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Assessment of Groundwater Potential using Geophysical Techniques in Some Part of OFU Local Government Kogi State, North Central Nigeria

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ABSTRACT

The groundwater potential of Some part in Ofu Local government Kogi State was investigated using vertical electrical sounding method. A total number of 20 vertical electrical sounding data were acquired using Schlumberger array configuration. The data obtained were iterated using IPI2WIN software from which the geoelectric parameters (Resistivity, thickness and depth) were obtained. A total of 4-5 earth modeled layers were delineated which include, Topsoil, clay, sandy clay, sandstone and water-saturated sand layers were identified. Resistivity values for topsoil ranges from 1103-294 Ωm with depth varying from of 0.146-1.61m; sandstone with resistivity values 2964-9655 Ωm with depth varying from 0.364-59.86m; clay with 135-2006 Ωm and depth 0.788-11.0m; sandyclay with 927-7111 Ωm with depth 0.364-59.86m; clayeysand of 224-2238 Ωm with depth 1.29-10.4m. Overburden thickness varied significantly with a range between 7.33-80m. Thin overburden layers (<20m) were found at VES 13 and 15.Moderate overburden layers (20-40m). Thick overburden layers (40-80m) and very thick layers (>80m) were identified at VES 4 and 19. The usage of VES technique has suggested future boreholes in the area should be drilled at an expected depth of 42.8 m to 112 m depth.

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CHAPTER ONE
INTRODUCTION

A. *Background of the Study*

The electrical resistivity method is a geophysical method that has been successfully used by several researchers for groundwater investigations. The electrical resistivity method (non-invasive) is usually preferable because of the resistivity contrasts obtained when the groundwater zone is reached. Research in groundwater geophysics reveals that this technique has been successfully employed for delineating/mapping of geo-materials in the subsurface that guides exploration of groundwater resources (Metwaly et al., 2012; Oyedele et al., 2009). The electrical resistivity method is the most versatile and the most popular method of all the geophysical methods that are used in groundwater investigation in Basement Complex area (Olorunfemi, 2009). It is relevant in the depth to bedrock estimation, aquifer delineation and structural mapping (Ademilua and Eluwole, 2013; Obasi et al., 2013).

Geophysical techniques have been applied to groundwater with some showing more success than others. The methods include gravity, magnetic, seismic, electrical and electromagnetic methods (Reynolds, 1997 and Somiah, 2013). One of the methods that have proved effective to groundwater studies are the electrical and electromagnetic. This is because many of the geological formation properties that are critical to hydrogeology such as porosity and permeability of rocks can be correlated with electrical

Geophysical resistivity methods are based on the effective response of the earth to the flow of subsurface electrical current. Electrical resistivity is widely used for hydrogeological studies, because the acquired data are mainly controlled by lithological conditions of the aquifer. The method is also useful in the correlation of lithological facies between wells (Obianwu et al. 2015). VESs, when combined with other geophysical methods, geologic mapping and available well data can greatly assist in the location and completion of water wells in bedrock areas of complex hydrogeology. The VES method is usually considered more suitable for the subsurface investigation of geologic environments consisting of horizontal or nearly horizontal layers, such as occur in unconsolidated sedimentary sequences (Ojekunle et al. 2015; Badmus and Olatinsu 2012; Alile et al. 2008).

Groundwater is used for various purposes in both the developed and developing countries. Among its major purposes are for use in municipal, agriculture and industries, often extracted through the construction of wells and boreholes. In most parts of the countries where there is no (or limited) supply of freshwater from the surface water sources, groundwater serves the alternative natural sources. In Nigeria, large portions of its freshwater usage come from groundwater sources. The regional distribution of groundwater within the earth varies and this depends on the geology of the subsurface.

The reliance on groundwater is such that it is necessary to ensure that there are significant quantities of water and that the water is of a high quality. The principal source of groundwater is meteoric water, that is, precipitation. However, two other sources are occasionally of some consequence. These are juvenile water and connate water. The former is derived from magmatic sources, whereas the latter represents the water in which sediments are deposited. Connate water is trapped in the pore spaces of sedimentary rocks as they are formed and has not been expelled.

The amount of water that infiltrates into the ground depends on how precipitation is dispersed, namely, on the proportions that are assigned to immediate run-off and to evapotranspiration, the remainder constituting the proportion allotted to infiltration/percolation. Infiltration refers to the seepage of surface water into the ground, percolation being its subsequent movement, under the influence of gravity, to the zone of saturation. In reality, one cannot be separated from the other. The infiltration capacity is influenced by the rate at which rainfall occurs (which also affects the quantity of water available), the vegetation cover, the porosity of the soils and rocks, their initial moisture content and the position of the zone of saturation. The retention of water in soil depends on the capillary force and the molecular attraction of the particles. As the pores in the soil become thoroughly wetted, the capillary force declines, so that gravity becomes more effective. In this way, downward percolation can continue after infiltration has ceased but the capillarity increases in importance as the soil dries. No further percolation occurs after the capillary and gravity forces are balanced. Thus, water percolates into the zone of saturation when the retention capacity is satisfied. This means that the rains that occur after the deficiency of soil moisture has been catered for are those that count as far as supplementing groundwater is concerned. The water in the zone of aeration is referred to as vadose water. This zone is divided into three subzones, those of soil water, the intermediate belt and the capillary fringe. The uppermost or soil water belt discharges water into the atmosphere in perceptible quantities by evapotranspiration. In the capillary fringe, this occurs immediately above the water table, water is held in the pores by capillary action.An immediate belt occurs when the water table is far enough below the surface for the soil water belt not to extend down to the capillary fringe. The degree of saturation decreases from the water table upwards. An aquifer is the term given to a rock or soil mass that not only contains water but from which water can be abstracted readily in significant quantities. The ability of an aquifer to transmit water is governed by its permeability.By contrast, a formation with permeability of less than 10-9 m is one that, in engineering terms, is regarded as impermeable and is referred to as an aquiclude. For example, clays and shales are aquicludes. Even when such rocks are saturated, they tend to impede the flow of water through stratal sequences. An aquitard is a formation that transmits water at a very slow rate but that, over a large area of contact, may permit the passage of large amounts of water between adjacent aquifers that it separates.

B. Location and Accessibility of the Study Area

The study area (Fig 1) is located in some part of Ofu Local government Kogi State, North centre Nigeria. It is bound by latitudes 7°00' N and 7°50' N, and longitude 7°00' E and 7°50' E. The study area has an estimated population of 16,500 people consisting of 8,322 males and 8,178 females (NPC, 2006). It is located in the middle belt region of the country and covers a land mass area of 12sq.km.

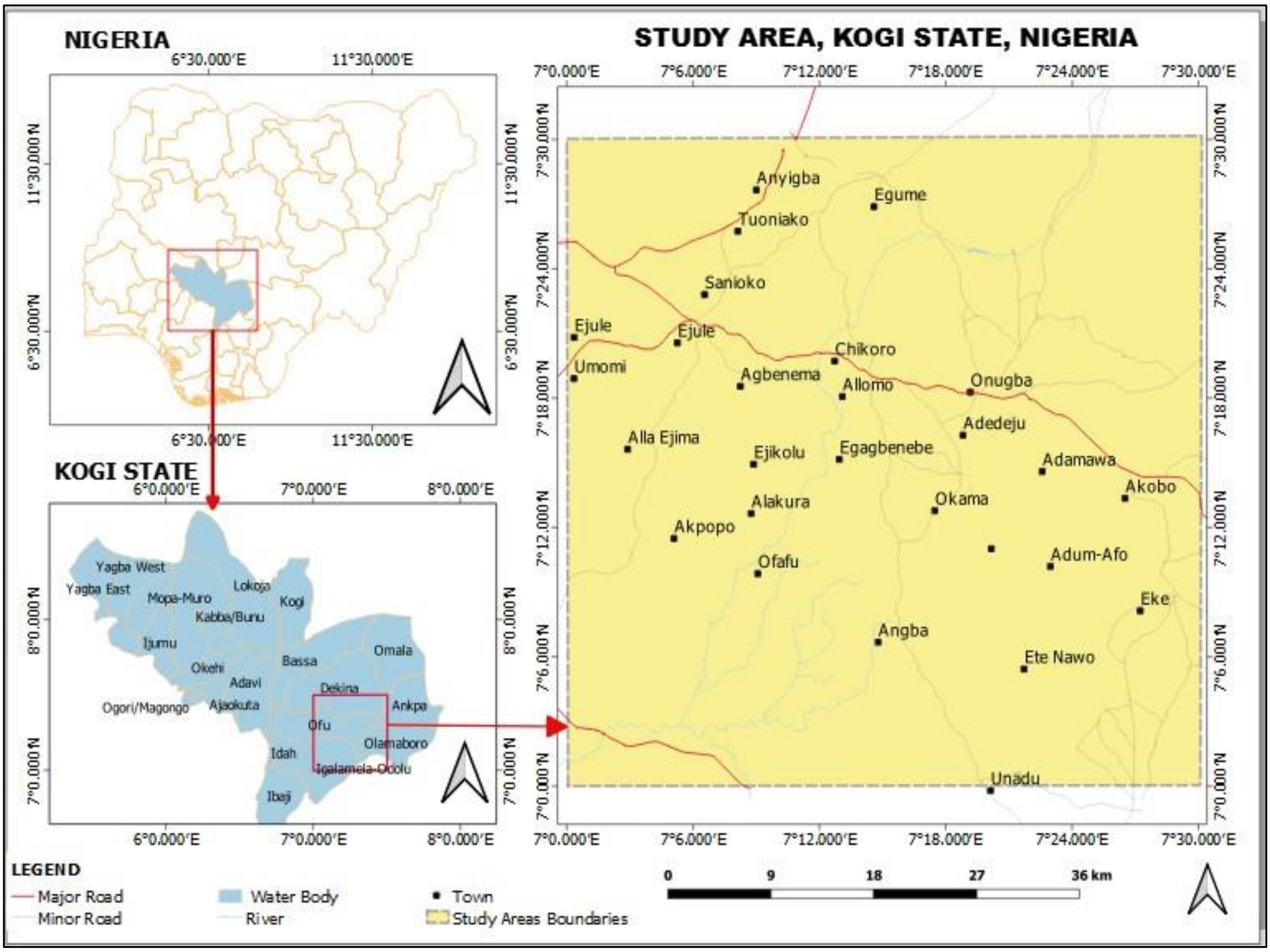

Fig 1: Location Map of the Study Area (Adopted from Q-GIS V 3.0)

C. Aim and Objectives of the Study

The main aim of this research is to assess the availability and distribution of groundwater resources within the selected areas of some part in Ofu Local government Kogi State.

➢ *The Specific Objectives are as Follow:*

- To identify potential aquifer(s) zone within the study area.
- To determine the geoelectric parameters
- To provide a comprehensive understanding of the hydrogeological characteristics.

D. Climate and Vegetation

The study area lies within the humid semi-hot savannah zone. The climate is dominated by two major air masses; the warm and the dry tropical continental wind from the Sahara Desert and the hot, humid tropical maritime wind from the Atlantic zone (the south West Monsoon wind). The wet/rainy season starts from middle of April to October while the dry/cool season runs from November to March. The study area has mean annual rainfall of about 1100mm while the mean temperature ranges between 28°C to 34°C. Relative humidity is about 74% to 80% for dry and wet seasons respectively. The vegetation of the area falls under tropical Guinean belt.

E. Significance of the Study

The project holds significant importance for environmental researchers. The main reasons for the significance of this project include:

- To provides valuable information about the availability, distribution, and quality of groundwater resources in the region.
- To access to clean and reliable water sources is a fundamental requirement for the socioeconomic development of any region. Identifying potential aquifers and zones with significant groundwater resources can support local communities in meeting their water needs, which in turn promotes better health, education, and overall quality of life (Ayoade and Akintola, 2012).

CHAPTER TWO
LITERATURE REVIEW AND GEOLOGICAL SETTING

A. Review of Previous Knowledge

Augie and Ologe (2015) conducted a hydrogeophysical investigation in Toto Area, Nassarawa State, North Central Nigeria, using electrical resistivity methods. The aim was to assess groundwater potential and delineate aquifer depth in the region. The work utilized the vertical electrical sounding (VES) technique to acquire data and interpret subsurface geological layers and hydrogeological conditions. The project work revealed three to five subsurface layers in the study area, comprising topsoil, weathered basement, fractured basement, and fresh basement. Auriferous zones were identified within the weathered and fractured basement layers, with varying depths across the study area. It also estimated aquifer parameters, such as transmissivity and hydraulic conductivity, to further characterize groundwater potential and provide insights for sustainable exploitation.

Alile *et al.* (2011) conducted a geoelectric investigation to identify potential groundwater resources in Obaretin - Iyanomon locality, Edo State, Nigeria. The researchers employed the Vertical Electrical Sounding (VES) method, acquiring data from three locations within the study area. The study revealed three to four subsurface geologic layers characterized by varying resistivity and thicknesses and interpreted these layers as sandy topsoil, sandy clay, sand, and coarse sand or fractured bedrock, respectively. Based on the resistivity values and layer thicknesses, the authors identified potential aquifer zones within the study area.

