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Assessment of Groundwater Potential of Imo Formation (Ebenebe Sandstone) in Anambra State, Nigeria Using Geo-electrical Sounding Data

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Abstract

Failure of public water scheme and adverse pollution of surface water sources have made residents of Anambra State to resort to groundwater resource. The objective of this study is to provide data on groundwater prospect considering the subsurface geophysical conditions of Imo formation (Ebenebe Sandstone) to enhance the availability of clean water source. Vertical Electric Sounding (VES) method was used for this study by measuring 15 VES stations using Schlumberger configuration. The results revealed thatthe subsurface section consists of five geo-electrical layers namely: Top soil/laterite, Clayey sand, Dry sandstone, Water saturated sand and Shale. The predominant curve types found in the formation were AK, HK and K. The first layer encountered had depth that ranges from 2.94 to 5.21m, thickness of 2.94 to 5.21m, with resistivity values ranging from 278 to 1959.96 Ohm.m. The second layers thickness and resistivity values for all the VES stations ranged between 13.38 – 23.66m and 304.12 - 909.7Ωm respectively, this layer was delineated mainly as clayey sand. The third layers were delineated mainly as sandstone; the thickness and resistivity ranged between 26.53 – 68.89.89m and 7548.4 – 14026.15Ωm respectively. The depth of the third layer varied from 44.44m to 88.72m. For the forth layers, the thickness and resistivity ranged between 18.73 – 43.96m and 13499.1 – 4620.14Ωm respectively and they are delineated mainlyas water saturated sand for all the VES stations. The fifth/last layers bases were not reached, the values of their resistivity ranged between 29.663 – 60.41Ωm and they were delineated as shale.

Keywords: Geo-electrical data**,** Groundwater, Imo Formation, Aquifer, Anambra State.

1. Introduction

Water is one of the most essential commodities to the survival of life (Ubuohet al. 2016). In Anambra State of Nigeria, there exists disrupted pipe water supply system; the system is basically non-existed in major areas of the state. Due to the inability of the government to provide potable water scheme in the State, the state is faced with scarcity of water in most areas especially in the semi-urban and rural communities. The World Health Organization (WHO/UNICEF, 2017) reported that as at 2015, 844 million people still do not have access to even a basic drinking water service. Insufficient water supply and pollution of surface water sources, has made individuals to resort to exploitation of groundwater supplies in order to meet their daily water needs.

The occurrence of groundwater below the earth surface is simply as a result of some hydrogeological factors. Recognizing the importance of groundwater resource, several studies have attempted to provide information on changes on groundwater for effective decision making. Over the years, in the cause of groundwater development and management, Geologists, Hydrologists and water Engineers have not only identified the different geological formations, where water can be found but also gave information on the conditions favourable to the occurrence of groundwater. The purpose of groundwater exploration is to delineate the water bearing formation, estimate their hydrological characteristics and determine the quality of water present in these formations. Recently significant attention has been drawn to exploitation of groundwater supplies. However, many problems exist as a result of insufficient knowledge of the subsurface geophysical conditions in many parts of the study area.

A number of geophysical exploration techniques are available, which gives insight on the nature of water bearing layers, they include: geo-electric, electromagnetic, seismic and geophysical borehole logging (Alileet al. 2008). These methods measure properties of formation materials, which determine whether such formation may be sufficiently porous and permeable to serve as an aquifer. The electrical resistivity method and seismic refraction method are the surface geophysical methods commonly used for groundwater exploration. Resistivity of a material is defined as the opposition to the flow of current in Ohms between opposite surfaces of a unit cube of material. Electrical method utilizes direct current or low frequency alternating current to investigate the electrical properties of the subsurface. It is a technique used to study the shallow layer of the earth by sending direct electric current through a pair of electrodes and analysing the potential distribution it produces. From Ohm’s law, resistance and resistivity can then be deduced. The purpose of electrical surveys is to determine the subsurface resistivity distribution by making measurements on the ground surface. From these measurements, the true resistivity can be estimated.

