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GEOELECTRICAL AND DOWN-HOLE INVESTIGATIONS FOR DELINEATING FRESHWATER AQUIFER IN PARTS OF OBIO/AKPOR LOCAL GOVERNMENT AREA, RIVERS STATE, NIGERIA.

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ABSTRACT

Geoelectrical and down hole investigations were carried out in some parts of Obio/Akpor local government area of Rivers State Nigeria to evaluate the aquifer parameters, geophysical characteristics of the subsurface, and delineate fresh water aquifers of the study area. The Vertical Electrical Sounding (VES) technique using the Schlumberger array for resistivity and Self potential log were employed. The ABEM terameter SAS 300B and SAS log 200 for resistivity meter and logging tool was used respectively for the survey and down-hole investigations. The interpretation of the geoelectric survey was done using IP12win software, while the down-hole was interpreted using the Microsoft excel package. Fifteen vertical electrical soundings were done which revealed 4 to 6 geoelectric layers, comprising the top soil, lateritic sand, clay, water saturated fine-medium sand, gravely sand and conglomerate. Results of the Vertical Electrical Soundings from the various survey areas show that the aquifer potential depths range from 13 – 85.3 m. The resistivities of the aquifers in the study area vary from 43.1 – 1203 Ωm. *The down-hole investigations revealed freshwater occurrence at a depth of 10 – 48 m in three locations and in two separate depths of 34 – 74 m and 110 – 122 m in the fourth location. The aquifer depth in the geophysical log chart is in agreement with the vertical electrical sounding result. From the findings, it is evident that geophysical down-hole result is a confirmatory test for VES result in terms of groundwater prospecting.*

Key Words: Geoelectrical, Down-hole, Freshwater, Aquifer, Obio/Akpor, Electro-kinetic.

INTRODUCTION

Obio Akpor is situated in the Eastern Niger Delta Basin. It is located between latitudes 4°45'N and 4°60'N and longitudes 6°50'E and 8°00'E. Ground water is a major economic resource and lies beneath the ground surface, filling pore space between grains in bodies of sediment and clastic sedimentary rock, filling cracks and crevices in all types of rock (Plummer and Carlson, 2000). Many homes in Obio Akpor, which is part of the Niger Delta, get good quantities of water from drilled wells. A very important source of fresh water is the ground water. Water is necessary for both plants and animals to not only thrive but also for their survival. In general, water is used for consumption, agriculture, transportation, industrial activities and some recreational activities. Although many communities obtain their water from rivers, that is, surface water. Ground water is regarded as being safe because it is less polluted than surface water. In terms of quality, it can be attributed to presence of protective surficial geological formations and the filtering capacity of most of their reservoirs (Abam and Nwankwoala, 2020). Based on the great depth from which they are extracted and high temperature beneath the earth most organisms than contaminate water cannot survive there. Several geophysical methods can be used to explore ground water from the subsurface of the earth. They include the electrical method or the geoelectric method at the surface or by carrying out down-hole investigations. Electrochemical or mechanical activity is responsible for the spontaneous or natural potential in the subsurface. Underground water is the major controlling factor in all of these. These potentials originate from weathering of sulphide mineral bodies, variation in mineral content of rocks at geological contacts, bioelectric activity of organic materials, corrosion, thermal and pressure gradients in underground fluids and different types of phenomena (Aweto, 2012). The mechanism responsible for these potentials can be mechanical or chemical. They are Electro-kinetic potential, Liquid-junction (diffusion) potential, Shale (Nerst) potential and Mineralization potential.

The Vertical Electrical Sounding technique using the Schlumberger array was employed in our geophysical survey in Obio Akpor Local Government Area. This technique is very important in terms of its effectiveness and cheaper cost in delineating the presence of ground water in sedimentary basin (Anomoharan, 2014).

Well logs can be seen as a legal paper that captures the activities of well right from the drilling stage through to its completion. A well log can be prepared by two different processes. The first is by virtual inspection of drill cuttings and the second is by specially designed logging equipment that can be lowered into the borehole to record various events. The log that is prepared by virtual inspection is known as geological log while the log that is prepared by the lowered equipment into the borehole is known as geophysical log (Amechi et al.,2022). The geophysical well log is primarily used for the evaluation of geological formations. This evaluation has wide application in ground water, hydrocarbons and mineral exploration. The study area Obio/Akpor and Nigeria is blessed with abundant water resources both from ground water and surface water. However, there is lack of adequate and safe potable water. As a result, most people in the area resort to private sources of water supply. Most of the boreholes that had been drilled in Obio Akpor were done without carrying a geophysical survey. As a result, locating the best spot for drilling before placing screen could be tricky because there could be more than one potential Aquifer in the place to be drilled and knowing the particular one with the highest yield might be a problem. In addition, there are also surface water bodies like stream, ponds and hand dug wells in the region which are not only inadequate for water supply but also more often than not are contaminated (Alaminiokuma *et al*, 2017). Because of these reasons, the need for both geophysical and down-hole investigations in locating fresh water is of paramount importance.