Adeniran *et al.* (n.d.) investigated the hydrogeophysical implications of geoelectric sounding at Igarra Comprehensive High School, located in Akoko Edo Local Government Area of Edo State, Nigeria. The study aimed to determine the subsurface geology and its impact on groundwater occurrence and movement in the area. The study used the VES method to collect geoelectric data from various locations within the study area. The resulting data revealed the presence of three to four subsurface geoelectric layers, characterized by distinct resistivity values and thicknesses. These layers were interpreted as topsoil, weathered/fractured basement, and fresh basement rocks. Based on their findings, Adeniran *etal*. (n.d.) identified potential aquifer zones within the weathered and fractured basement layers, emphasizing the importance of these geological features in trapping and storing groundwater.

Ojo *et al*. (2017) conducted a study to determine the groundwater potential in the permanent site of the University of Abuja, located in Nigeria's Federal Capital Territory (FCT). The authors used the Vertical Electrical Sounding (VES) technique to collect geoelectric data from ten locations within the study area. The collected data were interpreted using the Psartial Curve Matching (PCM) method and numerical modeling software.The results revealed three to five subsurface geoelectric layers characterized by different resistivity values and thicknesses. These layers were identified as topsoil, weathered basement, fractured basement, and fresh basement. The authors identified potential aquifer zones in the weathered and fractured basement layers, Ojo *etal.* (2017) concluded that the groundwater potential in the study area is relatively high and that the identified aquifer zones can be targeted for sustainable groundwater exploitation.

Saleh *et al.* (2019) investigated the groundwater potential of Kaltungo and its environs in Northeastern Nigeria using geoelectric techniques. The authors employed the VES method to collect geoelectric data from twenty locations across the study area. The data were analyzed and interpreted using the PCM method and 1D-Inversion software.The interpreted results revealed three to five subsurface geoelectric layers, including the topsoil, lateritic clay, weathered/fractured basement, and fresh basement. Based on the resistivity values and layer thicknesses, Saleh *et al.* (2019) identified potential aquifer zones in the weathered and fractured basement layers. The study concluded that the groundwater potential in Kaltungo and its environs is moderate to high and that the identified aquifer zones can be targeted for groundwater exploitation.

Nwachukwu *et al.* (2013) evaluated the groundwater potentials of Orogun in the South-South region of Nigeria using the electrical resistivity method. The study aimed to characterize the subsurface geology and identify potential aquifer zones in the area.Nwachukwu *et al.* (2013) identified potential aquifers in the sand layer.

Badmus and Olatinsu (2010) carried out a research work on aquifer characteristics and groundwater recharge pattern in a typical basement complex: A case study of Federal College of Education, Osiele, Abeokuta, South west of Nigeria. In their work, they used vertical electrical sounding (VES) using the Schlumberger electrode array. It was revealed that Abeokuta has seven major geological formations which are topsoil, shale or clay, sandy clay, clayey sand, sandstone, fractured basement and fresh basement. It also was discovered that the weathered and fractured basement constitute the main aquiferous units in the area. They were able to discover that the reasons for borehole failure and poor recharge in the area were due to inadequate geophysical investigation, the depth at which drilling was terminated and the geological formation of the aquifers. They also engaged 3-D view to show the overburden thickness.

B. Geology of the Study Area

The geology of the area figure 2.1 is full of sedimentary rock. The various sedimentary rocks of River Niger and Benue extend southeastwards through Enugu and Anambra States (www.onlinenigeria.com). Amhakhian and Osemwota (2012) reported geological formations of Cretaceous age within the study area. A study of sediment geochemistry of River Okura confirmed study area as falling within the Anambra sedimentary basin which is Cretaceous in age (Gideon and Fatoye, 2012). The study further revealed that the rocks had low silica (SiO_2) but high iron (Fe) content suggesting lithic arenite type of sandstone. Some parts of the study area have also been found to be made up of geologic materials such as Awgu shale group (Fagbami and Akamigbo, 1986; Ukabiala, 2012). The area is naturally drained to the Niger and Benue Rivers through their tributaries, rivers and streams forming various lowlands and floodplains. This zone falls in the middle belt of Nigeria.

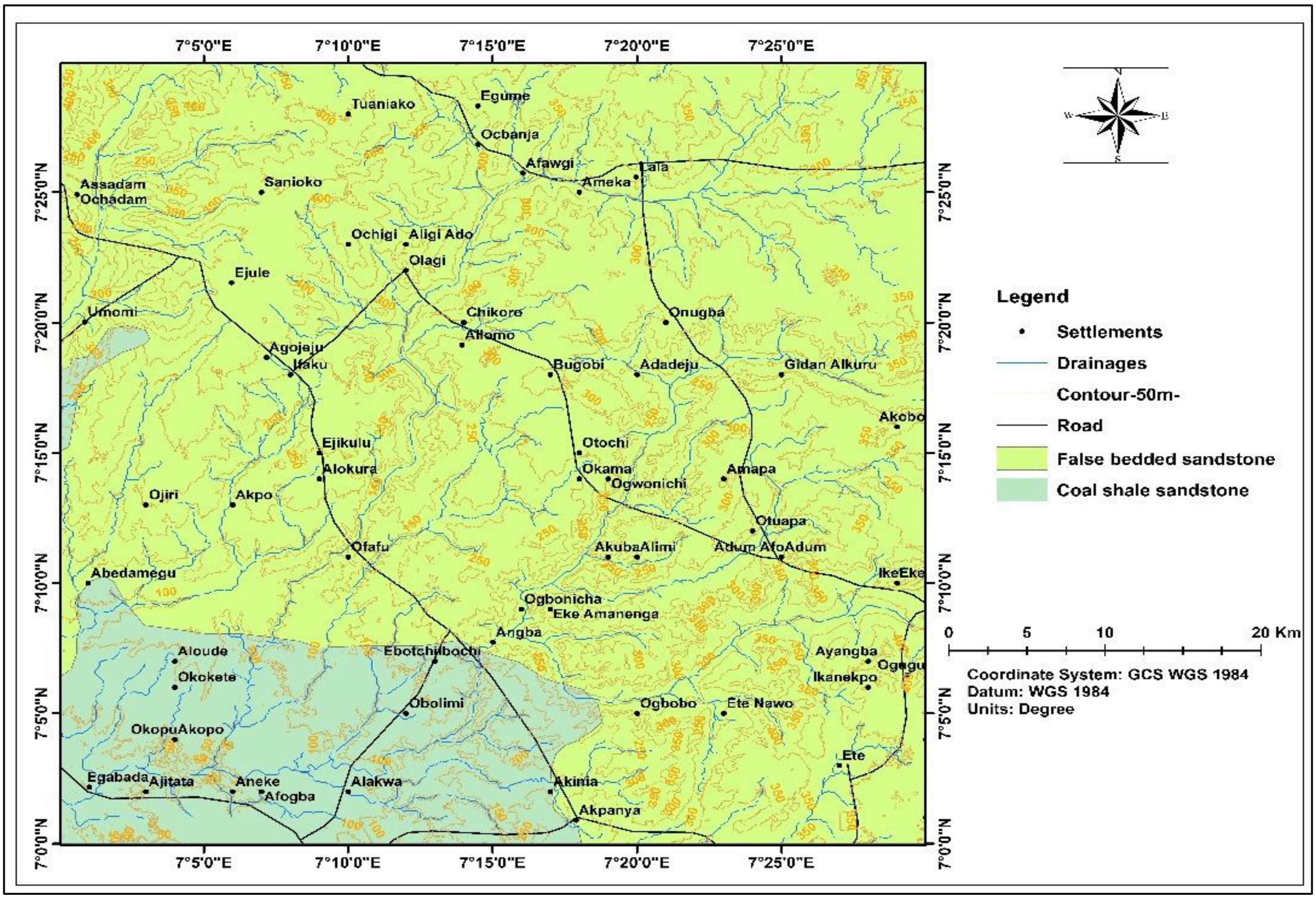

Fig 2: Geological Map of the Study Area

C. Electrical Resistivity Method

Surface electrical resistivity surveying is based on the principle that the distribution of electrical potential in the ground around a current-carrying electrode depends on the electrical resistivity and distribution of the surrounding soil sand rocks. The usual practice in the field is to apply an electrical direct current (DC) between two electrodes implanted in the ground and to measure the difference of potential between two additional electrodes that do not carry current. Usually, the potential electrodes are in line between the current electrodes, but in principle, they can be located anywhere. The current used is either direct current, commutated direct current (i.e., a square-wave alternating current), or AC of low frequency (typically about 20 Hz).All analysis and interpretation are done on the basis of direct currents.

Of all surface geophysical methods, the electrical resistivity method has been applied most widely for ground water investigations out of the entire surface geophysical methods. The electrical resistivity method can be best employed to estimate the thickness of overburden and the thickness of weathered/fractured zones with reasonable accuracy. Though both Wenner and Schlumberger electrode configuration methods are popularly employed, the Schlumberger electrode configuration method is more suited to the study area, ensuring better results. The method has practical, operational and interpretational advantages over other methods such as the Wenner method of electrode arrangement (Zohdy *et al.*, 1974). Most of the electrical resistivity techniques require injection of electrical currents into the subsurface via a pair of electrodes planted on the ground. By measuring the resulting variations in electrical potential at other pairs of planted electrodes, it is possible to determine the variations in resistivity. A conventional vertical electrical sounding (VES) survey was used for quantitative interpretation where the center point of the array remains fixed and the electrode spacing is increased for deeper penetration (Loke,1999).

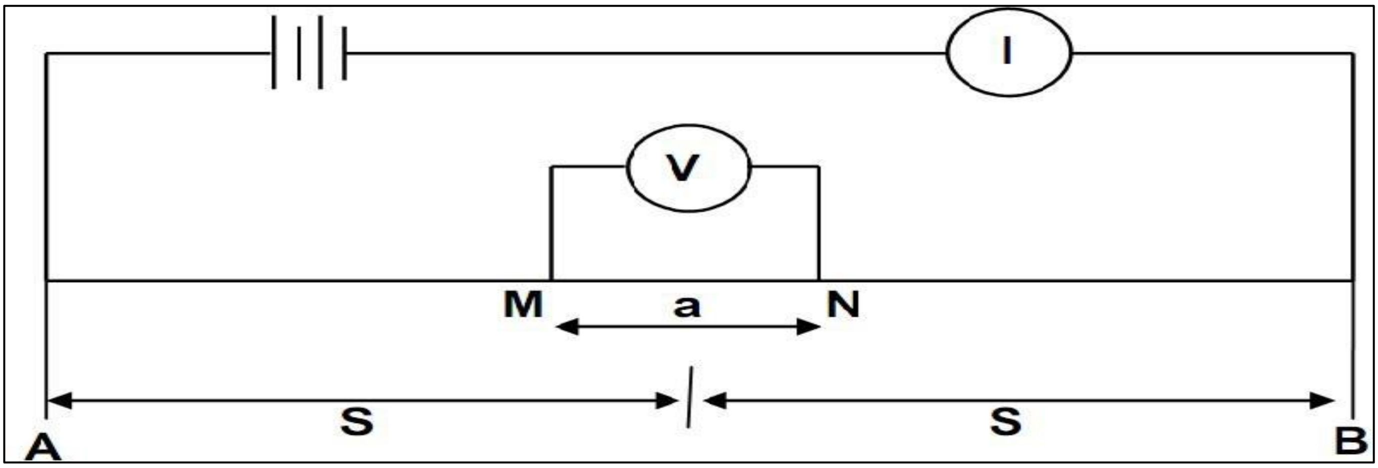

Fig 2.2: Geometric Arrangement of the Schlumberger Array Configuration

In carrying out resistivity sounding survey, electrodes are distributed along a line centered about a midpoint that is considered the location of the sounding. The electrode arrangement used in data acquisition is the Schlumberger array of electrodes. The Schlumberger survey involves the use of two current electrodes labeled A and B, and two potential electrodes M and N placed in line with one another and centered on some location. It is worthy to state that the potential and current electrodes are not placed equidistant from one another. To acquire the resistivity data in the field, current is introduced into the ground through the current electrodes and the potential electrodes are then used to quantitatively measure the voltage pattern. The apparent resistivity data obtained from the measurements are presented on maps at various levels and they are useful in the first stage of interpretation. More realistic sections of the earth are obtained only after interpretation of the data in terms of true variations of the resistivity distribution. This is a very important step because it allows the estimation of the true position and depth of formations. Moreover, it is possible to estimate the actual electrical resistivity of the region and relate it to its physical state.

D. Resistivity Method

The electrical resistivity method measures potential differences at points on the Earth's surface that are produced by directing current flow through the subsurface. This leads to the determination of resistivity distribution in the subsurface and to an interpretation of. Earth materials. The movement of charges through the conducting wire is termed current.

Specifically,

I=Q/t …….. (2.0)

Where *I* is current in amperes, *Q* is charge in coulombs, and *t* is time in seconds. Also, another important concept in electrical resistivity surveying is the current density *J*, which is defined as the current divided by the cross-sectional area of the material through which it is flowing

From Ohm's law,

J=I/A……….(2.1)

I=V/R………(2.2)

V=IR………..(2.3)

Electrical resistivity method is basically conducted to measure and map the resistivity of subsurface materials. It also refers to survey that is carried out to present the image of electrical properties of the subsurface by passing an electrical current along many different paths and measuring the associated voltage. Resistivity method is based on the response between the earth and the flow of electrical current. It sensitive to variations in the electrical resistivity of the subsurface measured in Ohms meter. Resistivity measurement are conducted by inducing an electric current into the earth through two current (C1 and C2) electrodes and measuring the resulting voltage at two potential electrodes (P1 and P2). The apparent resistivity (pa) value can be calculated based on the current (I) and voltage (V).

