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Lithostratigraphic Characterization of the Subsurface Soil and Lithological Identification Using Electrical Resistivity Method' on Ovade Community of Oghara, Southern Nigeria

Komolafe Nkechi Perpetual[1], Ese Anthony Aladin[1]*

[1]*Department of Geology, Dennis Osadebay University, Anwai, Asaba, Delta State, Nigeria*

INFORMATION

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Contact
*Ese Anthony Aladin
anthonyoriginal26@gmail.com

ABSTRACT

This research is carried out to determine the lithostratigraphic characterization of the Subsurface Soil and lithological identification using Electrical Resistivity Method' on Ovade Community of Oghara, Southern Nigeria. The study area is located between latitudes 5°38'37.782"N to 5°58'33.894"N and longitudes 5°41'20.32"E to 5°41'17.52"E. The geophysical prospecting method adopted for this study is the Wenner Survey profiling and Vertical Electrical Sounding (VES) techniques of the Electrical resistivity method which ABEM SAS-300C Terrameter was used determine to the stratigraphy of the subsurface soil and identify the lithology and determine drilled depth to groundwater. The data were analyzed using IX1Dv3 and Dipro software. The 2-D Resistivity structure reveals five (5) layers in the subsurface of the study area which are the lateritic soil (clay), fine to coarse sand, very coarse sand, weathered zone and Bedrock. The clay materials presence in the subsurface soil has apparent resistivity ranges from 286 – 414 Ωm. The aquifer zone is revealed to be at 25m to 50m depth with resistivity range of 511 - 2688Ωm. The aquifer is not contaminated with any leachate plume. The VES reveals Seven (7) geoelectric layers. The apparent resistivity ranges from 1221 Ωm to 9948.7 Ωm, overburden has a thickness range from 0.94013 m to 2.5055 m and depth ranges from 0.94013 m to 3.4456 m. The VES reveals that the third, fourth, fifth and sixth geoelectric layer is sand with little presence of gravel with an average thickness range of 15.088 m to 87.252 at depth range of 18.534 m to 87.252 m with resistivity range of 1396.7 Ωm to 9948.7 Ωm. The recommended drilled depth to groundwater is 53m (174 ft) and 72 m (240 ft) resistivity respectively. The first aquifer is for shallow well and second aquifer is for deep well. The curve type is AKH curve. From the results of 2D and 1D resistivity structure, the study area is predominantly Sand and little presence of clay materials before the aquifer zone. The study will provide detail information about the presence of clay materials which is a disadvantage to water from hand dug wells and building foundation.

1. Introduction

Water is life. Humans, animals and plants need water for various purposes. It is difficulties to identify and determine the best aquifer zone (depth to groundwater) for potable water because of the less knowledge and the condition of the soil. The aim of the study is to determine the lithostratigraphic characteristic of the subsurface soil and identify the lithology using resistivity method and also determine drilled depth to Groundwater of Ovade Community, Oghara. The people in this study area find it difficult to get clean water in hand dug wells because of presence of clay material with little presence of Iron and the buildings usually has cracks because of the expansion and contraction of the clay material presence in the subsoil. This research will help researcher to identify the stratigraphy of the soil and determine the drill depth to groundwater in that area and help to reduce the impact of contaminated water on the people for hand dung wells and help the Engineering geologist to know the best foundation design for buildings in that area. To avoid collapsed buildings and cracks on their foundation. The study is carried out on Ovade Community of Oghara in Ethiope West Local Government Area of Delta State, Nigeria. The study area is accessible through Warri-Sapele-Benin Road. The study area is along Ovade Road, Oghara. It is situated between latitudes 5°38'37.782"N to 5°58'33.894"N and longitudes 5°41'20.32"E to 5°41'17.52"E. (Fig. 1). It resides within the equatorial region having two climatic regimes, which are the rainy season and dry season. Typically, the region has the characteristic feature of the humid tropical wet and dry climate governed primarily by the rainfall. The dry season is from November to February, and the wet season is from March to October. The Oghara Community is in the Niger Delta Basin characterized by three major depositional (sedimentary) environments (marine, mixed, and continental). The people are predominantly farmers.