This study will give the opportunity to relevant agencies and the inhabitants of Obio/Akpor and its environs to know the groundwater potential of the aquifers and better drilling sites to get good water, whereby reducing to a large extent the problems of lack of quality potable water.

The Study Area

Obio/Akpor Local Government Area is the largest local government area in Rivers State and the second centre of business activities in the state. It is bounded by Ikwerre and Etche Local Government areas in the North, Oyigbo and Eleme local Government areas in the East, Port Harcourt in the South and Emohua. It is situated in the Eastern Niger Delta Basin. It is located between latitudes 4°45'N and 4°60'N and longitudes 6°50'E and 8°00'E. The Local Government Area covers 260 km^2 and it is generally a lowland area with average elevation below 30m above sea level. Its geology comprises basically of alluvial sedimentary basin and basement complex (Weli et al., 2016). The thick mangrove forest, raffia palms and light rainforest are the major types of vegetation.

Obio/Akpor is located within the Niger Delta region which is characterized by its beaches, mangrove swamps and barrier bars. The Niger Delta Basin is also referred to as the Niger Delta province. The basin comprises several types of geologic formations, indicative of how this basin could have formed. At the beginning of the Paleocene there was a tremendous shoreline transgression. During the Paleocene, the Akata Formation had been deposited, before the Agbada Formation during the Eocene.(Alaminiokuma *et al*., 2017). The Akata Formation is 7,000 m thick.

The Agbada Formation is marine facies defined by both freshwater and deep-sea characteristics. This is the main oil and natural gas-bearing facies in the basin. The hydrocarbons in this layer were formed when this layer of rock became subaerial and was covered in a marsh-type environment that is very rich in organic content. It is about 3,700 meters thick (Tuttle *et al*., 2015). Agbada Formation which is generally fluviatile and fluviomarine is primarily of interest to the hydrocarbon industry. The depositional pattern which accompanied sedimentation during the formation of the delta, gave rise to structural traps (growth faults and roll-over anticlines) in the Agbada Formation, which facilitated the accumulation of petroleum in the reservoirs of the Niger Delta. The Agbada Formation while suitable for petroleum accumulation is considered too deep to be of interest for groundwater abstraction (Nwankwoala and Omunguye, 2013).

The Benin Formation is Oligocene and is the youngest in age. It comprises continental flood plain sands and alluvial deposits and it is estimated to be about 2,000m thick. Also, the Benin formation is still being deposited today (Alaminiokuma *et al*., 2017). The Benin Formation on the other hand which occurs at shallower horizons consists of continental deposit of sand and gravel and is therefore of greater significance to the groundwater and civil construction sectors. It is now well known that the Benin Formation (Miocene to Recent) possesses excellent water yielding properties even at great depths. Well cuttings from the logs of oil wells spread across the Niger delta, reveal that the Benin Formation is laterally extensive and extends to depths of 2000 m in places (Ezemokwe et al., 2018).

The Deltaic plains (upper and lower) and Benin Formation are the main aquifer formations. The area is dominated by both confined and unconfined aquifers at different depths and they contain highly saline groundwater. Because of high permeability, high recharge potential and the enormous thickness of the aquifers, groundwater is found to be very high. Water table distribution within the area is in the range of about 1.6 to 9.0 m (Ochuko, 2015)).