Resistance R is given by:

$$R = \frac{V}{I} \quad \text{………(3.1)}$$

Where R is the resistance,

V is the voltage and
I is the current.

The resistance is also proportional to the cross sectional area and the distance between the electrodes. The relationship is given by:

$$R = \frac{\rho L}{A} \quad \text{(3.2)}$$

Combining equations (2.1) and (2.2),

$$\frac{V}{I} = \frac{\rho L}{A} \quad \text{(3.3)}$$

Where A is the cross-sectional area,

V is the voltage,
I is the current and

L is the distance between the electrodes, the constant of proportionality, is the apparent resistivity.

Data from resistivity surveys are represented by apparent resistivity which takes into account, the arrangement and spacing of electrodes.

From the relationship above, the potential at any point is given by:

$$V = \frac{\rho I}{2\pi r} \quad \text{(3.4)}$$

Where: V is the potential in volts ρ is the resistivity of the medium and r is the distance from the electrode.

The resistivity of the ground is calculated from the potential difference between P_1 and P_2. The potential V_{P1} at the internal electrode P_1 is given by the algebraic sum of the potential contributions V_{C1} and V_{C2} from the current source at C_1 and the sink at C_2.

$$V_{P1} = V_{C1} + V_{C2} \quad \text{(3.5)}$$

The potentials at electrodes P_1 and P_2 are:

Therefore, the potential difference ΔV equals

$$\Delta V = Vp_1 - Vp_2 \ldots \text{(3.6)}$$

$$V_{P1} = \frac{\rho I}{2\pi}\left(\frac{1}{C1P1} - \frac{1}{C2P1}\right) \text{ and } \quad \text{(3.6.2)}$$

$$V_{P2} = \frac{\rho I}{2\pi}\left(\frac{1}{C1P2} - \frac{1}{C2P2}\right) \quad \text{(3.6.3)}$$

Where V is the voltage and R is the resistance.

Because various ecologic materials can be expected to have different resistance to current flow, it might seem fairly straight forward to measure current and voltage to calculate resistance and determine the material in the subsurface. One immediate complication is that resistance depends not only on the material but also on its dimensions.

$$\left(\frac{I\rho}{2\pi r_1} - \frac{I\rho}{2\pi r_2}\right) - \left(\frac{I\rho}{2\pi r_3} - \frac{I\rho}{2\pi r_4}\right) \quad \text{(3.6.4)}$$

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$$\Delta v = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right) \quad (4)$$

The two pairs of electrodes P_1 and P_2 (Fig. 2.3) carry no current but are used to measure the potential difference between the points P_1 and P_2.

The change in potential ΔV may be measured.

$$\Delta V = V_{P1} - V_{P2} = \frac{\rho I}{2\pi}\left(\frac{1}{C1P1} - \frac{1}{C2P1} - \frac{1}{C1P2} - \frac{1}{C2P2}\right) \quad (4.2)$$

$$\rho = \frac{\Delta V 2\pi}{I\left(\frac{1}{C1P1} - \frac{1}{C2P1} - \frac{1}{C1P2} - \frac{1}{C2P2}\right)} \quad (4.3)$$

Where

$$k = 2\pi\left(\frac{1}{C1P1} - \frac{1}{C2P1} - \frac{1}{C1P2} - \frac{1}{C2P2}\right)^{-1}$$

is the geometric factor, and is only a function of the geometry of the electrode arrangement

Resistivity can be found from measuring values of V, I and K. So the apparent resistivity (ρ_a) equation becomes; In the resistivity method current is entered into the ground, potential difference ismeasured and resistivity is determined. For ρ, equation 7 becomes.

$$\rho = \frac{2\pi\Delta v}{I}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right)^{-1} \quad (5)$$

$$\rho_a = \frac{\Delta V 2\pi}{I}\left(\frac{1}{\frac{1}{C1P1} - \frac{1}{C2P1} - \frac{1}{C1P2} - \frac{1}{C2P2}}\right) \quad (5.2)$$ (Amadi, 2016).

Resistivity ρ is thus given as

$$\rho = \frac{\Delta v}{I}.G = RG \quad (6)$$

Where R is the measured resistance and G is the Geometric Constant which is a function of the electrode configuration employed during the survey.

E. Principle of Resistivity Method

The principle of the electrical resistivity method is the measurement of an earth resistance by passing low frequency current into the ground through two stakes or electrodes. If the distances between the four (4) electrodes are known then the current and the potential difference measurements may be used to calculate a "resistivity" value of the earth (Thomas, 1986). All resistivity methods employ an artificial source of current which is introduced into the ground through point electrode or long line contacts. The latter arrangement is rarely used nowadays. The procedure is to measure potential difference at other electrode in the vicinity of the current flow. Because the current is measured as well, it is possible to determining an effective apparent resistivity of the subsurface. In this regard the resistivity technique is superior at least theoretically to all other electrical methods because quantitative results are obtained by using a controlled source of specific dimension (Telfordetal,1990).The resistivity of the rock usually depends on the amount of ground water present and upon the amount of salt dissolve in it. It decreases by the presence of many ore minerals and by high temperature (Alan et al, 2000). Conduction of electrical through rock of three types; electronic conduction which occur when the mineral grains are electrically conductive as with minerals such as pyrite and magnetite. Most common minerals grains such as quartz, feldspar and calcite are non-conductive and conductive ionic.

CHAPTER THREE
MATERIAL AND METHOD

A. Introduction

The electrical resistivity method measures potential differences at points on the Earth's surface that are produced by directing current flow through the subsurface. This leads to the determination of resistivity distribution in the subsurface and to an interpretation of earth materials. The movement of charges through the conducting wire is termed current.

B. Material

- Ohmega1000C Terameter Unit
- Electrodes (Two current and Two potentials)
- Reels and Cables
- Measuring Tape
- Hammers
- Cutlass
- Battery (power source)
- Recording Sheet
- A Global Positioning System (GPS)

- **Ohmega 1000C Terrameter**: **-** This equipment involves VES and electrical profiling method that is based on the four-electrode principle used by geophysicist for evaluation of greater penetration depth of the injected current for successive readings. The current injected into the ground could be DC or AC.
- **Electrode: -** This enables the electrode convey current into the subsurface when driven into the earth with the hammer. Two pairs of electrodes were used; a pair is current electrodes while the other pair is potential electrodes.
- **Reels and Cables**: It is usually connected with a clip attached to one end of the electrode while the other end connects sat the terrameter. The cable is made of an insulating material outside housing the flexible copper wire. Due to the flexibility of the cable, it can be easily recoiled back into its reel.
- **Global Positioning System (GPS)**: **-** Garmin GPS72H GPS was used to take the coordinates as well as the elevation of the surveyed areas. This is necessary so that the exact position of each VES point could be located in the future if the need arises.
- **Hammer:** This was used to drive the electrodes into the ground.

C. Research Methodology

There are two basic procedures in resistivity work. The procedure to be used depends on whether we are interested in lateral or vertical variations in resistivity. Resistivity surveys are made to satisfy the needs of two distinctly different kinds of interpretation problems:

- The variation of resistivity with depth, reflecting more or less horizontal stratification of earth materials; and
- Lateral variations in resistivity that may indicate soil lenses, isolated ore bodies, faults, or cavities. For the first kind of problem, measurements of apparent resistivity are made at a single location (or around a single center point) with systematically varying electrode spacing.

D. Schlumberger Array

This type of configuration deals with vertical electrical sounding. Electrical sounding is the process by which the variation of resistivity with depth below a given point on the ground surface is deduced and it can be correlated with the available geological information in order to infer the depths (or thicknesses) and resistivity of the layers (formations) present.

The procedure is based on the fact that the current penetrates continuously deeper with the increasing separation of the current electrodes.

The current electrodes are spaced much further apart than the potential electrodes. The potential electrodes remain fixed while the current electrodes are expanded symmetrically about the center of the spread.

E. Field Procedures

The Schlumberger array is a commonly used electrode configuration in electrical resistivity surveys for both vertical electrical sounding (VES) and profiling. The array consists of four collinear electrodes: two outer current electrodes (A and B) and two inner potential electrodes (M and N). The current is transmitted through the outer electrodes, and the resulting voltage is measured between the inner electrodes.

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➢ *Here is a Step-by-Step Guide to Performing a Schlumberger Array Survey:*

- **Select the survey area**: Choose the location where you want to investigate the subsurface resistivity. The area should be clear of any obstructions, such as trees or buildings, and the ground should be relatively flat
- **Set up the equipment**: Connect the resistivity meter or multi-meter to the electrodes using appropriate cables. Ensure that the meter is set to measure resistance or resistivity and that it is calibrated correctly.
- **Establish the initial electrode spacing**: The outer electrodes (A and B) were positioned at a specified distance from each other (AB), typically several times the expected investigation depth.The inner electrodes (M and N) were also positioned at a smaller distance (MN) from each other, usually between 10% and 30% of AB.
- **Take measure**ments: Switch on the resistivity meter and allow it to stabilize. Record the measured resistance or resistivity value and the corresponding electrode spacing (AB and MN). Ensure that the measured value is stable before recording it.
- **Increase electrode spacing**: Move the outer electrodes (A and B) further apart, and keep the inner electrodes (M and N) at a constant distance from each other. Take another measurement at this new electrode spacing and record the value.
- **Repeat the process**: Continue increasing the distance between the outer electrodes and taking measurements until you reach the desired depth of investigation. Keep the inner electrode spacing constant throughout the survey.
- **Analyze the data**: Plot the measured resistivity values as a function of electrode spacing. The resulting curve can be interpreted to determine the subsurface resistivity distribution, which provides information on the geological layers and the presence of groundwater or other subsurface features.
- **Profiling (optional)**: If profiling is required, keep the outer electrodes (A and B) at a fixed distance from each other and move the inner electrodes (M and N) along the survey line, taking measurements at regular intervals. This provides information on lateral resistivity variations in the subsurface.
- **Pack up the equipment**: Once the survey is complete, disconnect the cables, remove the electrodes from the ground, and pack up the resistivity meter and other equipment.
- The Schlumberger array is advantageous for VES and profiling due to its efficient use of personnel and time during field surveys. Additionally, the variable electrode spacing allows for detailed investigations of specific depths, making it suitable for various geological and hydrogeological application.

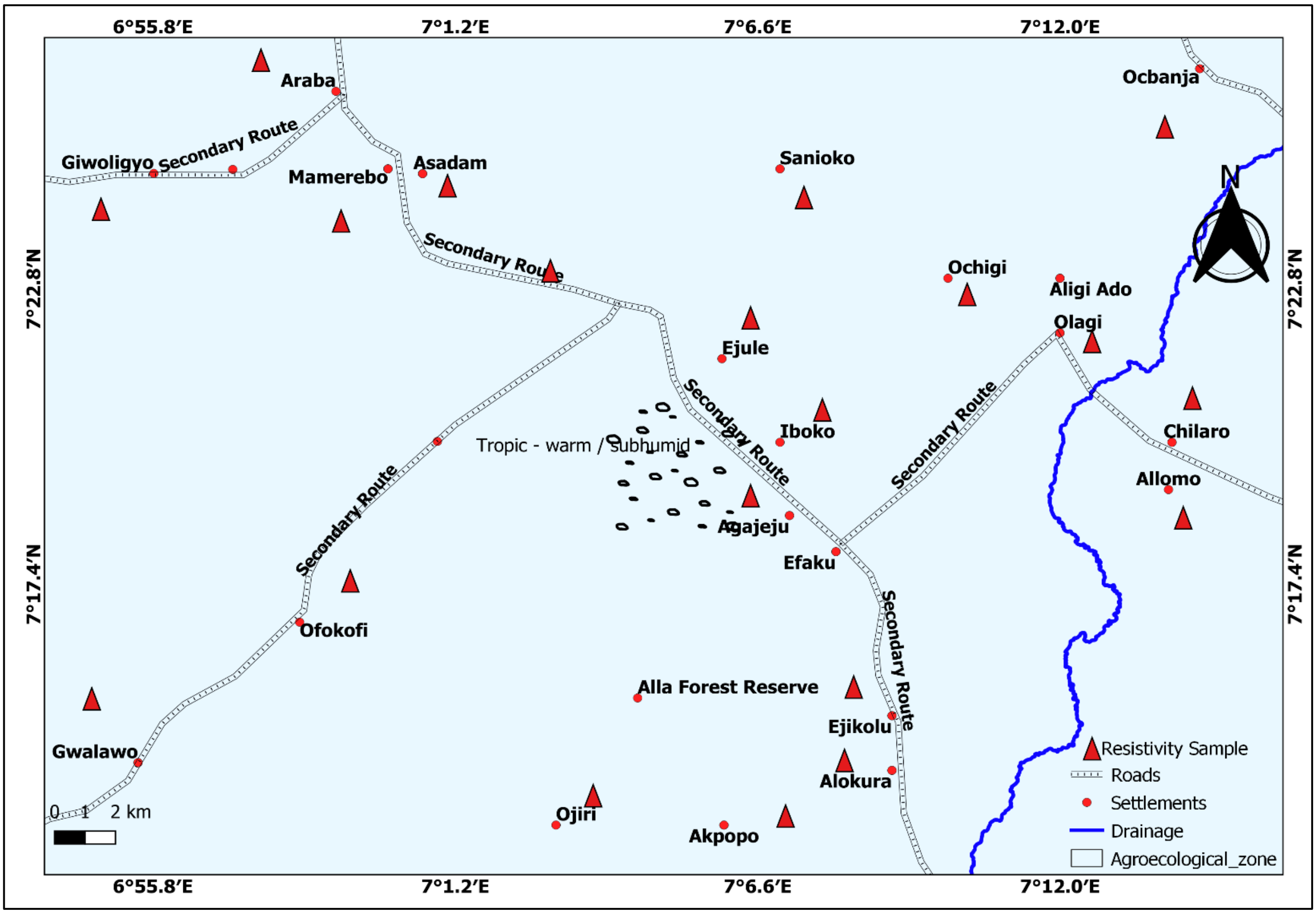

Fig 3.4: Resistivity Map of the Study Area

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CHAPTER FOUR
RESULTS AND DISCUSSION