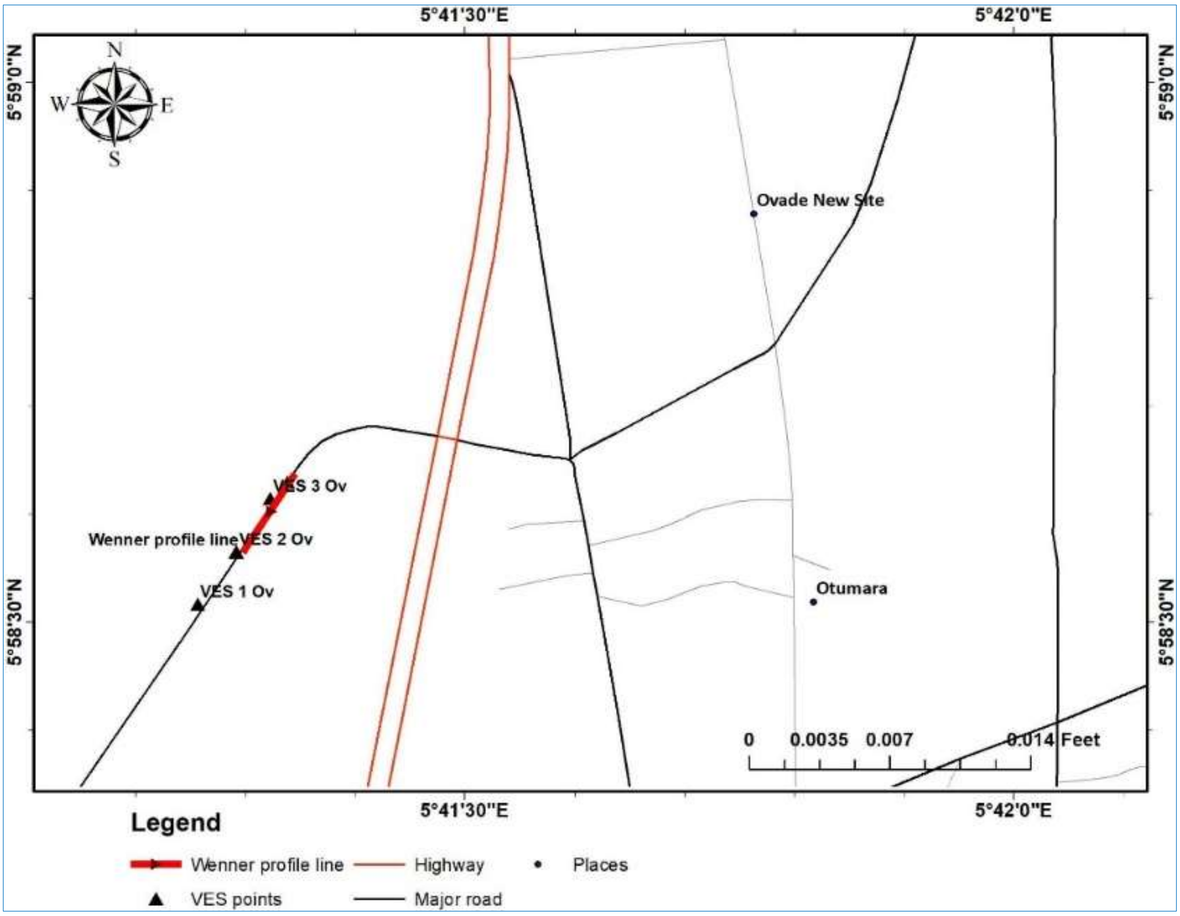

Fig. 1. Base map of the study area

The Delta Region is underlain by Sedimentary Formation of the South Sedimentary Basin. Delta Region comprises of Benin Formation, alluvium, drift/topsoil and Azagba-Ogwashi (Asaba-Ogwashi) Formation (Fig. 2). The study area is underlain by Benin Formation. The geology (lithology) is marked by lateralized clay and sand. The sandstone in the study area is from Paleo-Coastal Environment of Palaeocene-Pleistocene Age. These sediments spread across the southern fringes of the Anambra Basin and marking the upper facies off-flaps of the Niger Delta used the name Coastal Plain Sands to describe the Formation of red earth underlain by sands and clays that mark an ancient Coastal Plain Environment now exposed in Calabar, Owerri, Onitsha and the Delta Region with the age Oligocene-Pleistocene (Ikhile, 2016). The Benin Formation dip southward of the study area.