No geophysical method has yet surpassed the electrical resistivity method in groundwater studies (Araffaet al. 2019). Araffaet al. (2019 noted that it has the wildest adoption in groundwater exploration. This is due to the fact that the field operation is easy, the equipment is portable, less filled pressure is required, it has greater depth of penetration, and it is accessible to modern communication systems. The fundamental physical parameter used in the exploration and description of subsurface rock by the resistivity method is resistivity. In groundwater exploration, the resistivity method can determine the thickness of aquifer overlying resistive bedrock. The method is even capable of determining even the quality of groundwater i.e. whether the water is saline, brackish, fresh or contaminated with toxic wastes.

Several electrical resistivity investigations have been carried out in Anambra State of Nigeria (Anizoba et al. 2015; Chukwuma et al. 2015). A research by Bayewuaet al. (2018) was carried out at Olabisi Onabanjo University campus, Ago-Iwoye, Southwestern Nigeria with the aim of evaluating groundwater potential and aquifer protective capacity of the overburden units in the area. The study concluded that study area ground potential ranges from low to high, while the protective capacity rating of the study area shows a poor, weak and moderate protective capacity rating. Seven VES stations had poor protective capacity; sixteen (16) VES station showed weak protective capacity and only one (1) VES station indicated a moderate protective capacity rating. In the research done by Usma*n et al.*, (2015), hydro-geophysical investigation was conducted to ascertain aquifer characteristics in thirteen (13) communities in Nteje, Anambra East Local Government and environs.

The study discovered four to five geo-electric units, one unconfined aquifer and three or four confined aquifers with the aquifer thickness greater at the NE and NW because of more clusters of the peak contours. The authors in their quest to verify the sustainability of groundwater in the area concluded that regional water project should be sited at Umeri because of its high values of transmissivity and aquifer thickness. In a similar study by Akintorinwa, and Oluwole (2018) a study was carried out to establish an empirical relationship that relates the Apparent Resistivity and the geotechnical parameters of subsoil. It was observed that, the results of the geotechnical analyses and the electrical resistivity correlates with the composition of the weathering end-product of rocks. Despite several research works done to investigate groundwater prospect, none has concentrated solely on the prospect of groundwater for Imo formation in the study area. There is need to investigate the geological formation of Ebenebe sandstone, hence the objective of this study is to investigate the groundwater prospect of Ebenebe sandstone, this is essential to provide data for easy groundwater accessibility for the residents of the study area.

2.0 Materials and Method

2.1 The study area

Ebenebe sandstone geological formation is located at the eastern part of Anambra State of Nigeria. Anambra State occupies a land area of about 4,844 square kilometre and is bounded in the east by Enugu State, in the north by Kogi State, in the south by Rivers and Imo States, and in the west by Delta State. The national population census of 2006 gave the population of the State as 4.06 million with a population density of 1,500 to 2,000 persons living within every square kilometer. The State is divided into 7 major geological formations, as shown in Figure 1.

2.1.1 Geology of Anambra State

Anambra State lies within the Benue Trough and it is underlain by Cretaceous to recent sedimentary formations of the Anambra Basin that have varying aquifer potentials (Chinwuko & Anakwuba 2016). Most of the geological formations found within the Anambra Basin did not outcrop from the state but are found in the subsurface. Chinwuko and Anakwuba (2016) in the research done for the Anambra State Government, produced the most recent detailed geological mapping of the State, revealing the five predominant geological formations. These formations include: Nsukka Formation (Maastrichtian – Danian), Imo Formation (Imo shale and Ebenebe sandstone) (Paleocene), Ameki Formation (Nanka sandstone and Nsugbe sandstone) (Eocene), Ogwashi-Asaba Formation (Oligocene – Miocene) and Benin Formation (Pliocene-Recent). Figure 1 shows the various geological formations in the study area and the area of interest (Ebenebe Sandstone)enclosed as shown in the figure.