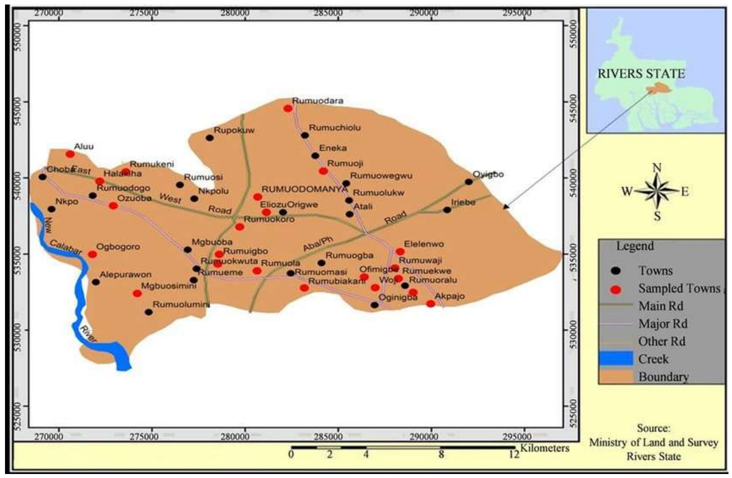


Figure 1: Map of Obio/Akpor Local Government Area, River State

MATERIALS AND METHODS

Vertical electrical sounding (VES) powered by 12V d.c source was carried out using the Schlumberger configuration with maximum electrode spacing AB/2 = 400m and MN/2 = 50m. Fifteen (15) vertical electrical soundings and four (4) down-hole investigations were carried out. The ABEM terameter SAS 300B, 2 current and 2 potential electrodes, insulated cables on reels, and 2 measuring tapes of 100m in length and hammer were used. Effects of electrolytic polarization caused by unidirectional current was switched off after taking reading before the electrodes were moved apart, and the electrodes were driven into the ground a few centimeters into the ground for good electric contact.

Resistance values $R(\Omega)$ at each VES point were recorded and apparent resistivity values ρ_a (Ωm) determined using the appropriate geomectric factor (K). Garmin GPS 72 was used in determining the coordinates in longitude and latitude and elevation height above mean sea level of the locations of sounding points. The apparent resistivity (Pa) was calculated using (Ibuot et al. 2013):

$$\rho_a = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] R = KR \qquad (1)$$

Where

$$K = \pi \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] \text{ being the geometric factor} \tag{2}$$

Logs are run over different parts of the various boreholes at different times in the study area to evaluate the productive potential of the reservoir sands. The loggings were done immediately after sands are drilled before drilling deeper to ensure constant log characteristics of the sands as a result of standing open to drilling fluid with the consequent invasion of mud filtrate. Four (4) down-hole logs were carried out from selected sites in the study area using resistivity log (ABEM terameter SAS 300 log 200 sonde). After drilling was completed at the various locations to be investigated without casing the well, geophysical measurements were done in the borehole in order to obtain more detailed data of the subsurface. The parameters measured are electrical resistance and self-potential against the corresponding depth. Measurements of the short normal resistivity, long normal resistivity and self-potential were taken as the cable was gradually pulled up the hole at intervals of 3m with an electrode placed at the surface the borehole.

Principles of Spontaneous Potential Log

There are three requirements for the existence of an SP current: A conductive borehole fluid (i.e., a water based mud), a sandwich of a porous and permeable bed between low porosity and impermeable formations, and a difference in salinity between the borehole fluid and the formation fluid, which are the mud filtrate and the formation fluid in most cases. In some special cases an SP current can be set-up when there is no difference in salinity, but where a difference in fluid pressures occurs. The origin of the spontaneous potential has four different components. The spontaneous potential is composed of contributions that are electrochemical (arise from electrical interactions between the various chemical constituents of the rocks and fluids), and electrokinetic (arise from the movement of electrically charged ions in the fluid relative to the fixed rock.

The total electrochemical component of the SP at 25°C for NaCl solutions is therefore;

$$E_c = E_d + E_m = -11.81 Log\left(\frac{R_1}{R_2}\right) + (-)59.15 Log\left(\frac{R_1}{R_2}\right)$$

$$= -71 Log\left(\frac{R_1}{R_2}\right) = -71 Log\left(\frac{R_{mf}}{R_w}\right) \tag{3}$$

where E_d = diffusion potential, E_m = membrane potential, R_1 = resistivity of the diluter solution, and R_2 = resistivity of the more saline solution.