The study area is within the Niger Delta Basin. The Sombreiro Deltaic Features and Benin Formation are characteristic of the study area. There are three major sedimentary environments which are: marine, mixed, and continental. Based on the sedimentary environmental classification, three rock formations, namely, Benin, Agbada and Akata, are used to describe the sedimentary sequence. In the Niger Delta oil producing communities, the source rocks and seal rocks are the marine/deltaic, plastic, and over-pressured shales of Akata and Agbada Formations (Chambers et al., 2006).

The geology of the study area shows the presence of Clay, Sand, Pebbles, Sandstone, Gravel, Shales, Mangrove Swamp, Lignite, and Alluvium. The Aquifers of the Benin Formation bears the ground water needs of the region, the poorly sorted coastal sands become increasingly sandy and unconsolidated towards the surface. These parameters increase the porosity and permeability and thus, the increase in storage coefficient of the aquifer. Recharge through the surrounding water bodies and extensive rainfall percolating down with a fairly, thick vegetation run-off is negligible, this has resulted in a prolific hydrologic unit within the area.

2. Related Work

VES is a resistivity method that is used for depth sounding due to its simplicity and reliability (Okolie et al., 2007; Olawuyi and Abolarin, 2013; WRAL, 2021). It is used to determine the vertical variation of the apparent resistivity below the earth surface (Anomohanran, 2013) since the apparent resistivity of most rocks is dependent on the amount of water in the pore spaces within the rocks (Rai, 2017). The results from seismic reflection and VES reveal that there is feasible aquifer zone at Sapele and Jesse which is within 20-25 m but at Oghara, is at 40 m. False and contaminated aquifer may be intercepted at 10-15 m at sapele but not in Jesse and Oghara (Loke, 2004).