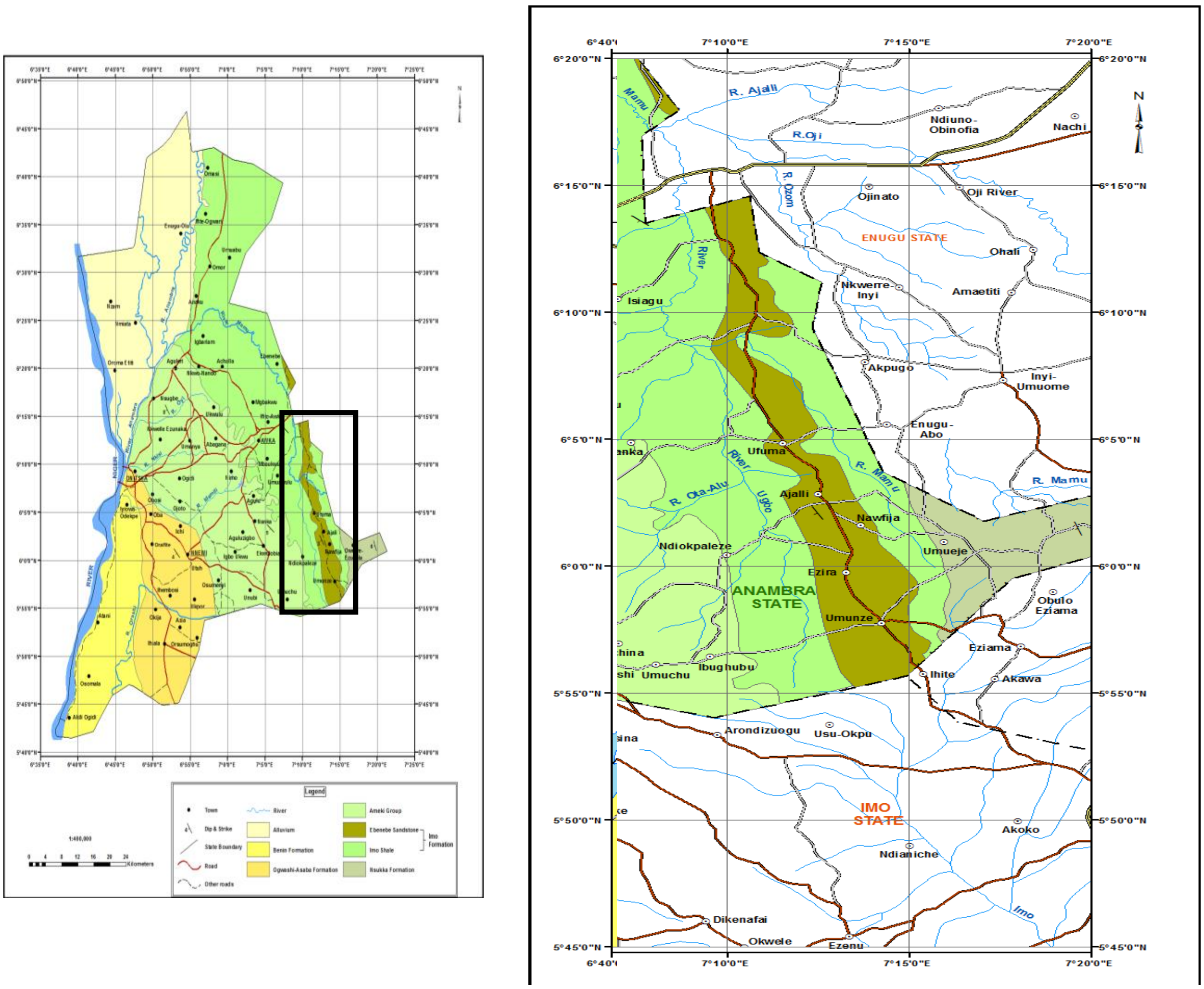

Figure 1: Map of Southern Parts of Anambra State showing the study area

Figure 1 shows that Ebenebe Sandstone spans through several towns such as Umunze, Ufuma, Ajali, Ezira, Nawfija and Ihite in Anambra State. A total of fifteen VES points were determined in this study. Figure 2 shows the schematic diagram illustrating the basic arrangement used in the VES measurement.