The VES data obtained were in resistance (Ω), using ohmega 1000c terrameter which were then multiplied by their corresponding geometric factor (k) in order to obtain an apparent resistivity in ohm-meter. Computer software called IPI2WIN was used to processes the data, the apparent resistivity values for each point was plotted against the half current electrode spacing AB/2 on log-graph to obtain sounding curves. The purpose of these curves is to determine the subsurface layers beneath each VES point as well as their thickness and resistivity variation, the results of the analysis of data were correlated with a borehole log data obtained near the study area. Boreholes log data are a necessary and reliable source of data, and electrical resistivity method using vertical electrical sounding (VES) interpretations provide basic information of the area. The data was firstly processed and analyzed using IPI2win version 3.0.1 Software which gave automatic geo-electric parameters of the study area. The output of VES data is resistivity layer, log resistivity graph and resistivity depth table. Sounding curve obtained from the study area showed variation of four - five geo-electrical layers.

A. Acquired Sounding Data From Study Location

Fig 4.1.1 VES 1 and 2 Data

S. nO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	158.2	1863.596
2	3	0.5	27.5	54.81	1507.275
3	6	0.5	112.3	15.26	1713.698
4	9	0.5	254	6.308	1602.232
5	9	2.0	60.5	31.94	1932.37
6	15	2.0	173.6	10.88	1888.768
7	25	2.0	488	4.690	2288.72
8	40	2.0	1253	2.177	2727.781
9	50	2.0	1960	1.455	2851.8
10	75	2.0	4410	0.831	3664.71
11	75	10.0	868	3.795	3294.06
12	100	10.0	1555	2.523	3923.265
13	150	10.0	3520	1.271	4473.92
14	200	10.0	6270	0.766	4802.82
15	300	10.0	14120	0.404	5704.48
16	300	20.0	7040	0.783	5512.32
17	400	20.0	12530	0.519	6503.07
18	500	20.0	19600	0.353	6918.8
LOCATION: ST.MICHAEL CHURCH ARABA **TOWN: ARABA VES 1** **L.G.A: OFU** **STATE: KOGI** **LATITUDE: N06^0 14'.56''** **LONGITUDE: E06^0 07'.23''** **ELEVATION: 355 m**					

Fig 4.1.2 VES 3 and 4

S. nO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	60.66	714.5748
2	3	0.5	27.5	30.93	850.575
3	6	0.5	112.3	8.424	946.0152
4	9	0.5	254	3.591	912.114
5	9	2.0	60.5	21.87	1323.135
6	15	2.0	173.6	6.105	1059.828
7	25	2.0	488	2.289	1117.032
8	40	2.0	1253	1.383	1732.899
9	50	2.0	1960	1.200	2352
10	75	2.0	4410	0.709	3126.69
11	75	10.0	868	4.629	4017.972
12	100	10.0	1555	2.889	4492.395
13	150	10.0	3520	1.662	5850.24
14	200	10.0	6270	1.078	6759.06
15	300	10.0	14120	0.566	7991.92
16	300	20.0	7040	1.239	8722.56
17	400	20.0	12530	0.742	9297.26
18	500	20.0	19600	0.512	10035.2

LOCATION: GIWOLIGYO
TOWN: GIWOLIGYO 2
L.G.A: OFU
STATE: KOGI
LATITUDE: N06^0 03'.42''
LONGITUDE: E006^0 69'.46''
ELEVATION: 370 m

B. Processed Resistivity Data Showing Sounding Curves Of Each Ves Points

Using IPI2WIN version 3.0.1 software, Fig 4.2.1 was generated. It displays an HAA curve type, with five different layers showing different lithology through the resistivity values(Ohm) in the location Araba, thickness(m)and depth(m) of each of these layers are displayed as well as one dimensional pseudo section which image the distribution of the VES in the subsurface.

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S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	96.13	1132.411
2	3	0.5	27.5	33.75	928.125
3	6	0.5	112.3	10.03	1126.369
4	9	0.5	254	4.721	1199.134
5	9	2.0	60.5	31.54	1908.170
6	15	2.0	173.6	11.70	2031.120
7	25	2.0	488	4.497	2194.536
8	40	2.0	1253	1.536	1924.608
9	50	2.0	1960	0.953	1867.880
10	75	2.0	4410	0.338	1490.580
11	75	10.0	868	1.516	1315.888
12	100	10.0	1555	0.623	968.765
13	150	10.0	3520	0.165	580.800
14	200	10.0	6270	0.087	545.490
15	300	10.0	14120	0.029	409.480
16	300	20.0	7040	0.051	359.040
17	400	20.0	12530	0.035	438.550
18	500	20.0	19600	0.020	392.000

LOCATION: OFOKOFI
TOWN: OFOKOFI VES 3
L.G.A: OFU
STATE: KOGI
LONGITUDE: E006^0 10'.26''
LATITUDE: N06^0 48'.51''
ELEVATION: 177 m

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	47.46	559.079
2	3	0.5	27.5	24.68	678.700
3	6	0.5	112.3	7.860	882.678
4	9	0.5	254	3.960	1005.840
5	9	2.0	60.5	23.19	1402.995
6	15	2.0	173.6	7.407	1285.855
7	25	2.0	488	2.584	1260.992
8	40	2.0	1253	1.119	1402.107
9	50	2.0	1960	0.762	1493.520
10	75	2.0	4410	0.370	1631.7
11	75	10.0	868	2.676	2322.768
12	100	10.0	1555	1.251	1945.305
13	150	10.0	3520	0.459	1615.680
14	200	10.0	6270	0.190	1191.300
15	300	10.0	14120	0.085	1200.200
16	300	20.0	7040	0.198	1393.920
17	400	20.0	12530		
18	500	20.0	19600		

LOCATION: GWALAWO
TOWN: GWALAWO VES 4
L.G.A: OFU
STATE: KOGI
LONGITUDE: E006^0 06'.19''
LATITUDE: N06^0 57'.125''
ELEVATION: 253 m

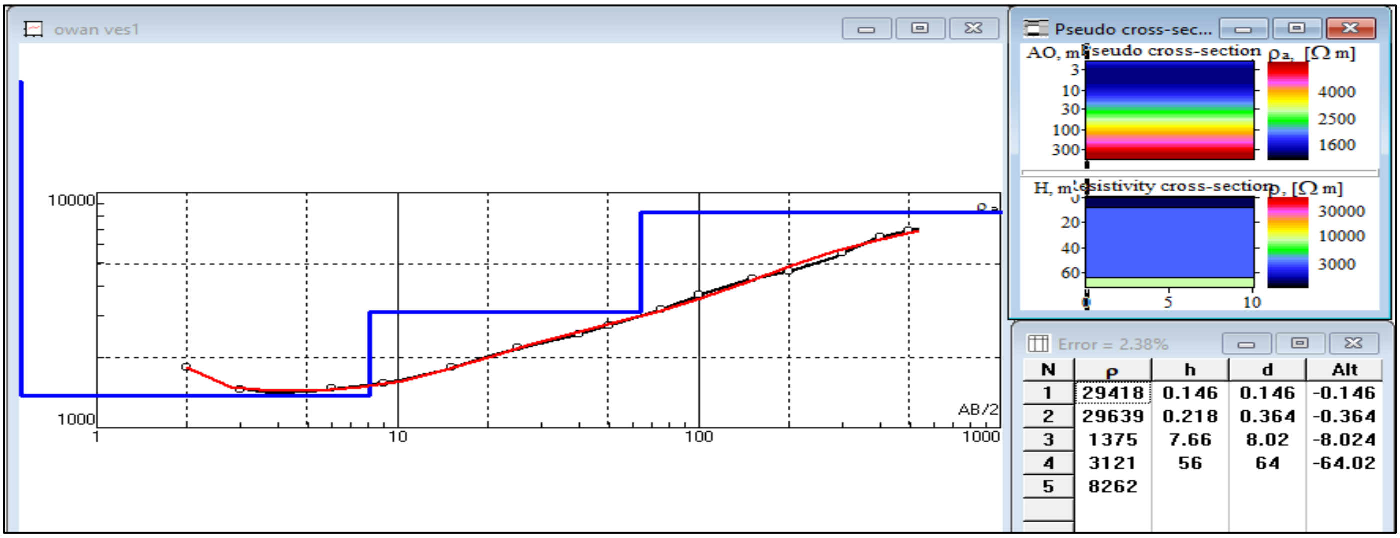

Fig 4.2.1 VES 1 Curve

Fig 4.2.2 displays KHK curve type with seven different layers which indicates different lithology by the resistivity values (Ohm) in location Giwoligyo(m)and depth(m) of each of these layers are displayed as well as one dimensional pseudo section which image the distribution of the VES in the subsurface.

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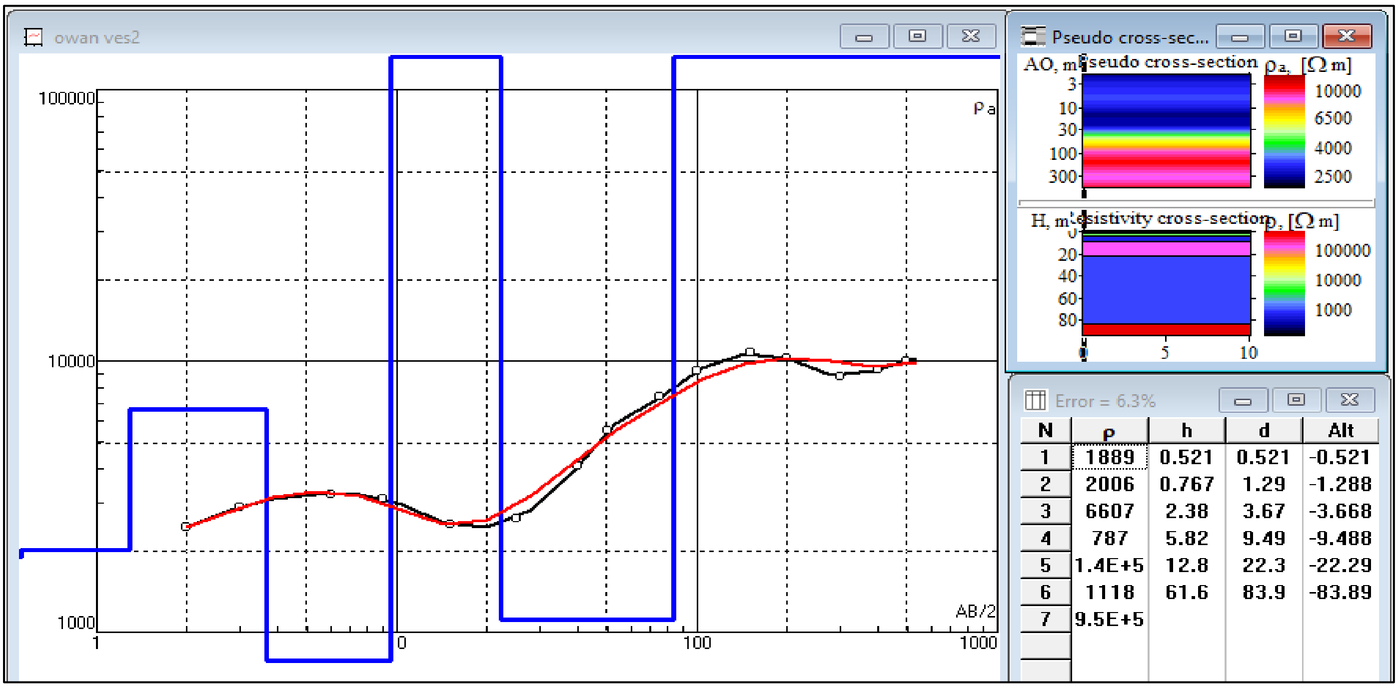

Fig 4.2.2 VES 2 curve

Fig 4.2.3 displays an HKH curve type with five different layers which indicates different lithology by the resistivity values(Ohm) in location Ofokofi, thickness(m)and depth(m) of each of these layers are displayed as well as one dimensional pseudo section which image the distribution of the VES in the subsurface.