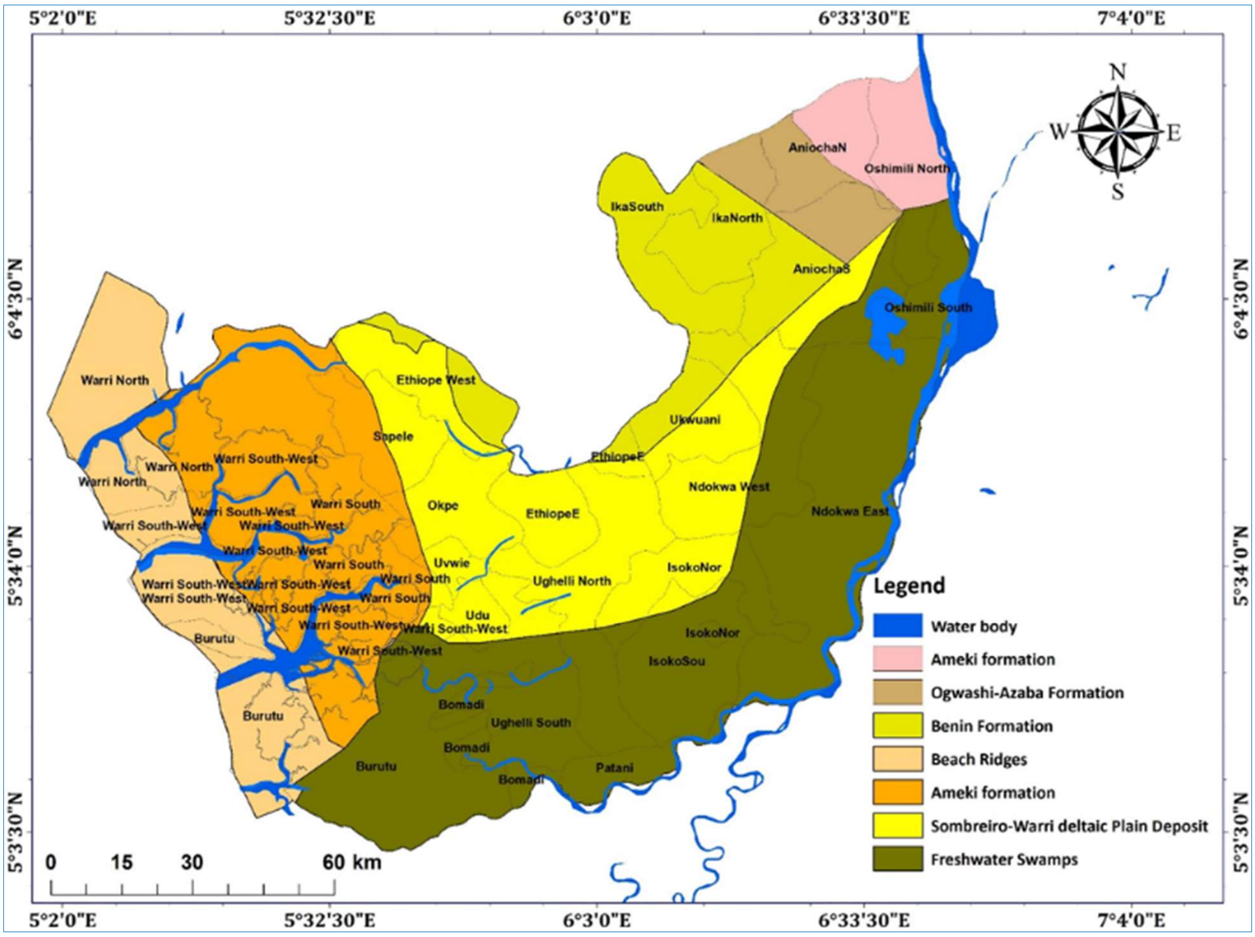

Fig. 2. Geological map of Delta State, Nigeria (NGSA, 2009)

3. Materials and Method

In this research work, the Wenner and Schlumberger array of Electrical Resistivity Survey method was adopted. The basic field equipment for this research is ABEM Terrameter SAS 300C which displays resistance in ohms, the values are digitallycomputed from ohms' law. It uses 12.5v D.C power source. Other materials used along with the Terrameter includes the booster, four metal electrodes, reels of wire, hammers (3), measuring tapes, mobile phones for very long spread. Electric current was introduced into the ground through the Terrameter. The Wenner method is a 2D resistivity survey method and electrode spacing of 10m was adopted (Oseji et al., 2020).

The Schlumberger configuration was adopted for the vertical electrical sounding with a maximum current electrode separation AB of 200m, which was deemed sufficient in allowing a depth penetration of 100 m (AB/2) while the Potential electrode separation was increased several times during the sounding at MN/2 equals 0.2 m to 10m. GPS (global positioning system) Germin model instrument was used to determine well coordinates and elevation of the study area. Different electrode spacing is used when sending electric current into the ground depending on which part of the earth the anomaly is to be investigated. For the field work, the following electrode spacing was used. The Wenner array is a 2-D imaging technique that involves the measurement of lateral electrical profiling of apparent resistivity of the subsurface earth (Bayowa et al., 2015).

The Wenner electrode array consists of two sets of electrodes, the current C1 and C2 and potential electrodes P1 and P2. The spacing between adjacent electrodes is "a" (Ogungbemi et al., 2021). The Wenner electrode array is the simplest of arrays; in it, the four electrodes -C1, P1, P2, and C2- are placed in line and spaced equidistant from each other. The two outer electrodes, C1 and C2, are current electrodes, and the two inner electrodes, P1 and P2, are potential electrodes. With the Wenner array (Fig. 3), the resistivity of subsurface layers is found by increasing the distance between the electrodes while maintaining the location of the center point of the array (Oseji et al., 2018) and the Schlumberger array is more complex when spacing between the current electrodes is not equal to the spacing between the potential electrodes. The vertical electrical sounding with Schlumberger array (Fig. 4) is a low-cost technique for groundwater exploration. The method is regularly used to solve a wide variety of groundwater problems.

For Wenner array, the geometric factor is obtained from the values of 'a'.

