10]. Omosuyi, G.O., Ojo, J.S., Olarunfemi M.O., 2008, Geoelectric Sounding to delineate shallow aquifer in the coastal plain sands of Okitipulpa Areg, South-western Nigeria. The pacific J. Sci. and Technol. 9 (2): 562 – 577.

[11]. Selemo, A.O.I., Okeke, P.O., Nwankwor G.I. 1995, An appraisal of the usefulness of VES in groundwater exploration in Nigeria. Water resources 6 (1 and 2), 61 – 67

[12]. Telford, W.M, Geldart, L.P., Sheriff, R.E. 1990 Applied Geophysics 2nd Ed. Cambridge Uni. Press, Cambridge. P. 770

[13]. Vander Velpen B.P.A. 1988, RESIST Version 1.0 M.Sc Research project ITC, Deft, Netherlands.

[14]. Van Overmeeren R.A., 1989, Aquifer boundaries explored by geoelectric measurement in the coastal plain of Yamen: A case of equivalence, Geophysics, 54: 38 – 48

[15]. Wright, J.B. 1968, Oligochase-andesine phonocryst and related inclusions in basalts from part of the Nigeria Cenozoic province Mineral mag., 36, 1024 – 31.

[16]. Yilmaz, O. 1987, Seismic data processing Pub. By society of Exploration geophysics, 3rd Ed. P. 526

[17]. Zohdy, A.A.R., Eaton, C.P., Mabey, D.R., 1974, Application of surface Geophysics to groundwater investigation. Tech. Water resources Investigation, Washington, U.S Geophysical surveys.