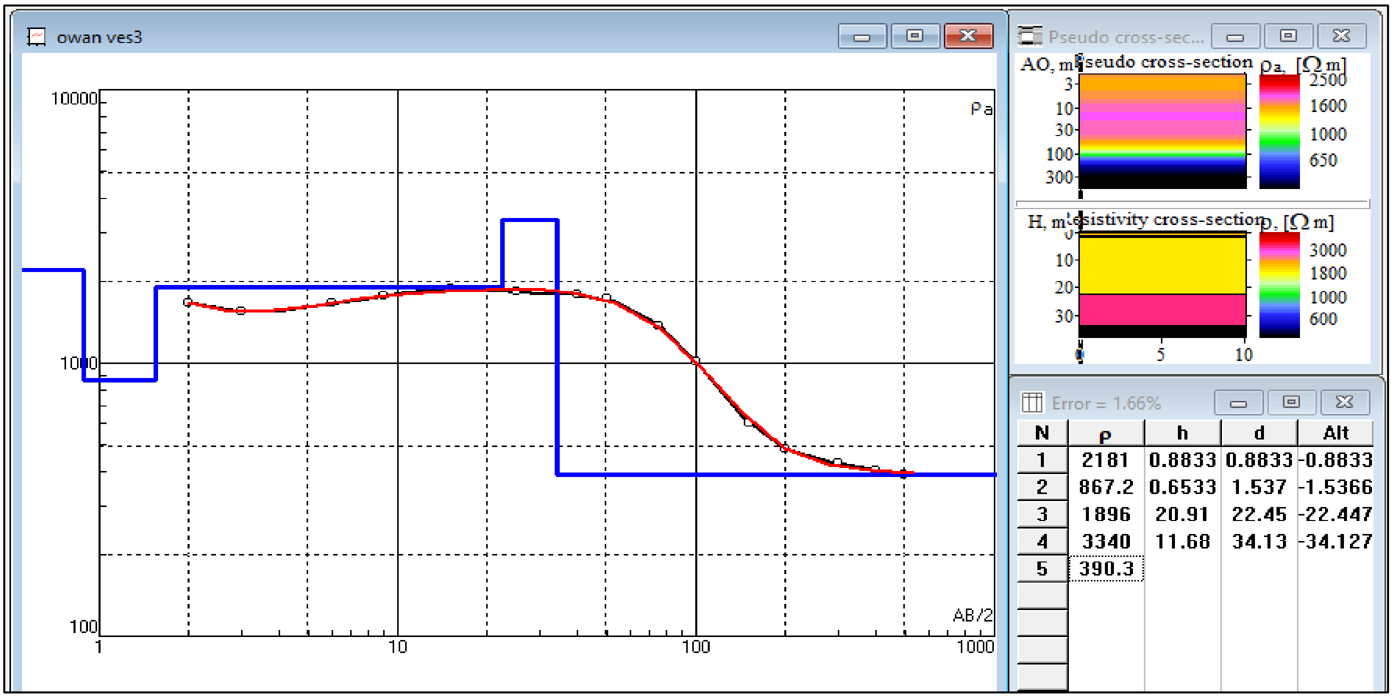

Fig 4.2.3 VES 3 curve

Fig 4.2.4 displays KHK curve type with seven different layers which indicates different lithology by the resistivity values (Ohm) in location Gwalawo, thickness (m) and depth (m) of each of these layers are displayed as well as one dimensional pseudo section which image the distribution of the VES in the subsurface. Thicker aquifers with moderate to low resistivity values are more likely to yield significant water flows. Based on the analysis, Fig 4.2.2 emerges as one of the promising drilling target.

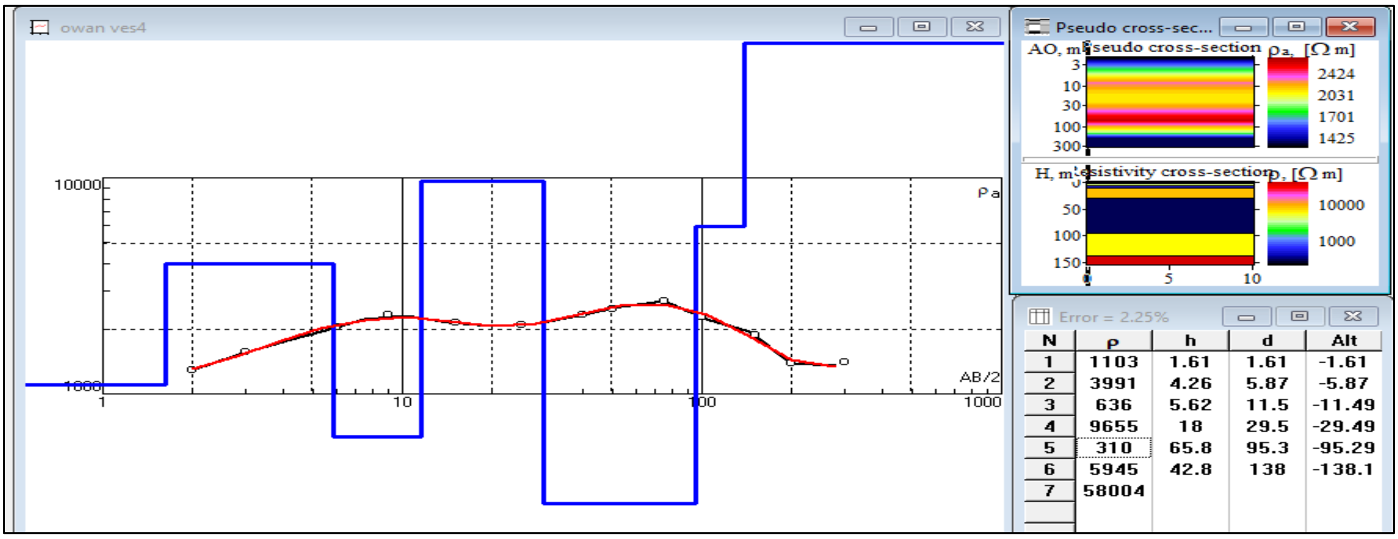

Fig 4.2.4 VES 4 Curve

C. Analysis Of VES Data For Groundwater Exploration

The VES data in fig 4.1 provided consists of 4 sounding locations while 16 sounding locations can be seen in the appendix, each with multiple layers of varying resistivity values, thicknesses, and depths. The primary objective of this analysis is to identify potential aquifers

➢ *Resistivity Values and Aquifer Identification*

Low resistivity values (<100 Ωm) typically indicate high conductivity, which is often associated with water-saturated formations. In contrast, high resistivity values (>1000 Ωm) suggest low conductivity, potentially indicating unsaturated or low-permeability materials like clay or sandstone.

➢ *Aquifer Thickness and Depth*

Thicker aquifers with moderate to low resistivity values are more likely to yield significant water flows. Based on the analysis, four locations emerge as promising drilling targets which are fig (GWALAWO) exhibits a potential aquifer in Layer 6 (42.8-138 m) with a low resistivity value of 5945 Ωm and significant thickness of 42.8 m,VES 14 (EFAKU) reveals a water-saturated sand layer in Layer 4 (101-120 m) with a moderate resistivity value of 275 Ωm and moderate thickness of 19 m,VES 16 (OLAJI) displays a potential aquifer in Layer 4 (29.5-45 m) with a relatively low resistivity value of 485 Ωm and moderate thickness of 15.5 m,VES 19 (CHIKORO) shows a potential aquifer in Layer 5 (113-212.3 m) with a moderate resistivity value of 3549 Ωm and significant thickness of 99.3 m.VES 14, 16, and 19 can be seen in the Appendix.

Fig 4.3: Estimated Table of Geologic Formation of the Study Area

StationID/Layers	**AppRes (Ωm)**	**Thickness (m)**	**Depth (m)**	**Description**
VES1(ARABA) (RMS: 2.38%)				CURVE TYPE HAA((ρ1>ρ2< ρ3< ρ4<ρ5)
1	29418	0.146	0.146	Toplayer
2	29639	0.218	0.364	Sandstone
3	1375	7.66	8.02	Sandyclay
4	3121	56	64	Water Saturated Sand
5	8262	Undetermined	120	Sandstone
VES 2(GIWOLIGYO) (RMS:6.3%)				CURVE TYPE KHK(ρ1<ρ2> ρ< ρ4>ρ5)
1	1889	0.521	0.521	Toplayer/Laterite
2	2006	0.767	1.29	Clayeysand
3	6607	2.38	3.67	Sandyclay
4	787	5.82	9.49	Clay
5	140000	12.8	22.3	Sandstone
6	1118	61.6	83.9	Water-SaturatedSand
7	950000	Undetermined	145.5	Sandstone
VES3(OFOKOFI) (RMS:1.66%)				CURVE TYPE HKH((ρ1>ρ2< ρ3> ρ4<ρ5)
1	2181	0.8833	0.8833	Topsoil

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2	867.2	0.6533	1.537	Clayeysand
3	1896	20.91	22.45	Sandyclay
4	3340	11.68	34.13	Sandstone
5	390.3	Undetermined	45.81	Water-SaturatedSand
VES4(GWALAWO) (RMS:2.25%)				CURVE TYPE KHK(ρ1<ρ2> ρ3< ρ4>ρ5)
1	1103	1.61	1.61	Toplayer/Laterite
2	3991	4.26	5.87	Sandyclay
3	636	5.62	11.5	Clay
4	9655	18	29.5	Sandstone
5	310	65.8	95.3	Clay
6	5945	42.8	138	Water-SaturatedSand
7	58004	Undetermined	180.8	Sandstone

Start drilling at Fig 4.2.4 (GWALAWO) to a depth of 138 m, targeting the potential aquifer in Layer 6, Consider drilling at VES 14 (EFAKU) to a depth of 120 m, targeting the water-saturated sand layer in Layer 4.Drill at VES 16 (OLAJI) to a depth of 45 m, targeting the potential aquifer in Layer 4.If the above locations do not yield satisfactory results, consider drilling at VES 19 (CHIKORO) to a depth of 212.3 m.

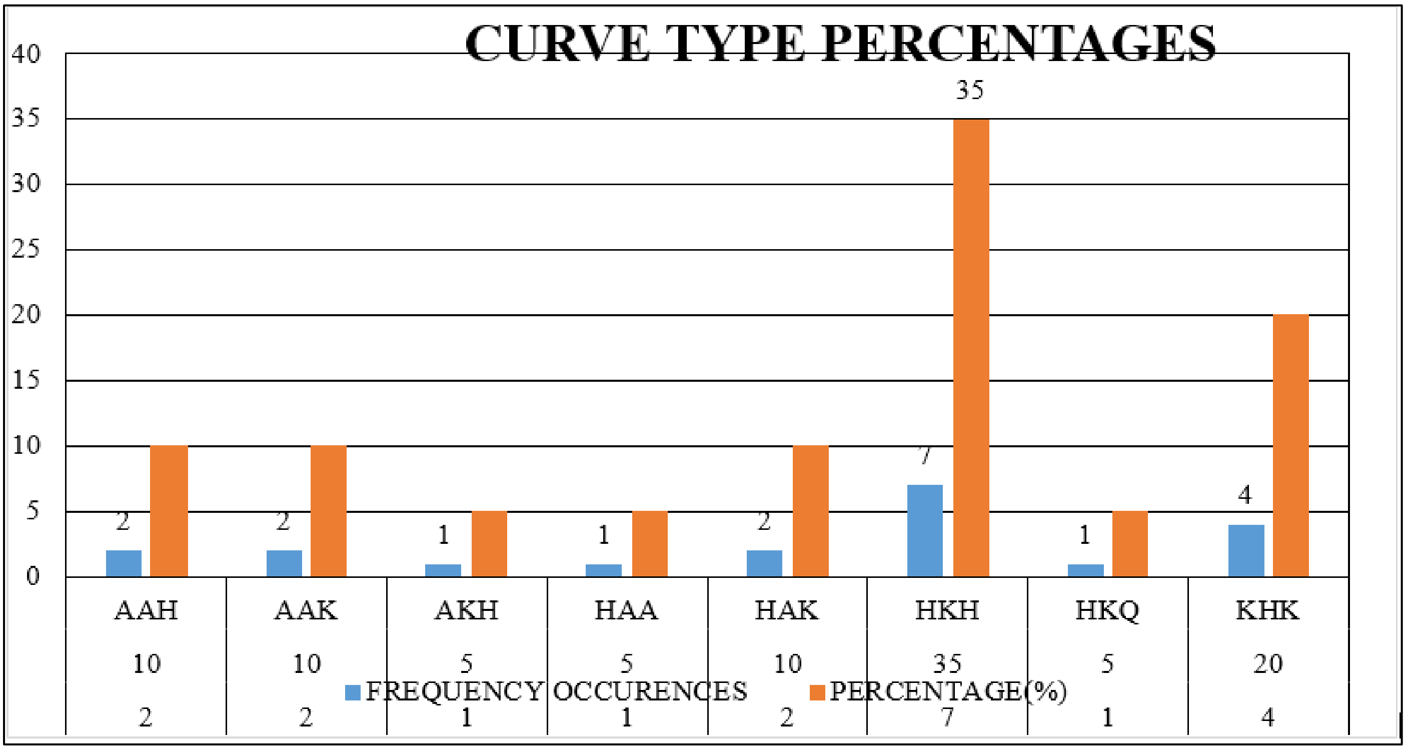

Fig 4.4: Resistivity Curve Type of the Study Area

The VES curve obtained from plotting the apparent resistivity against the corresponding half of electrode spacing (AB/2) gives curves types such a s HAK, HKQ, AAH, AAK, AKH,KHK and HAA. Most of the obtained sounding curves were of the HKH type (D1>D2<D3>D4<D5) as shown and the HKQ type (D1>D2<D3>D4) . These curves types indicated five to eight lithologies. The HAK curves rose steeply into positive slopes and such curves are a reflection of a highly resistive sedimentary rock at depth which 20 serves as underlying beds for unconfined aquifers. Fig 4.3.4 shows the curve types, sequence and number of layers for the four resistivity sounding curves, while others can be seen in the appendices.