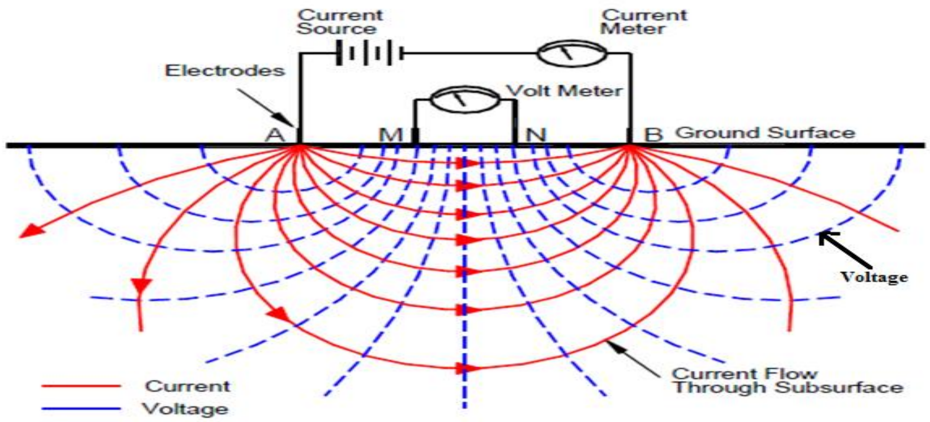

Figure 2: Schematic diagram Illustrating basic arrangement for Electrical Resistivity Measurement (Northwest Geophysical Associates, 2013).

From the current (I) and voltage (V) values, an apparent resistivity (ρ_a) values is calculated using an equation:

$$\rho_a = \frac{kV}{I} \quad (1)$$

Where, k is geometric factor, which depends on the arrangement of the four electrodes.

The apparent resistivity is computed from the potential drop, the applied current, and the electrode spacing. Resistivity meters normally give a resistance value, R = V/I so in practice the apparent resistivity value is calculated by

$$\rho_a = kR \quad (2)$$

The resistivity value calculated is not the true resistivity of the subsurface, but an "apparent" value, which is the resistivity of a homogeneous ground, which will give the same voltage, and current values for the same electrode arrangement. The relationship between the "apparent" resistivity and the "true" resistivity is a complex relationship. To determine the true subsurface resistivity, an inversion of the measured apparent resistivity values using a computer program was carried out.The Schlumberger configuration is most commonly used for vertical electrical sounding investigation (Lowrie, 2007). For this study, the Vertical electrical sounding using Schlumberger arrangement was used because the instrumentation is simple, filed logistics are easy and straightforward, analysis of data is less tedious and economical, less manpower is required (Ekwe, et al. 2010).

3.0 Results and Discussion

The results of the fifteen VES points that spanned through the geological formation for the various towns are as shown in Table 1. The VES interpretation results within the study area show that there are five geo-electrical layers within the geological formation. Namely: Top soil/laterite, Clayey sand, Dry sandstone, Water saturated sand and Shale.The VES stations in Ufuma town indicated the top layers thickness ranges between 3.78m to 5.21m for the four VES stations in the area. HK and AK curve types were observed in the area. The two VES stations in Ajalli were characterized with HK curve types, while Nawfija, Ezira and Ihite were classified as K, HK and AK curve types. Umunze had both HK and K curve types.

Table 1: Interpreted geo-electric model parameters for Imo Formation (Ebenebe Sandstone)

VES No. & Name	Layer	App. Res. (Ohm-m)	Thickness (m)	Depth (m)	Description
	1	1629.6	3.78	3.78	Top soil/laterite
VES 1	2	435.85	14.13	17.91	Clayey sand
HK-Curve Type	3	7548.4	26.53	44.44	Dry sandstone
Ufuma-1	4	1349.1	18.73	63.17	Water saturated sand
	5	29.663	Base not reached		Shale
	1	1700.86	4.04	4.04	Top soil/laterite
VES 2	2	566.72	17.79	21.83	Clayey sand
HK-Curve Type	3	9104.64	29.95	51.78	Dry sandstone
Ufuma-2	4	3301.49	28.83	80.61	Water saturated sand
	5	50.19	Base not reached		Shale
	1	1607.87	3.85	3.85	Top soil/laterite
VES 3	2	608.24	15.98	19.83	Clayey sand
AK-Curve Type	3	8772.72	68.89	88.72	Dry sandstone
Enugwu-Abo Ufuma-3	4	2605.08	36.28	125	Water saturated sand
	5	60.41	Base not reached		Shale
	1	1959.96	5.21	5.21	Top soil/laterite
VES 4	2	785.71	17.85	23.06	Sandy-clay
AK-Curve Type	3	9012.28	60.85	83.91	Dry sandstone
Enugwu-Abo Ufuma-4	4	4102.83	26.31	110.22	Water saturated sand
	5	49.63	Base not reached		Shale
	1	1388.4	3.98	3.98	Top soil/Laterite
VES 5	2	672.26	14.7	18.68	Clayey-sand
HK-Curve Type	3	9623.4	51.35	70.03	Dry sandstone
Ajalli-1	4	2385.3	39.35	109.38	Water saturated sandstone
	5	26.138	Base not reached		Shale
	1	1601.52	4.79	4.79	Top soil/Laterite
VES 6	2	582.08	17.73	22.52	Clayey-sand
HK-Curve Type	3	10041.23	44.71	67.23	Dry sandstone
Ajalli-2	4	4031.85	37.38	104.61	Water saturated sandstone
	5	43.67	Base not reached		Shale
	1	320.15	2.94	2.94	Top soil/Laterite
VES 7	2	700.11	17.09	20.03	Clayey sand
K-Curve Type	3	14026.15	52.76	72.79	Dry sandstone
Nawfija-1	4	4394.27	37.28	110.07	Water saturated sandstone
	5	50.69	Base not reached		Shale