Formula of Geometric factor (G) and Apparent resistivity (ρ_a) for Wenner array is given as:

$$G = 2\pi a \quad (1)$$

$$\rho_a = 2\pi a \frac{V}{I} \quad (2)$$

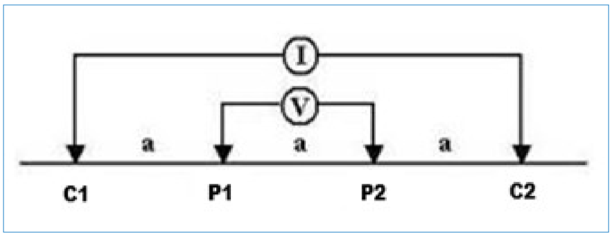

Fig. 3. Wenner array

$$G = \pi \frac{b(b+a)}{b} \quad (3)$$

$$\rho_a = \pi \frac{b(b+a)}{b} \quad (4)$$

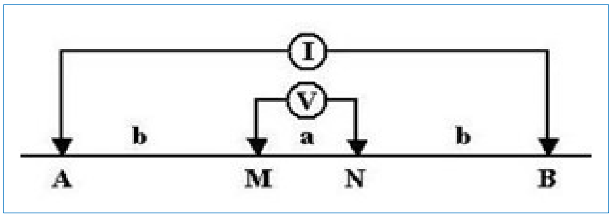

Fig. 4. Schlumberger array

3.1. Data Acquisition for Wenner Array and Schlumberger Array

The Wenner array survey, potential electrodes are kept between the current electrodes at fixed configuration (Bayowa et al., 2015). The electrodes are separated by a distance 'a' (Salami and Ogbamikhumi, 2017) which in this case was 10 m. The current electrode stays at the positions (C1 and C2) one and four point while the potential electrode (P1 and P2) stays at positions two and three point while moving all the electrode at the time with equal spacing for each reading. The first step is to make all the possible measurements with the Wenner array with an electrode spacing of "1a" (Ogungbemi et al., 2021). For the first measurement, electrodes number 1, 2, 3 and 4 are used. Notice that electrode 1 is used as the first current electrode C1, electrode 2 as the first potential electrode P1, electrode 3 as the second potential electrode P2 and electrode 4 as the second current electrode C2. For the second measurement, electrodes number 2, 3, 4 and 5 are used for C1, P1, P2 and C2 respectively. This is repeated down the line of electrodes until electrodes 17, 18, 19 and 20 are used for the last measurement with "1a" spacing. For a system with 20 electrodes, note that there are 17 (20 - 30) possible measurements with "1a" spacing for the Wenner array (Loke, 2000) and Schlumberger array survey, the distance between the current electrodes was represented by AB and each current electrode is placed at AB/2 from the center point and MN/2 from the point for the potential electrode. For the first reading, the potential electrodes were at 0.2 m from the center point while the current electrodes were at 1m. The current electrodes keep changing while the potential electrodes remain constant until AB/2 equals 14.7 m and 100 m, respectively.

4. Data Pre-Processing

The data collected from the field were pre-processed and post processed by ensuring high quality data, and calculating the resistivity of the various reading by multiplying it with the necessary constant. Also, field graphs were plotted using manual graphs. The resistivity and thickness values obtained from the partial curve matching were imputed into the software program (IX1Dv3 and Dipro) in a computer as model parameters. The process is now run by the program as a routine which in turn displayed an automatically plotted graph with an error tolerance limit set forth eprogram iteration, and when this is done or achieved, the model match becomes the interpreted layer parameters as shown in Figs. 4-6. The data were analyzed using the geophysical software IX1Dv3 and Dipro. The geo-electric layers, thickness and depth were generated, as well as the resistivity spread. The analyzed data was interpreted to determine the aquifer potential zone and delineate the lithology of the investigated area. The resistivity values, thickness and depths obtained after iteration were used to infer the stratigraphy and lithology of the subsoil of the study area as shown in (Table 2 and Figs. 5-6).

5. Results and Discussion

From (Table 1 and Fig. 5), the Wenner survey reveals the Apparent Resistivity generally varies from 286 Ωm to 177228 Ωm in the entire study area. An horizonal distance of 150m was covered to a depth of 50 m deep and the 2D resistivity reveals five (5) resistivity structures as shown in Fig. 5. The apparent resistivity of the five 2D resistivity layers varies from 286 - 414 Ωm, 511 - 2688 Ωm, 3813 - 7053 Ωm, 8445 Ωm - 12980 Ωm and 14634 Ωm - 177228 Ωm respectively as shown in Fig. 5. The 2-D Apparent Resistivity structure reveals five (5) layers in the subsurface of the study area which are the lateritic soil (clay), fine to coarse sand, very coarse sand, weathered zone and bedrock. The blue colouration indicates the presence of clay materials along 40-60 m, 100-130 m horizontally at 5 m to 15 m depth with resistivity range of 286 -414 Ωm. The green colouration indicates the presence of fine, medium to coarse sand along 25 m - 130 m horizontally at 0 m to 25 m depth with resistivity range of 511 - 2688 Ωm and yellow colouration indicates the presence of very coarse Sand at 25 m to 50 m depth with resistivity 3813 - 7053 Ωm. The light brown and deep brown colouration indicate the presence of weathered rock and bedrock at 30 to 50 m depth with resistivity 8445 Ωm - 12980 Ωm and 14634 Ωm - 177228 Ωm respectively as shown in Fig. 5. The Aquifer zone is revealed to be at 25 m to 50 m depth with medium to coarse sand as the lithology presence there. The aquifer is not contaminated with any leachate plume.