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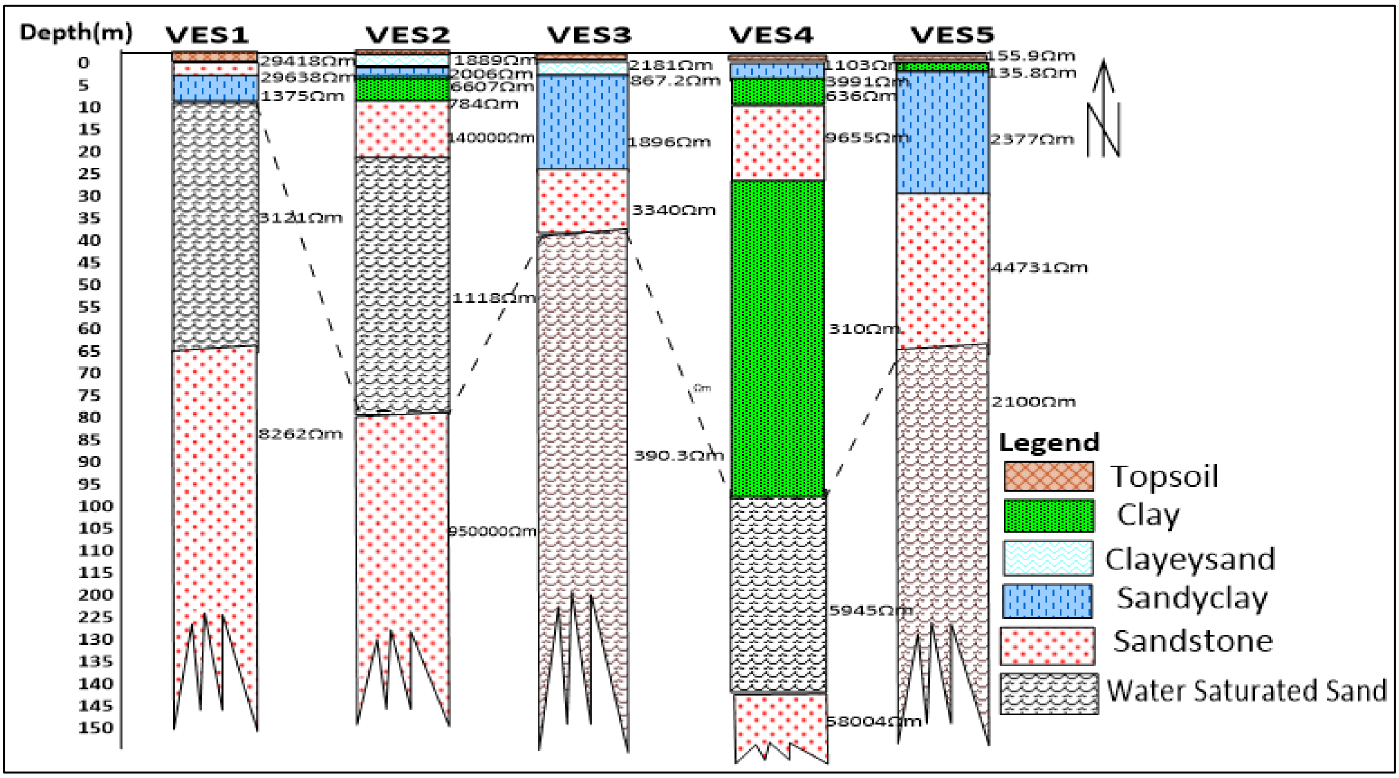

Fig 4.5: Lithologic Table of the Study Area

D. VES Data Analysis Summary

The Vertical Electrical Sounding (VES) data analysis revealed varying subsurface lithologies across the 4 sounding locations. The primary goal was to identify potential aquifers.

➢ *Lithology Description*

In fig 4.4 each VES location exhibits a unique layered sequence, comprising laterite, clay, sandyclay, sandstone, and water-saturated sand layers. The resistivity values range from low (<100 Ωm) to extremely high (>100000 Ωm), indicating varying degrees of compactness, fracturing, and water saturation. The reconstruction was done by interpreting the resistivity values from each layer curves, the resistivity and thickness of the individual layers. It was noted that different layer exhibit same resistivity. The interpretation was solved b y understanding the deeper knowledge of the underlying geology. The results of the quantitative interpretation revealed that typical 5- and 8 geoelectrical subsurface layers characterize the area, generating eight types of resistivity curves. The surface underlying laterite is a layer correlated to reddish brown, sandy clay and clayey sands, with thickness range from 1.4 m to 8.4 m, averaged 4.68 m, and resistivity range with an average of 168.94 Ωm

Fig 4.6: Resistivity Depth(s) of the Study Area

VES NO	Aquifer App.Res (Ωm)	Depth to Groundwater (m)	Depth of Overburden (m)	Thickness of Overburden Layers(m)
VES 1	3121	64	8.024	8.024
VES 2	1118	83.9	22.3	22.3
VES 3	390.3	45.81	34.13	34.13
VES 4	5945	138	95.3	95.3

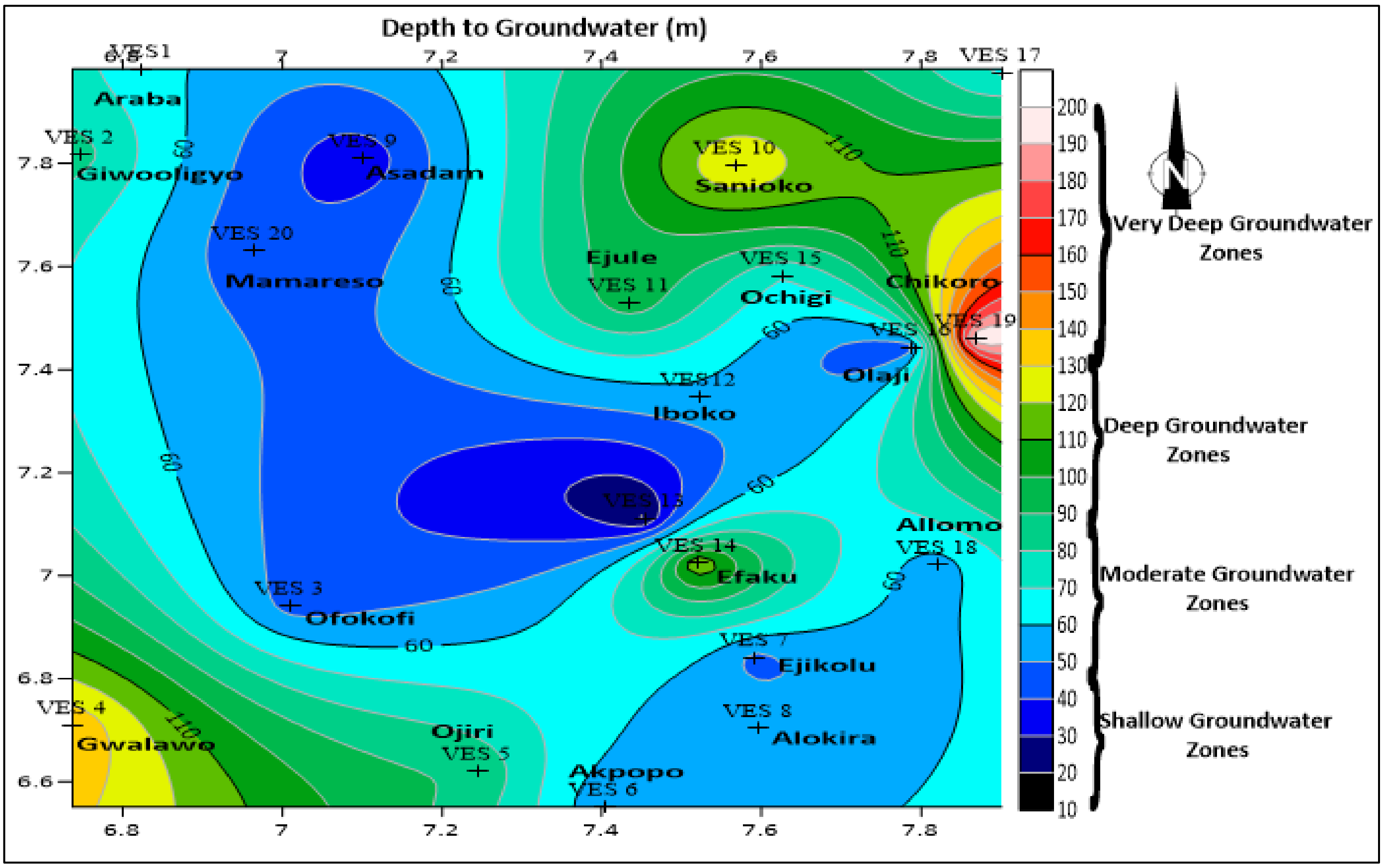

Fig 4.7: Depth to Groundwater Potential

E. Depth to Groundwater (m)

The depth to groundwater ranges from 10m to 200m across the 20 VES locations.

➢ *Shallow Groundwater Zones*

Fig 4.2.3, located in the southwestern part of the study area, exhibits a shallow groundwater depth of 45.81m. Similarly, VES 7, situated in the central region, has a groundwater depth of 47.2m. VES 15, located in the southeastern part shows a shallow groundwater depth of 45m. Notably, VES 13, positioned in the northwestern region, exhibits the shallowest groundwater depth of 19.1m.thes VES can be seen in the appendix.

➢ *Moderate Groundwater Zones*

Several VES locations exhibit moderate groundwater depths, ranging from 50m to 90m. These include VES 1 (64m), VES 2 (83.9m), VES 6 (51.49m), VES 8 (57m), VES 9 (33.5m), VES 16 (68.2m), and VES 18 (56.1m). These locations are scattered throughout the study area, indicating a relatively uniform distribution of moderate groundwater depths.

➢ *Deep Groundwater Zones*

A few VES locations display deep groundwater depths, ranging from 90m to 130m. These include VES 4 (138m), VES 5 (88.33m), VES 10 (131m), VES 11 (96.4m), VES 12 (57.2m), and VES 14 (120m). These locations are primarily situated in the eastern and central parts of the study area.

➢ *Very Deep Groundwater Zones*

VES 19, located in the easternmost part of the study area, exhibits an exceptionally deep groundwater depth of 212.3m. This location likely represents a localized groundwater flow system. Conversely, VES 20 displays an anomalously shallow groundwater depth of 42.6m.

➢ *Spatial Distribution*

The spatial distribution of groundwater depths reveals an increase in depth towards the eastern part of the study area. This suggests a potential groundwater flow direction, with recharge areas located in the western and central regions. Shallow groundwater zones (<50m) may require shorter drilling depths, reducing costs. Moderate groundwater zones (50-100m) require standard drilling depths. Deep groundwater zones (100-150m) require deeper drilling, increasing costs. Very deep groundwater zones (>150m) may require specialized drilling equipment.