In situation where the mud filtrate is lower salinity than the formation fluid. Equation (3) can be generalized by the formula;

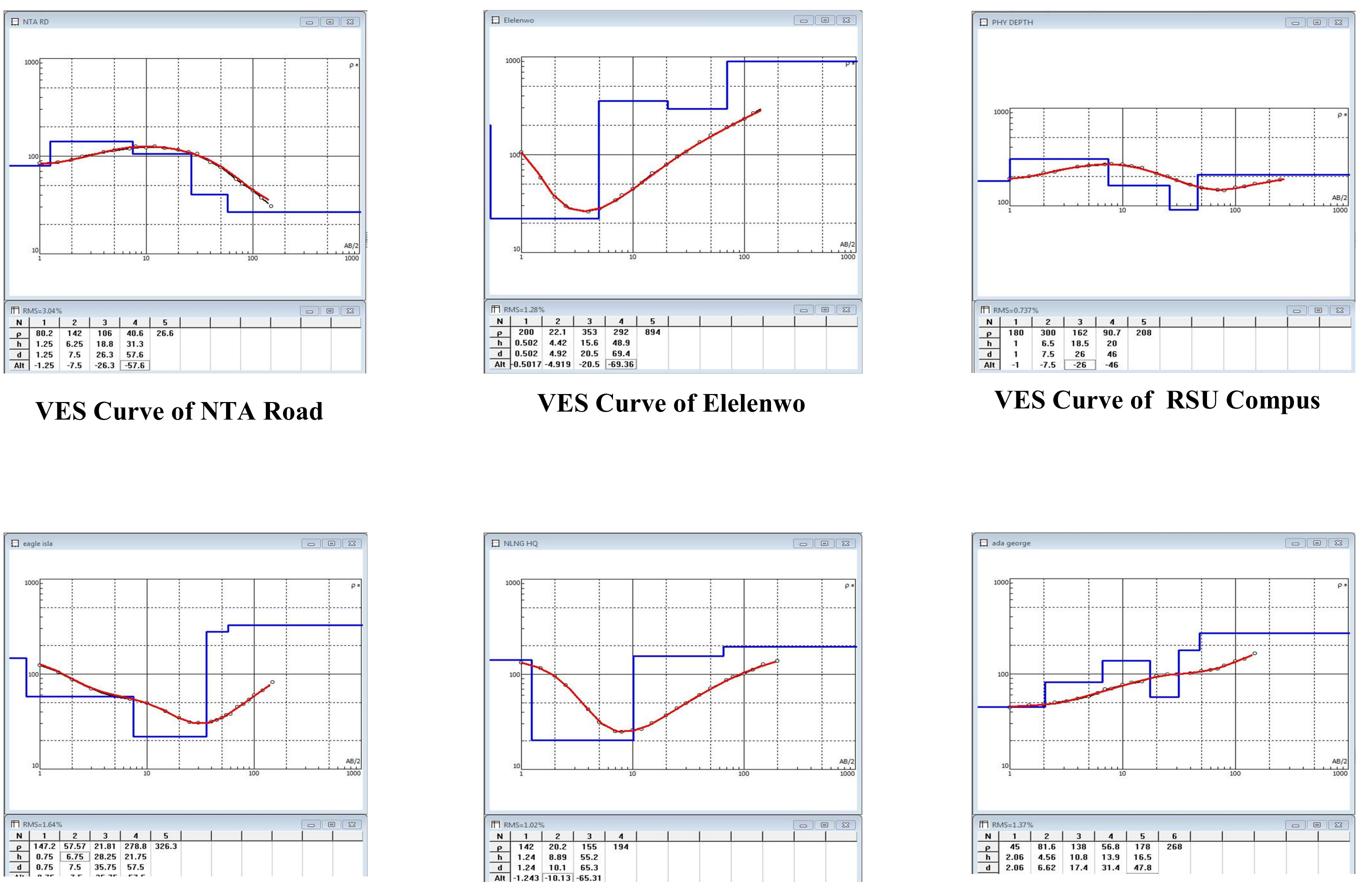
$$E_c = -KLog\left(\frac{A_w}{A_{mf}}\right) \qquad (4)$$

where; K is a coefficient that depends upon temperature, A_w is the activity of the formation water, and A_{mf} is the activity of the mud filtrate. This relationship breaks down for very saline solutions ($Rmf < 0.08\ Wm$), when corrected formation and mud filtrate resistivities must be obtained from charts. In this circumstance Eq. (4) is rewritten as

$$E_c = -KLog\left(\frac{A_w}{A_{mf}}\right) = -KLog\left(\frac{R_{mfe}}{R_{we}}\right) \qquad (5)$$

where R_{mf} and R_{mfe} are corrected resistivities obtainable from charts

The interpretation of the geoelectrical survey using the Schlumberger array was carried out using IP12win software. The interpretation of well log for both resistivity and spontaneous potential log was done on a graph of Microsoft excel package. The isopach and isoresistivity map from the resistivities were obtained from the field curves using Surfer 13 golden software.