	1	483.05	3.64	3.64	Top soil/Laterite
VES 8	2	878.76	14.23	17.87	Clayey sand
K-Curve Type	3	12062.15	56.14	74.01	Dry sandstone
Nawfija-2	4	3816.48	38.43	112.44	Water saturated sandstone
	5	46.27	Base not reached		Shale
	1	981.79	3.88	3.88	Top soil/Laterite
VES 9	2	420.74	15.17	19.05	Clayey-sand
HK-Curve Type	3	9063.51	54.31	73.36	Dry sandstone
Ezira-1	4	4355.68	36.72	110.08	Water saturated sandstone
	5	45.81	Base not reached		Shale
	1	831.07	4.13	4.13	Top soil/Laterite
VES 10	2	502.03	13.38	17.51	Clayey-sand
HK-Curve Type	3	10602.66	57.58	75.09	Dry sandstone
Ezira-2	4	3917.04	33.47	108.56	Water saturated sandstone
	5	49.85	Base not reached		Shale
	1	882.79	3.47	3.47	Top soil/Laterite
VES 11	2	304.12	18.15	21.62	Clayey-sand
HK-Curve Type	3	7890.65	27.27	48.89	Dry sandstone
Umunze-1	4	3148.35	43.96	92.85	Water saturated sandstone
	5	30.71	Base not reached		Shale
	1	308.2	3.71	3.71	Top soil/Laterite
VES 12	2	705.16	14.35	18.06	Clayey-sand
K-Curve Type	3	9410.62	35.52	53.58	Dry sandstone
Umunze-2	4	4303.91	38.55	92.13	Water saturated sandstone
	5	38.16	Base not reached		Shale
	1	278.63	4.06	4.06	Top soil/Laterite
VES 13	2	789.52	16.83	20.89	Clayey-sand
K-Curve Type	3	11356.04	50.02	70.91	Dry sandstone
Umunze-3	4	4620.14	36.65	107.56	Water saturated sandstone
	5	53.07	Base not reached		Shale
	1	680.91	3.88	3.88	Top soil/Laterite
VES 14	2	909.7	16.16	20.04	Clayey-sand
AK-Curve Type	3	9897.58	47.79	67.83	Dry sandstone
Ihite-1	4	4106.74	36.23	104.06	Water saturated sandstone
	5	56.02	Base not reached		Shale
	1	702.52	4.17	4.17	Top soil/Laterite
VES 15	2	891.81	23.66	27.83	Clayey-sand

AK-Curve Type	3	10976.18	42.86	70.69	Dry sandstone
Ihite-2	4	3410.32	28.96	99.65	Water saturated sandstone
	5	44.95	Base not reached		Shale