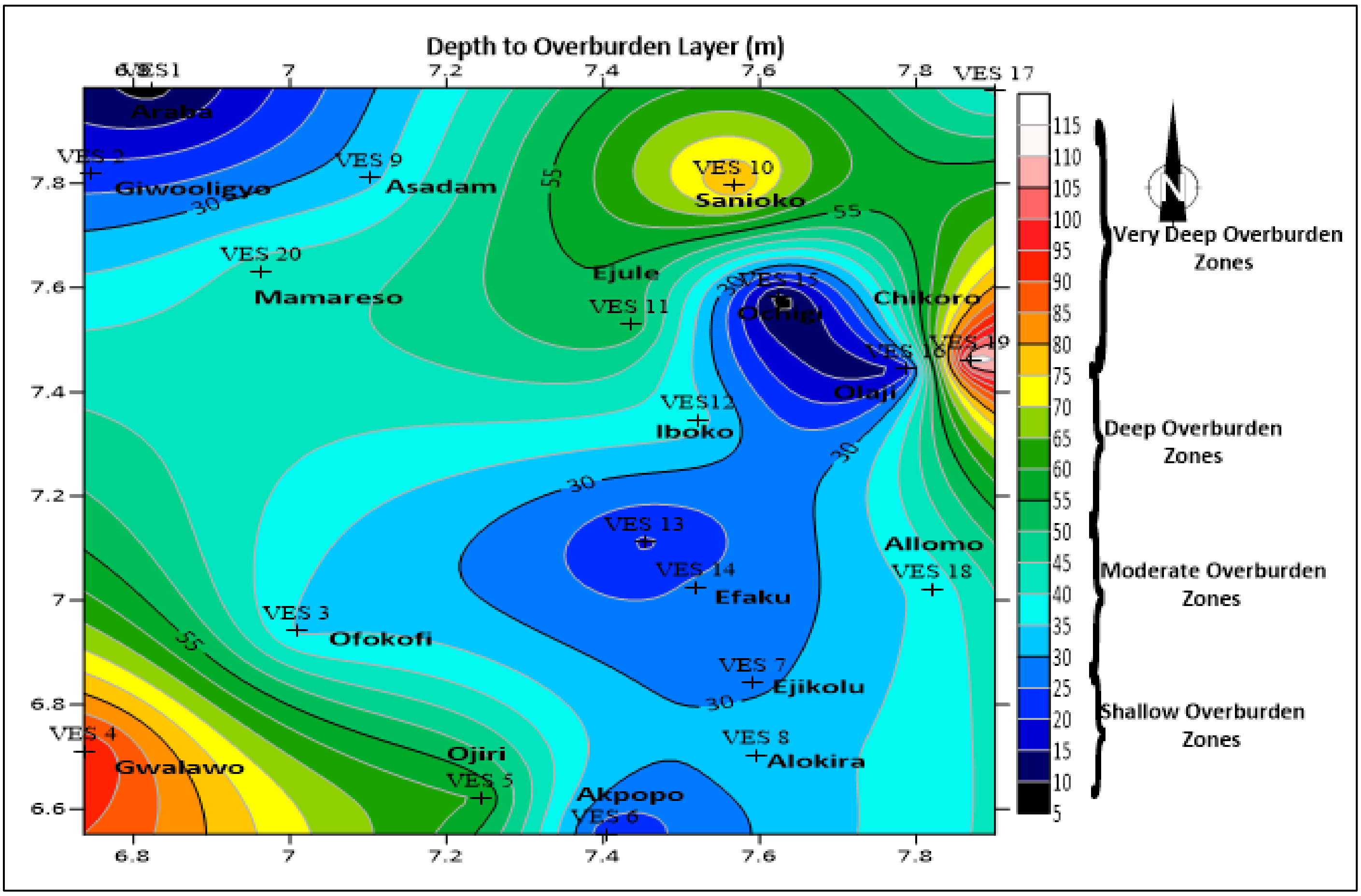

Fig 4.8: Depth to Aquifer

F. Depth of Overburden Analysis

The depth of overburden data ranges from 7.33m to 113m across the 20 Vertical Electrical Sounding (VES) locations. The overburden thickness varies significantly, indicating diverse geological and hydrological conditions.

- *Shallow Overburden Zones (<25m)*

VES 13 and VES 15 exhibit relatively thin overburden thicknesses of 19.1m and 7.33m, respectively. These locations likely represent areas with shallow water tables or high permeability, allowing for rapid groundwater recharge.

- *Moderate Overburden Zones (25-50m)*

Several VES locations display moderate overburden thicknesses, including VES 1 (8.024m), VES 2 (22.3m), VES 6 (21.13m), VES 7 (29m), VES 9 (33.5m), VES 10 (33.7m), VES 12 (37.1m), VES 16 (15.5m), and VES 18 (37m). These locations are scattered throughout the study area, indicating a relatively uniform distribution of moderate overburden thicknesses.

- *Deep Overburden Zones (50-75m)*

VES 5, VES 8, and VES 11 exhibit thicker overburden thicknesses of 59.86m, 33.7m, and 54.2m, respectively. These locations likely represent areas with low permeability or high clay content, restricting groundwater flow.

- *Very Deeep Overburden Zones (>75m)*

VES 4 and VES 19 display exceptionally thick overburden thicknesses of 95.3m and 113m, respectively. These locations likely represent areas with complex geological structures or high water tables, influencing groundwater flow and recharge.

- *Spatial Distribution*

The spatial distribution of overburden thickness reveals a general increase in thickness towards the eastern part of the study area. This suggests a potential relationship between overburden thickness and groundwater flow direction.

Thin overburden zones may require shorter drilling depths, reducing costs. Moderate overburden zones require standard drilling depths. Thick overburden zones require deeper drilling, increasing costs.

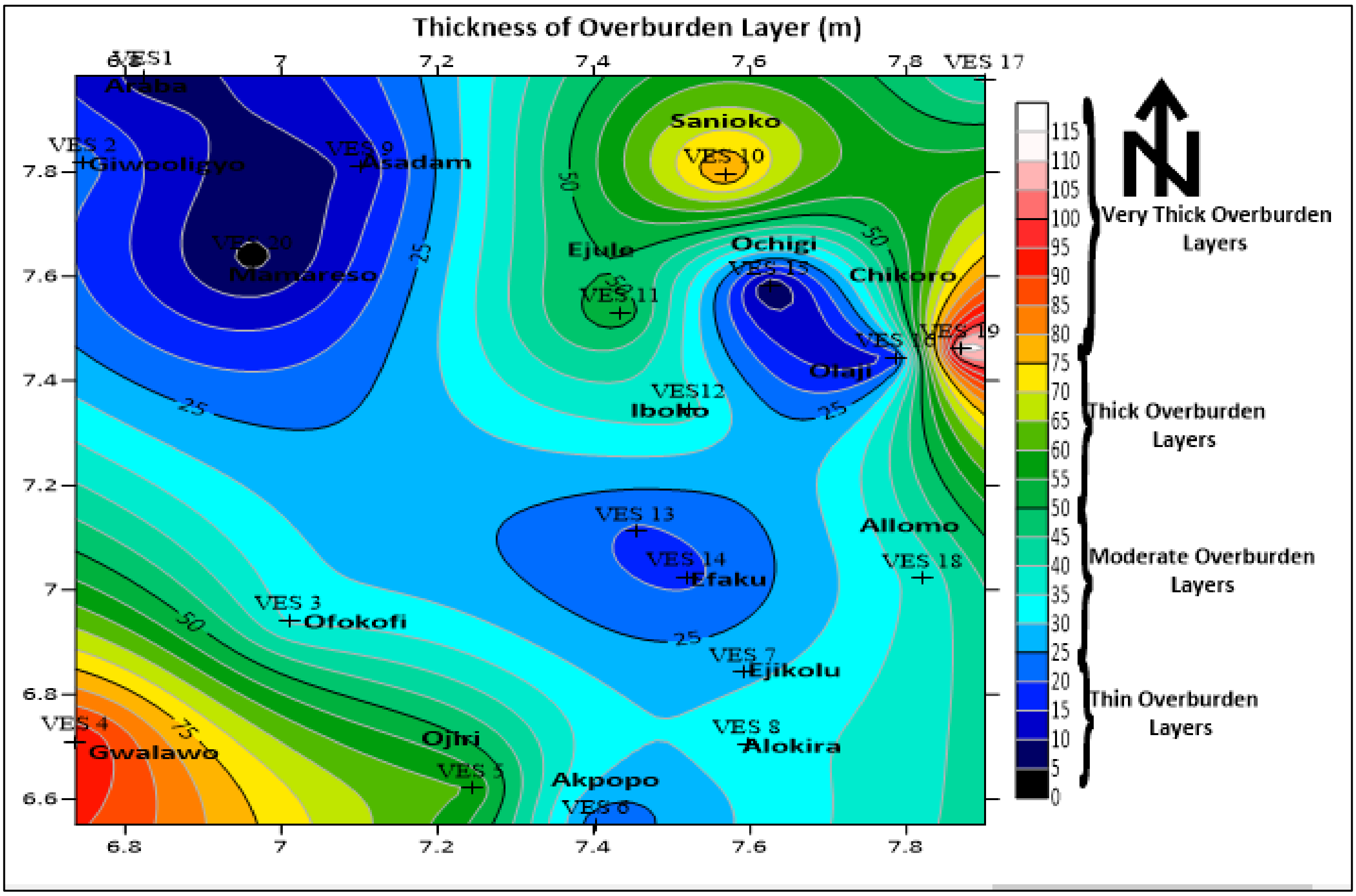

Fig 4.9: Thickness of Overburden Map

G. Thickness of Overburden Layers Analysis

The thickness of overburden layers varies significantly across the 20 Vertical Electrical Sounding (VES) locations, ranging from 0 m to 115m. This variability indicates diverse geological and hydrological conditions.

➢ *Characterization of Overburden Thickness*

The overburden thickness can be categorized into four main groups:

Thin Overburden Layers (<25m): VES 13 (19.1m), VES 14 (18.8m), VES 16 (15.5m), VES 20 (3.5m), and VES 1 (8.024m) exhibit relatively thin overburden layers. These areas likely have shallow water tables or high permeability, facilitating rapid groundwater recharge.

Moderate Overburden Layers (25-50m): VES 2 (22.3m), VES 3 (34.13m), VES 6 (21.13m), VES 7 (29m), VES 9 (33.7m), VES 10 (11.3m), VES 12 (37.1m), and VES 18 (37m) display moderate overburden thicknesses. These locations are scattered throughout the study area, indicating a relatively uniform distribution.

Thick Overburden Layers (50-75m): VES 5 (59.86m), VES 8 (33.7m), and VES 11 (54.2m) exhibit thicker overburden layers. These areas likely have low permeability or high clay content, restricting groundwater flow.

Very Thick Overburden Layers (>75m): VES 4 (95.3m) and VES 19 (113m) shows exceptionally thick overburden layers. These locations likely represent areas with complex geological structures or high water tables, influencing groundwater flow and recharge.

➢ *Spatial Distribution*

The spatial distribution of overburden thickness reveals a general increase in thickness towards the eastern part of the study area. This suggests a potential similarities between overburden thickness and groundwater flow direction.

CHAPTER FIVE
SUMMARY, CONCLUSION AND RECOMMENDATION

A. *Summary*

Geophysical investigation using Vertical Electrical Sounding (VES) was adopted *in* Some part of Ofu Local government Kogi State for the exploration of groundwater potential in the area. The interpreted results of the VES data were done using IPI2WIN and suffer software packages and the results are presented as sounding curves, geo-electric sections and contour map . A total of 4-5 earth modeled layers were delineated which include, Topsoil, clay, sandy clay, sandstone and water-saturated sand layers were identified. Resistivity values for topsoil ranges from 1103-294 Ωm with depth varying from of 0.146-1.61m; sandstone with resistivity values 2964-9655 Ωm with depth varying from 0.364-59.86m; clay with 135-2006 Ωm and depth 0.788-11.0m; sandyclay with 927-7111 Ωm with depth 0.364-59.86m; clayeysand of 224-2238 Ωm with depth 1.29-10.4m.

The resistivity parameters of the geo electric layers across the entire area were used to delineate the parameters of the identified aquifers in the study area.

B. *Conclusion*

20 Schlumberger vertical electrical soundings (VES) were used in the geophysical research survey. The designation of an aquifer unit in the research area has been made possible by the survey's findings. In the study region, three (4) to five (5) unique geo-electric layers were identified, including the lateritic sand/topsoil, sandy clay, clay, Clayey sand ,sandstone, and Water saturated sand tone indicated in fig 4.5. The productive aquifer unit in the area has been identified by survey results. According to computer study, the specific layers, which is made up of sandstones, where a groundwater search is necessary in the research region, its subsurface soil type has been identified, and geophysical data on the groundwater has been provided.

C. *Recommendation*

It is recommended that a thorough study of any project be done before any operation so as to know whether the aquifer is naturally sealed or not. And the presence of clay above the aquifer must be sought for before choosing any site for drilling.