VES Curve of NTA Road **VES Curve of Elelenwo** **VES Curve of RSU Compus**

VES Curve of Rumuokuta **VES Result of NLNG** **VES curve of Ada George** Road

Fig. 2: Some Typical VES Curve of the Study Area

RESULTS AND DISCUSSION

Table 1: Summary of Aquifer Parameters of the Study Area

S/N	VES Location	Aquifer Depth (m)	Aquifer Thickness (m)	Aquifer Resistivity (Ωm)	Northing	Easting
1	NTA Road	26.3	18.8	106.0	542563	278209
2	Elelenwo	69.4	48.9	292.0	533437	281868
3	RSU Compus	60.4	37.1	175.0	530818	275524
4	Rumuokwuta	57.5	21.5	278.8	537467	274561
5	Rumuola	83.1	54.7	131.0	534221	276539
6	Senate Road	51.0	43.8	043.1	530708	276428
7	Deeperlife road	64.0	39.0	109.0	530532	276223
8	Rumuoghalu	23.5	15.3	053.3	540492	273698
9	Near Phy. Dept. RSU	46.0	20.0	090.7	530957	276388
10	Convocation arena RSU	13.0	7.25	1203.0	530813	276249
11	Hostel H	36.3	21.3	216.0	530279	276288
12	NLNG HQTR	85.3	55.2	155.0	530307	280446
13	Rumuolumini	34.9	17.3	309.0	531386	270834
14	Elekahia	65.0	27.5	235.0	533437	281568
15	Ada George Road	47.5	16.5	178.0	533211	275098

The summary results of the aquifer parameters of the study area are as shown in table 1. The vertical electrical soundings revealed 4 to 6 subsurface layers revealing top soil, lateritic sand, clay, water saturated fine-medium sand; gravely sand and conglomerate. The depth to aquifers ranges from 13.0 to 85.3m with an average value of - , while the resistivity values of the aquifers ranged from 43.1 to 1203.0 Ωm with an average value of 238.3 Ωm.