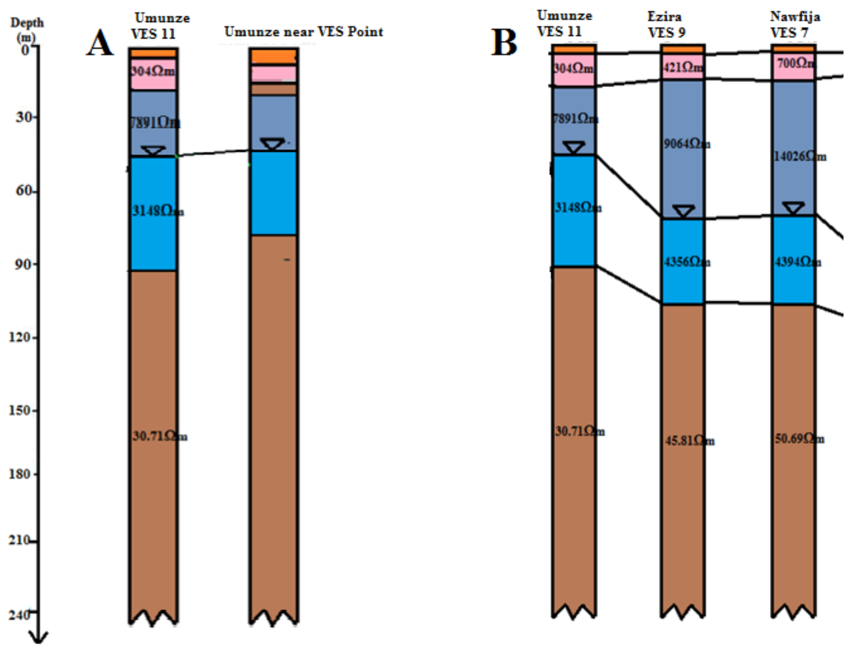

Figure 3: Geo-electrical section of some of the sample points

The second layers thickness and resistivity values for all the VES stations ranged between 13.38 – 23.66m and 304.12 - 909.7Ωm respectively, this layer was delineated as mainly of clayey sand. The second layer had maximum thickness at Ihite 2 (VES 15), while the least thickness was observed in Ezira 2 (VES 10).The third layers was delineated as mainly of sandstone, the thickness and resistivity range between 26.53 – 68.89.89m and 7548.4 – 14026.15Ωm respectively. The depth of the third layer varied from 44.44m to 88.72m. For the forth layers, the thickness and resistivity range between 18.73 – 43.96m and 13499.1 – 4620.14Ωm respectively and they are delineated as mainly of water saturated sand for all the VES stations. The fifth/last layers bases were not reached, the values of their resistivity ranged between 29.663 – 60.41Ωm and they were delineated as shale. The result of the various VES points revealed the presence of five geo-electric layers in all, with the prolific aquifer identified to be in the fifth layer, the presence of this aquifer was however reached at the depth of 63.17m to 125m. Thus suitable the depths for groundwater exploration have been identified for the study area.

The geo-electric correlation result among various VES stations was also carried out (see Figure 3). Figure 3b shows the sections of the vertical and lateral variations in layer resistivity and thickness, for VES 11 (Umunze), VES 9(Ezira) and VES 7 Nawfija. This also reveals the vertical lithological changes in VES stations, and the similarities in the number of layers, and little variation in each layers' thickness is also visible.

For better delineation of the underlying geology, results from one vertical electrical soundings (VES 11) conducted in close proximity to one water boreholes was correlated with known borehole log (Fig. 3a). Correlation of sounding result with lithological data from nearby borehole is as shown in figure 3a. The VES data interpretation results obtained from the area showed five geo-electrical layers as well as the borehole lithological layers. The result shows the capability of the VES stations to adequately capture the geophysical conditions of the subsurface layers. This study has provided information on suitable depth for groundwater development for Ebenebe sandstone geological formation.

4.0 Conclusion

Poor accessibility to public water scheme has made the residents of Anambra State of Nigeria to resort to borehole water for adequate water supply. Failed boreholes, poor sitting of boreholes and unguided sinking of boreholes have been a major challenge in the area . This study investigated the groundwater prospect of Ebenebe Sandstone in Anambra State of Nigeria, using VES technique. 15 (Fifteen) VES stations that spanned across several towns were used in the study. The result of the study shows that second layers thickness and resistivity values for all the VES stations ranged between 13.38 – 23.66m and 304.12 - 909.7Ωm respectively while the third layer ranged between 26.53 – 68.89.89m and 7548.4 – 14026.15Ωm respectively. The forth layers' thickness and resistivity ranged between 18.73 – 43.96m and 13499.1 – 4620.14Ωm respectively. The second layer sand the third layers were delineated as mainly of clayey sand and dry sandstone saturated with water respectively. The third layers was delineated as mainly of sandstone while the fifth/last layers bases were not reached, the values of their resistivity however ranged between 29.663 – 60.41Ωm and they were delineated as shale. This fifth layers is identified as aquifer depth for groundwater exploration for the study area, this study has therefore provided information on suitable depth for groundwater development for Ebenebe sandstone geological formation.