From (Table 2 and Figs. 6-7), the resistivity model of VES reveals seven (7) geoelectric layers. The Apparent resistivity ranges from 1221 Ωm to 9948.7 Ωm, overburden has a thickness range from 0.94013 m to 2.5055 m and depth ranges from 0.94013 m to 3.4456 m. The VES reveals that the third, fourth, fifth and sixth geoelectric layer is sand with little presence of gravel with an average thickness range of 15.088 m to 87.252 m at depth range of 18.534 m to 87.252 m with resistivity range of 1396.7 Ωm to 9948.7 Ωm. The depth to groundwater is at an average depth of 33.5 m. The VES data reveals two aquifer zones which are at 49.5 m and 87 m depth. The recommended drilled depth to groundwater is at 53 m (174 ft) and 72 m (240 ft) resistivity respectively the first aquifer is for shallow well and second aquifer is for deep well.

The aquifer depth to groundwater ranges from 32 m to 162 m in parts of Ethiopia West Local Government Area (Chambers et al., 2006).

Table 1. Summary of 2D resistivity structure (Wenner Survey)

2D Layers	Colour Indication	Apparent Resistivity Ranges	Infer Lithology
1	Blue	286 – 414 Ωm	Clay
2	Green	511 – 2688 Ωm	Fine, medium to coarse sand
3	Yellow	3813 – 7053 Ωm	Very coarse sand + Gravel
4	Light brown	8445 – 12980 Ωm	Weathered rock
5	Deep brown	14634 – 17722 Ωm	Bedrock