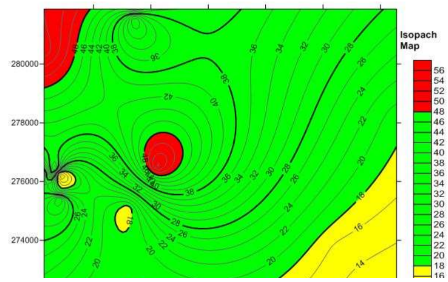


Fig. 3: Isopach Contour Map of the Study Area

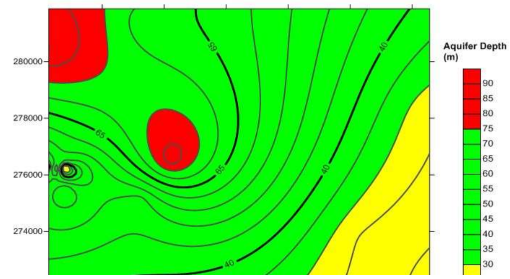


Fig. 4: Aquifer Depth Contour Map of the Study Area

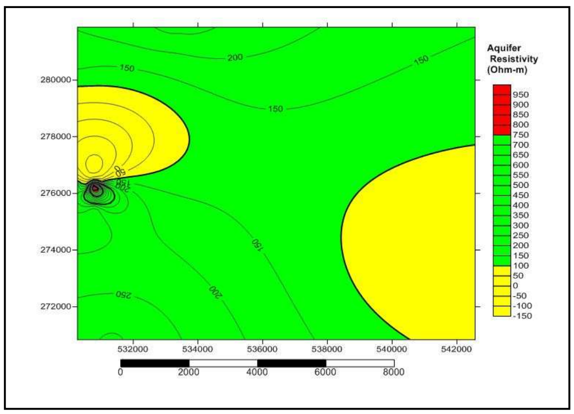


Fig. 5: Resistivity Contour Map of the Study Area

Figure 3 displays the Isopach plot of the Study area. It displays the lateral/ horizontal dissimilarity of how thick the overburdens are which ranges from 8 – 58 m. The study revealed that the overburden thickness is low at that South, and partly South East of the study area with thickness of 8m to 18m. The Map also revealed medium thickness range of 18m to 48m at the North, West, North -East and partly South West of the area. Towards the Central and partly North-West area, the overburden thickness is large with maximum thickness range of 48m to 56m. This coincides with the potential water bearing zone in the area. Hence, this part is termed the water potential zone. Figure 4 displays the aquifer depth contour map of the study area. The area has a maximum depth, partly central and partly North-West of the study area with depth ranging from 75 – 95 m. The South-East has a shallow depth of 15 – 30 m. The South-West and most part of the North-East have a medium depth ranging from 30 – 75 m. The distribution of resistivity values (figure 5) varies between 43.1Ωm to 1203Ωm (table 1). The resistivity contour map indicates three distinct zones within the area. The first zone which is the South, East and West half of the map reveals the existence of relatively low resistive formation with resistivity value ranging from 43.1 – 100 Ωm. The second zone which is in the Southern part shows a medium of resistive material ranging from 700 – 750m Ωm, while the third zone, the West part corresponds to relatively nonconductive material greater than resistivity of 900Ωm.

Resistivity and SP log charts

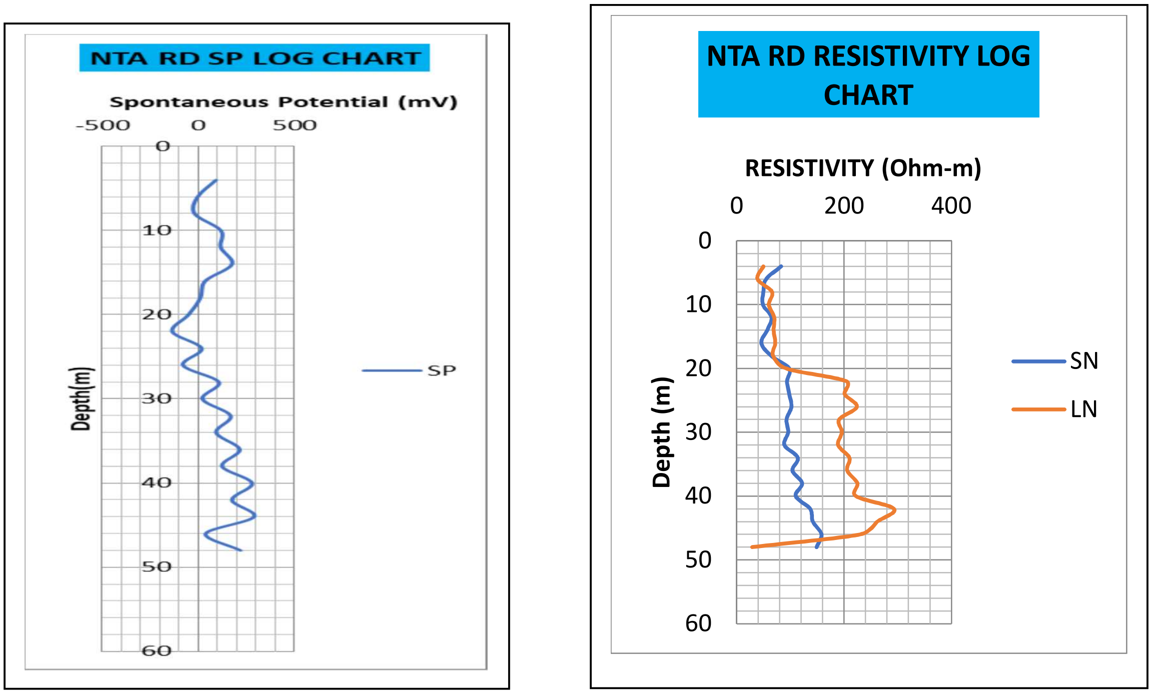


Figure 6: NTA Geo-Physical Log Charts

Figure 6 shows the result from the NTA Road log chart. It is seen from the chart that the borehole was logged to the depth of 48m. From the long normal resistivity chart, it is seen from the long chart that a non-aquiferous zone and conductive materials occurs from the surface to a depth of 20m. Below this zone is a porous and aquifer formation which starts from depth of 20m to depth of 48m.The SP log chart is featureless. This formation is termed the aquifer formation that can yield portable drinking water if a screen placed at this section.