Reference

Conley, TG & Galeson, DW 1998, 'Nativity and wealth in mid- nineteenth century cities', *Journal of Economic History*, vol. 58, no. 2, pp. 468-493.

Akintorinwa, OJ &Oluwole, ST 2018, 'Empirical relationship between electrical resistivity and geotechnical parameters: A case study of Federal University of Technology campus, Akure SW', *NigeriaNRIAG Journal of Astronomy and Geophysics*,vol. 7, pp. 123–133.

Alile, MO, Jegede, SI,&Ehigiato, OM2008,'Underground water Exploration Using Electrical Method in Edo State', *Asian Journal of Earth Sciences,* vol. 1, no. 1,pp 38-42.

Anizoba, D C, Chukwuma, GO, Chukwuma, EC, &Chinwuko, EC 2015,'Determination of Aquifer Characteristics from Geo-electrical Sounding data in parts of Anambra State, Nigeria',*International Journal of Innovation and Applied Studies*,vol. 1,no 4, pp. 832-843.

Araffa , SAS, Soliman, SA, El-Khafif, A, Younis, A, &Shazley, TF 2019,'Environmental investigation using geophysical data at East Sadat City, Egypt',*Egyptian Journal of Petroleum*,vol. 28,pp. 117–125

Bayewua, OO, Oloruntolab, MO, Mosuroa, GO, Laniyana, TA, Ariyoa, SO, &Fatoba, JO, 2018,'Assessment of groundwater prospect and aquifer protective capacity using resistivity method in OlabisiOnabanjo University campus, Ago-Iwoye, Southwestern Nigeria',*NRIAG Journal of Astronomy and Geophysics*,vol. 7, pp. 347–360.

Chinwuko, IA, & Anakwuba, EK 2016,'Re-Evaluation of Mineral Potential of Anambra State, Nigeria; A Report submitted to Anambra Government.

Chukwuma, EC, Orakwe, LC, Anizoba, DC, Amaefule, DO, Odoh, CC,&Nzediegwu C 2015,'Geo-electric Groundwater Vulnerability Assessment of Overburden Aquifers at Awka in Anambra State, South-Eastern Nigeria',*European Journal of Biotechnology and Bioscience*,vol. 3,no. 1,pp. 29-34.

Ekwe, AC, Nnodu, IN, Ugwumbah, KI,&Onwuka, OS 2010,'Estimation of Aquifer Hydraulic Characteristics of Low Permeability Formation from Geosounding Data: A Case Study of Oduma Town Enugu State', *Journal of Earth Sciences,* vol. 4, no. 1,pp. 19 -26.

Lowrie, W2007,*Fundamentals of Geophysics*. Second Edition, United Kingdom: University Press, New York, pp.145 -230.

Northwest Geophysical Associates, Inc. (NGA) 2013,*Electrical or D.C. Resistivity*, USA; 8366 SW Nimbus Avenue, Beaverton, pp. 2. www.nga.com.

Ubuoh, EA, Ikwa, LO, &Ogbuji, SI 2016,'Quality determination of Harvested Rainwater in selected storage tanks in Owerri, South-eastern Nigeria',*International Journal of Environmental chemistry and Ecotoxicology research*,vol.1, no. 3, pp. 11-19. http://www.eajournals.org

Usman, AO, Iheme, OK, Chinwuko, AI, Opia, FO, & Okonkwo, CC 2015, 'Hydrogeological Implications of Environmental Devastation in Orlu and Its Environs, South-Eastern, Nigeria',*Journal of Environment and Earth Sciences*, vol. 4, no. 23, pp. 84-93.

WHO/UNICEF, 2017. Progress on Drinking Water, Sanitation and Hygiene: 2017 Update and SDG Baselines. Geneva: World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), Licence: CC BY-NC-SA 3.0 IGO.