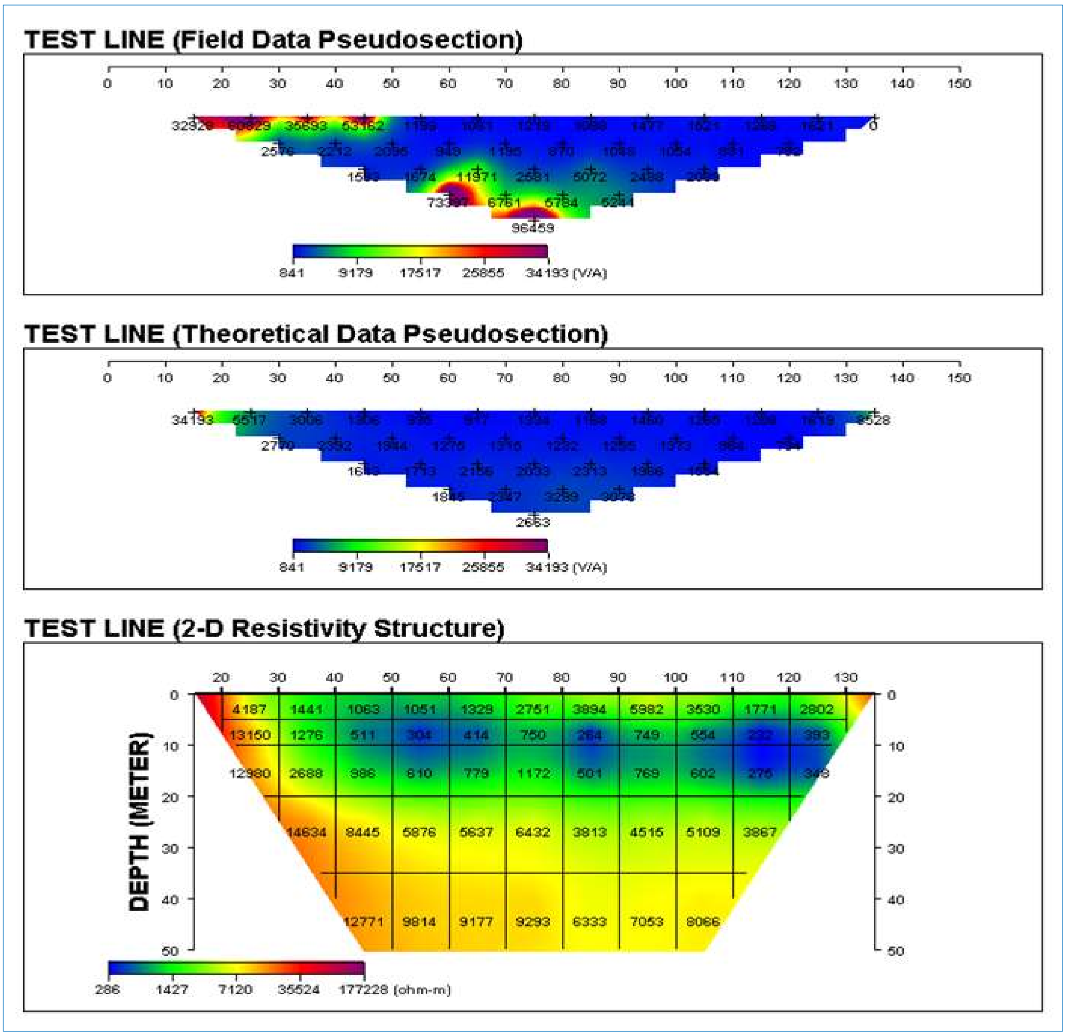

Fig. 5. 2D Resistivity structure (Wenner Survey) Dipro Inversion based on FEM modeling

Table 2. Summary of 1D apparent resistivity model and lithology

Geo-electric layers	Apparent resistivity (Ωm)	Thickness (m)	Depth (m)	Infer lithology
1	1221.0	0.94013	0.94013	Top soil
2	2753.8	2.5055	3.4456	Lateritic soil
3	2178.2	15.088	18.534	Medium-Coarse sand
4	1396.4	30.977	49.511	Medium-Coarse sand (Aquifer zone)
5	9948.7	9.1064	58.617	Coarse sand + Gravel
6	4567.9	28.635	87.252	Medium-Coarse sand (Aquifer zone)
7	8046.6	Infinity	Infinity	