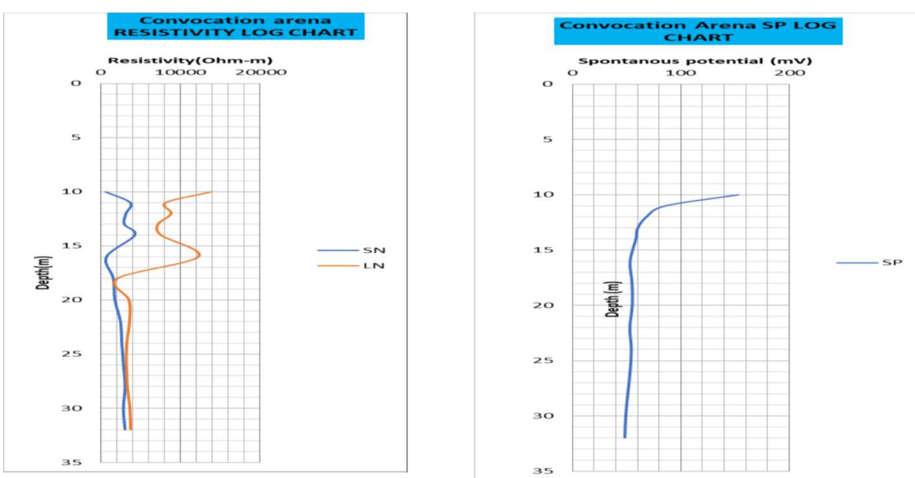


Figure 7: Convocation Arena Resistivity and SP log Chart

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Convocation Arena borehole log chart is shown in **Figure** 7. The borehole was logged to the depth of 33m. From the log-chart is evident that there was a conductor installation front the top to a depth of about 10m, hence there was no readings of the short and long normal resistivity values. From the long normal resistivity signatures, the fresh-water formation and the aquifer occurs at depth between 10-18m for shallow aquifer. Below this depth to depth of 33m is a clay formation which runs to the logged depth

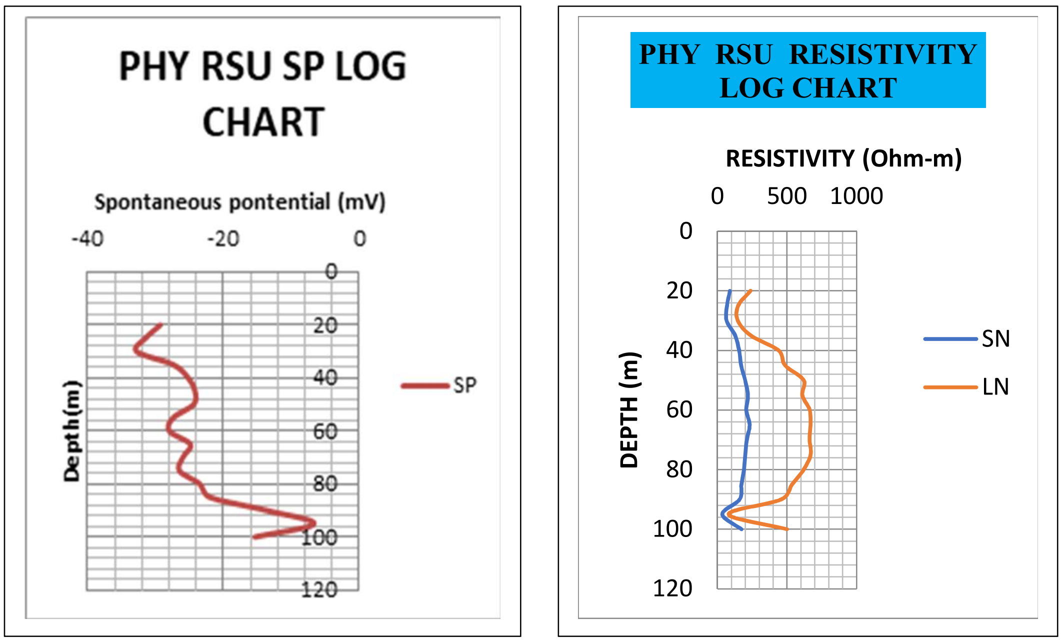
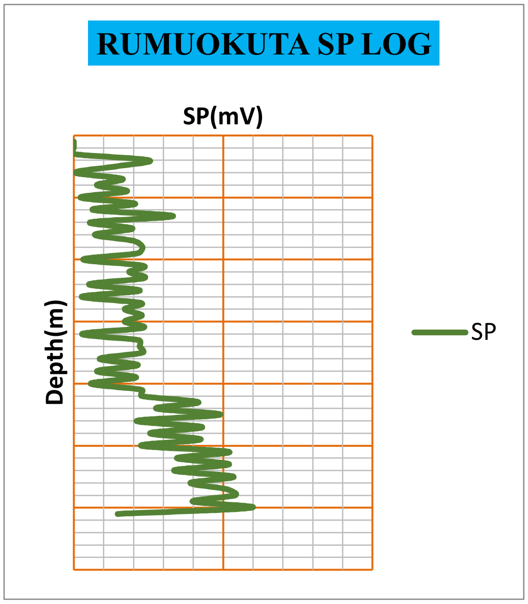