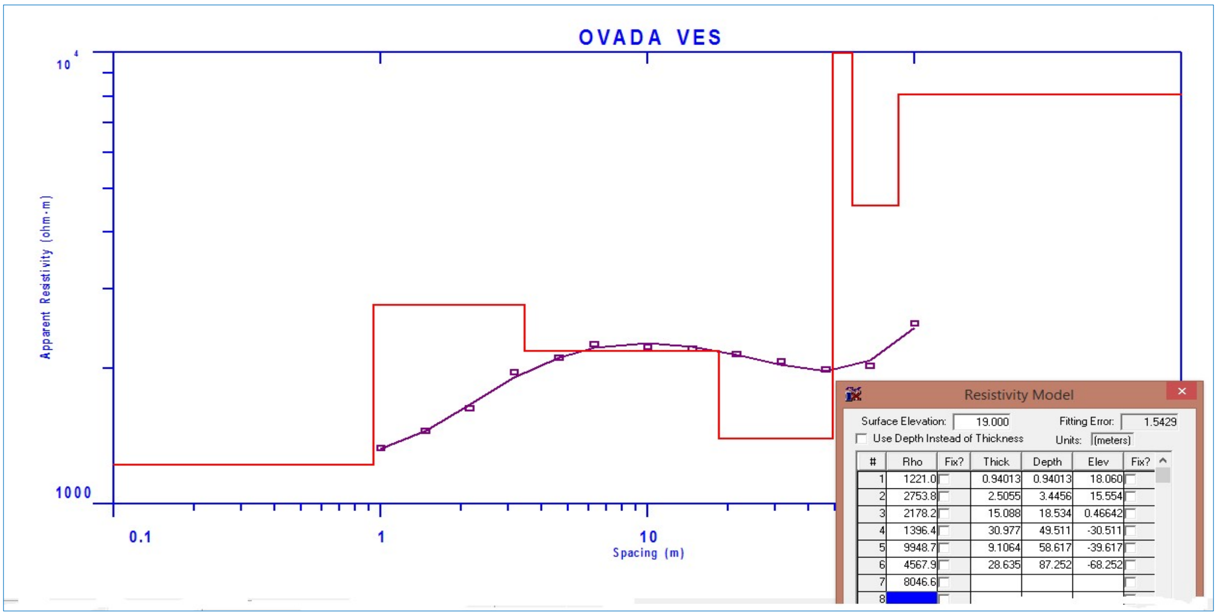

Fig. 6. Typical hydrogeophysical sounding curve and apparent resistivity model data

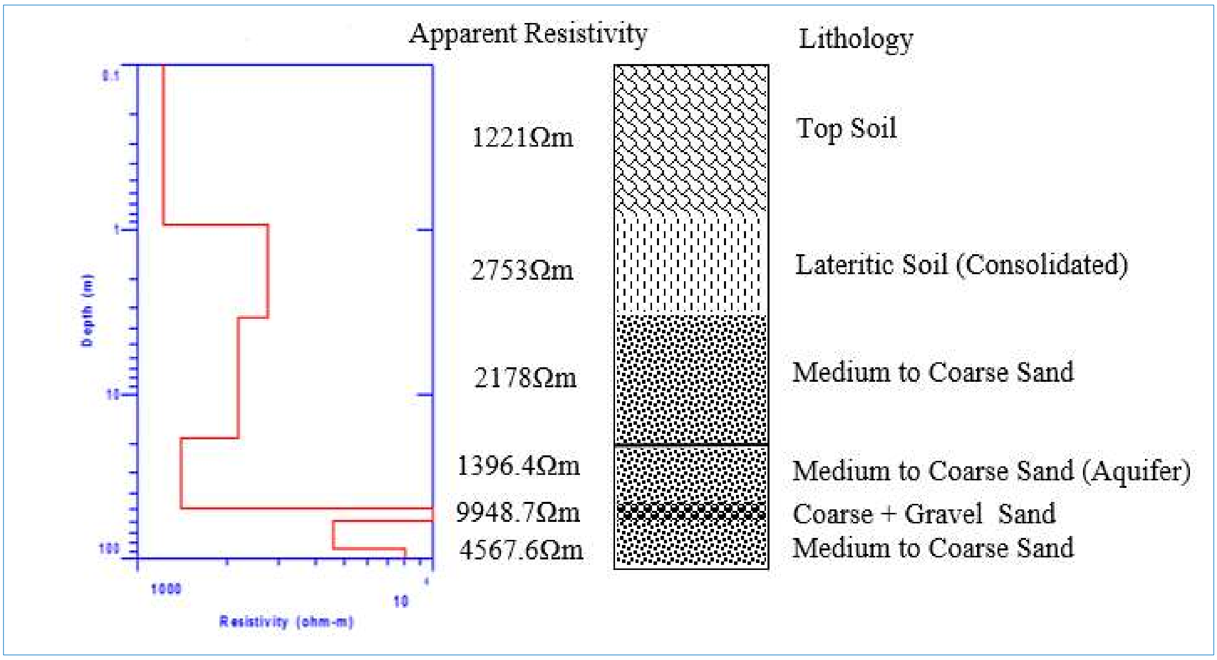

Fig. 7. Layered inversion model and lithology of the study area

The curve type is AKH curve. The results from seismic reflection and VES reveal that there is feasible aquifer at Sapele and Jesse which is within 20 – 25 m but at Oghara, its aquifer depth to groundwater is 40 m. Contaminated and shallow aquifer may be intercepted at 10 – 15 m at Sapele but not in Jesse and Oghara (Loke, 2004).

6. Conclusion

The depth to groundwater is at an average depth of 33.5 m. The VES data reveals two Aquifer zones which are at 49.5 m and 87 m depth. The curve type is AKH curve. From the results of 2D and 1D Resistivity structure, it is that the study area is predominantly with sand and little presence of clay materials before the aquifer zone.

7. Recommendation

We recommend that continue monitoring of the study area to avoid contamination of groundwater from improper dumping refuse. The study area is good for foundation design for uprise building. The recommended drilled depth to groundwater ranges from 53 m (174 ft) to 72 m (240 ft).

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