Figure 8: Physics Department RSU Resistivity and SP log Chart

From the log chart as shown in Figure 8 conductor installation starts from the surface through depth of 20m. From the long normal resistivity wiggles, a thick clay formation starts from the depth of 20m and terminate at 40m. Underneath this depth is porous aquiferous sand which starts from depth of 40m to the log depth of 90m, hence the aquifer starts from 40m and terminate at depth of 90m.



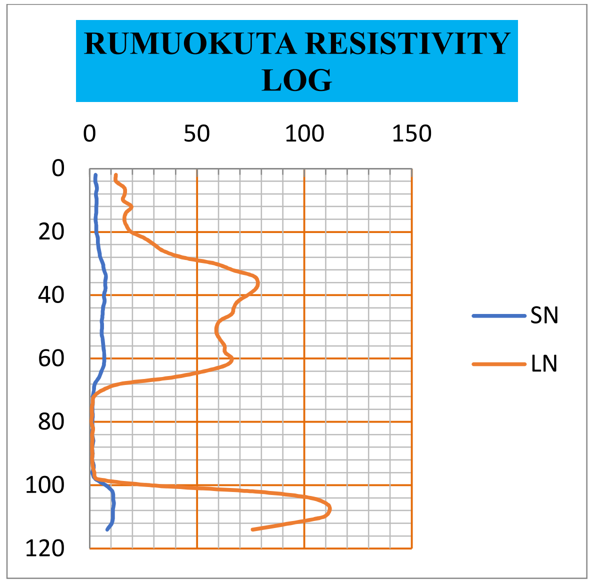


Figure 9: Rumuokuta Resistivity and SP log Chart

Figure 9 shows the geophysical log chart for Rumuokuta. The borehole was drilled to depth of 122m. From the chart, two boundaries occur between saline water and freshwater structure. It is seen that pockets of freshwater occurs at shallow depth between 34m to 74m and a deeper depth varying betwen110m to 122m. This depth is purely dominated by medium sand to very coarse sand. From the chart, it is also seen that saline water formation occurs at depth varying from 0 to 32m with some trace of brackish/saline water at depth of 96m to 108m. It is important to note that the zone of saline water is made of sandy to saturated clay compositions which separate the fresh water from the saline water.

Correlation of VES and Subsurface Geophysical log

The vertical Electrical Sounding is not a confirmatory test for portable groundwater extraction especially for screen placement; however, geophysical logging gives demarcation for permeable and impermeable beds and delineates the best thickness and extension of water bearing beds for proper screen placement. From some selected site where both VES and logging was done after borehole drilling as shown for Rumuokuta. Figure 2 shows that the VES result which revealed aquifer depth of 57.6 m agrees with the geophysical well log chart depth of the first aquifer. Similarly, the vertical electrical sounding result and other selected geophysical logging done on some selected site conform to the aquifer depth of interest.

CONCLUSION

Vertical electric sounding technique using the Schlumberger array together with resistivity log and Self potential log was carried out. From the VES, four to six layers comprising the top soil, lateritic sand, clay, water saturated fine-medium sand; gravely sand and conglomerate were revealed. Result of the vertical electrical sounding from the various survey areas revealed that the aquifer potential depth are 26.3 m, 69.4 m, 60.4 m, 57.5 m, 83.1 m, 51 m, 64 m, 23.5 m, 46 m, 13 m, 36.3 m, 85.3 m, 34.9 m, 65 m and 47.5m The aquifer depth in the geophysical log chart is in agreement with the vertical electrical sounding result. From the findings, it is evident that geophysical down-hole result is a confirmatory test for VES result in terms of groundwater prospecting. In view of the findings from the research area, water quality analysis should be carried out in the drilled boreholes to check the quality of the water, vertical electrical sounding should be conducted at different locations in future to delineate the appropriate deep aquifer zones before any borehole is drilled for possible ground water supply to avoid possible contamination, and pump testing should be carried out in the boreholes to determine the hydraulic properties of the wells.

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