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APPENDIX

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	14.24	167.7472
2	3	0.5	27.5	8.262	227.205
3	6	0.5	112.3	3.754	421.5742
4	9	0.5	254	2.167	550.418
5	9	2.0	60.5	13.32	805.86
6	15	2.0	173.6	6.796	1179.7856
7	25	2.0	488	3.256	1588.928
8	40	2.0	1253	1.719	2153.907
9	50	2.0	1960	1.332	2610.72
10	75	2.0	4410	0.742	3272.22
11	75	10.0	868	3.632	3152.576
12	100	10.0	1555	2.472	3843.96
13	150	10.0	3520	1.404	4942.08
14	200	10.0	6270	0.822	5153.94
15	300	10.0	14120	0.416	5873.92
16	300	20.0	7040	0.822	5786.88
17	400	20.0	12530	0.422	5287.66

LOCATION: OJIRI
TOWN: OJIRI VES 5
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^{0}08'. 048''
LATITUDE: N06^{0}58'. 999''
ELEVATION: 259 m

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	157.2	1851.816
2	3	0.5	27.5	69.83	1920.325
3	6	0.5	112.3	24.82	2787.286
4	9	0.5	254	12.00	3048
5	9	2.0	60.5	75.55	4570.775
6	15	2.0	173.6	24.11	4185.496
7	25	2.0	488	11.39	5558.32
8	40	2.0	1253	6.257	7840.021
9	50	2.0	1960	3.724	7299.04
10	75	2.0	4410	1.953	8612.73
11	75	10.0	868	9.149	7941.332
12	100	10.0	1555	4.975	7736.125
13	150	10.0	3520	2.431	8557.12
14	200	10.0	6270	1.414	8865.78
15	300	10.0	14120	0.529	7469.48
16	300	20.0	7040	0.957	6737.28
17	400	20.0	12530	0.583	7304.99

LOCATION: AKPOPO
TOWN: AKPOPO VES 6
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^0 07'.943''
LATITUDE: N06^0 60'.060'
ELEVATION: 249 m

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S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	69.43	817.25
2	3	0.5	27.5	17.90	492.25
3	6	0.5	112.3	6.695	751.85
4	9	0.5	254	4.446	1129.28
5	9	2.0	60.5	8.465	512.13
6	15	2.0	173.6	5.240	909.66
7	25	2.0	488	4.039	1971.03
8	40	2.0	1253	2.187	3415.68
9	50	2.0	1960	2.726	4286.52
10	75	2.0	4410	1.566	6906.10
11	75	10.0	868	5.708	4954.54
12	100	10.0	1555	4.395	6834.23
13	150	10.0	3520	2.503	8810.56
14	200	10.0	6270	1.638	10270.26
15	300	10.0	14120	0.839	11846.68
16	300	20.0	7040	1.648	11601.92
17	400	20.0	12530	1.261	15800.33

LOCATION: EJIKOLU
TOWN: EJIKOLU VES 7
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^{0}09'. 219''
LATITUDE: N06^{0}59'. 526''
ELEVATION: 267 m

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	16.17	190.4826
2	3	0.5	27.5	5.606	154.165
3	6	0.5	112.3	2.614	293.5522
4	9	0.5	254	2.055	521.97
5	9	2.0	60.5	17.19	1039.995
6	15	2.0	173.6	13.32	2312.352
7	25	2.0	488	9.015	4399.32
8	40	2.0	1253	5.667	7100.751
9	50	2.0	1960	4.436	8694.56
10	75	2.0	4410	2.686	11845.26
11	75	10.0	868	13.02	11301.36
12	100	10.0	1555	10.02	15581.1
13	150	10.0	3520	5.809	20447.68
14	200	10.0	6270	3.510	22007.7
15	300	10.0	14120	1.648	23269.76
16	300	20.0	7040	2.024	14248.96
17	400	20.0	12530	1.129	14146.37

LOCATION: ALOKURA
TOWN: ALOKURA VES 8
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^0 04'.321''
LATITUDE: N06^0 59'. 583''
ELEVATION: 278 m

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S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	221.6	2610.45
2	3	0.5	27.5	168.2	4625.5
3	6	0.5	112.3	61.27	6880.62
4	9	0.5	254	46.90	11912.6
5	9	2.0	60.5	52.40	3170.2
6	15	2.0	173.6	18.72	3249.79
7	25	2.0	488	8.526	4160.69
8	40	2.0	1253	4.368	5473.10
9	50	2.0	1960	3.811	7469.56
10	75	2.0	4410	1.008	4445.28
11	75	10.0	868	2.299	1995.53
12	100	10.0	1555	1.699	2641.95
13	150	10.0	3520	1.119	3938.88
14	200	10.0	6270	0.8761	5493.15
15	300	10.0	14120	0.5361	7569.73
16	300	20.0	7040	1.236	8701.44
17	400	20.0	12530	0.6343	7947.78

LOCATION: ASADAM
TOWN: ASADAM VES 9
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^{0}04'. 277''
LATITUDE: N06^{0}56'. 385''
ELEVATION: 202 m

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	23.40	275.65
2	3	0.5	27.5	6.379	175.42
3	6	0.5	112.3	3.367	378.11
4	9	0.5	254	1.973	501.14
5	9	2.0	60.5	6.837	413.64
6	15	2.0	173.6	4.059	704.64
7	25	2.0	488	2.482	1211.22
8	40	2.0	1253	1.556	1949.67
9	50	2.0	1960	1.221	2393.16
10	75	2.0	4410	0.793	3497.13
11	75	10.0	868	4.283	3717.64
12	100	10.0	1555	3.093	4809.62
13	150	10.0	3520	2.004	7054.10
14	200	10.0	6270	1.221	7655.67
15	300	10.0	14120	0.513	7243.56
16	300	20.0	7040	0.969	6821.76
17	400	20.0	12530		

LOCATION: SANIOKO
TOWN: SANIOKO VES 10
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^0 05'. 494''
LATITUDE: N06^0 56'. 579''
ELEVATION: 275 m

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S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	40.49	476.97
2	3	0.5	27.5	19.84	545.6
3	6	0.5	112.3	7.936	891.21
4	9	0.5	254	4.171	1059.43
5	9	2.0	60.5	19.12	1156.76
6	15	2.0	173.6	11.09	1925.22
7	25	2.0	488	5.809	2834.79
8	40	2.0	1253	3.846	4819.04
9	50	2.0	1960	3.062	6001.52
10	75	2.0	4410	1.862	8211.42
11	75	10.0	868	8.343	7241.72
12	100	10.0	1555	6.847	10647.09
13	150	10.0	3520	2.503	8810.56
14	200	10.0	6270	1.271	7969.17
15	300	10.0	14120	0.588	8231.96
16	300	20.0	7040	1.398	9841.92
17	400	20.0	12530		

LOCATION: EJULE
TOWN: EJULE VES 11
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^{0}07'. 495''
LATITUDE: N07^{0}55'. 509''
ELEVATION: 290m

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	22.28	262.46
2	3	0.5	27.5	8.750	240.63
3	6	0.5	112.3	3.642	408.99
4	9	0.5	254	2.289	581.41
5	9	2.0	60.5	7.061	427.20
6	15	2.0	173.6	3.947	685.20
7	25	2.0	488	2.248	1097.02
8	40	2.0	1253	1.231	1542.44
9	50	2.0	1960	0.914	1791.44
10	75	2.0	4410	0.473	2085.93
11	75	10.0	868	2.167	1880.96
12	100	10.0	1555	1.302	2024.61
13	150	10.0	3520	0.819	2882.88
14	200	10.0	6270	0.473	2965.71
15	300	10.0	14120	0.237	3346.44
16	300	20.0	7040		
17	400	20.0	12530		

LOCATION: IBOKO
TOWN: IBOKO VES 12
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^0 07'. 030''
LATITUDE: N07^0 55'. 958''
ELEVATION: 334 m

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	10.68	125.81
2	3	0.5	27.5	4.456	122.54
3	6	0.5	112.3	1.383	155.31
4	9	0.5	254	1.017	258.32
5	9	2.0	60.5	5.596	338.56
6	15	2.0	173.6	4.008	695.79
7	25	2.0	488	2.859	1395.19
8	40	2.0	1253	1.282	1606.35
9	50	2.0	1960	0.944	1850.24
10	75	2.0	4410	0.550	2425.5
11	75	10.0	868	1.924	1670.03
12	100	10.0	1555	0.563	875.47
13	150	10.0	3520	0.436	1534.72
14	200	10.0	6270	0.358	2244.66
15	300	10.0	14120	0.263	3713.56
16	300	20.0	7040	0.536	3773.44
17	400	20.0	12530	0.274	3433.22
LOCATION: AGOJEJU **TOWN: AGOJEJU VES 13** **L.G.A: OFU** **STATE: KOGI** **LONGITUDE: E007^{0}06'. 502''** **LATITUDE: N07^{0}57'. 475''** **ELEVATION: 289 m**					

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	12.31	145.01
2	3	0.5	27.5	6.746	185.52
3	6	0.5	112.3	3.683	413.60
4	9	0.5	254	2,279	578.87
5	9	2.0	60.5	10.02	606.21
6	15	2.0	173.6	7.537	1308.42
7	25	2.0	488	4.695	2291.16
8	40	2.0	1253	1.934	2423.30
9	50	2.0	1960	1.189	2330.44
10	75	2.0	4410	0.573	2526.93
11	75	10.0	868	2.075	1801.1
12	100	10.0	1555	1.434	2229.87
13	150	10.0	3520	0.604	2126.08
14	200	10.0	6270	0.158	990.66
15	300	10.0	14120	0.059	833.08
16	300	20.0	7040	0.119	837.76
17	400	20.0	12530	0.087	1090.11
LOCATION: EFAKU **TOWN: EFAKU VES 14** **L.G.A: OFU** **STATE: KOGI** **LONGITUDE: E007^0 06'. 582''** **LATITUDE: N07^0 58'. 408''** **ELEVATION: 247 m**					

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S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	25.13	296.03
2	3	0.5	27.5	15.46	425.15
3	6	0.5	112.3	6.990	784.98
4	9	0.5	254	4.232	1074.93
5	9	2.0	60.5	22.06	1334.63
6	15	2.0	173.6	10.68	1854.10
7	25	2.0	488	5.935	2896.28
8	40	2.0	1253	3.768	4721.30
9	50	2.0	1960	2.771	5431.16
10	75	2.0	4410	1.531	6751.71
11	75	10.0	868	6.429	5580.37
12	100	10.0	1555	4.232	6580.76
13	150	10.0	3520	1.058	3724.16
14	200	10.0	6270	0.511	3203.97
15	300	10.0	14120	0.233	3289.96
16	300	20.0	7040	0.411	2893.44
17	400	20.0	12530	0.237	2969.61

LOCATION:OCHANJA
TOWN: OCHANJA
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^{0}07'. 047''
LATITUDE: N07^{0}57'. 809''
ELEVATION: 300 m

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	27.61	325.25
2	3	0.5	27.5	15.11	415.53
3	6	0.5	112.3	5.596	628.43
4	9	0.5	254	3.296	837.18
5	9	2.0	60.5	14.75	892.38
6	15	2.0	173.6	7.142	1239.85
7	25	2.0	488	3.398	1658.22
8	40	2.0	1253	1.994	2498.48
9	50	2.0	1960	1.353	2651.88
10	75	2.0	4410	0.6573	2898.69
11	75	10.0	868	3.296	2860.93
12	100	10.0	1555	1.750	2721.25
13	150	10.0	3520	0.761	2678.72
14	200	10.0	6270	0.4772	2992.04
15	300	10.0	14120	0.1658	2341.10
16	300	20.0	7040		
17	400	20.0	12530		

LOCATION: ALLOMO
TOWN: ALLOMO
L.G.A: ALLOMO VES 18
STATE: KOGI
LONGITUDE: E007^0 07'. 526''
LATITUDE: N07^0 57'. 440''
ELEVATION: 311 m

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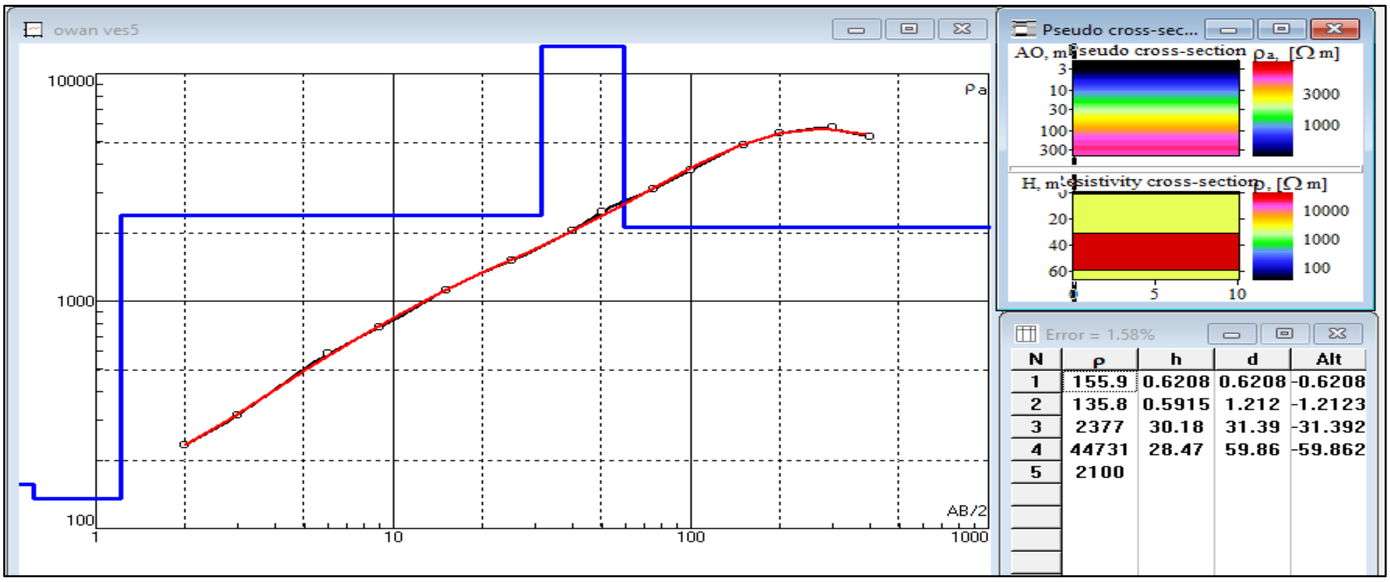
Acquired Sounding Data from Study Location



S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	22.89	269.64
2	3	0.5	27.5	15.16	416.9
3	6	0.5	112.3	8.211	922.10
4	9	0.5	254	7.529	1912.37
5	9	2.0	60.5	9.208	557.08
6	15	2.0	173.6	4.741	823.04
7	25	2.0	488	3.490	1703.12
8	40	2.0	1253	1.770	2217.81
9	50	2.0	1960	1.481	2902.76
10	75	2.0	4410	0.6531	2880.17
11	75	10.0	868	2.492	2163.06
12	100	10.0	1555	1.923	2990.27
13	150	10.0	3520	0.8984	3162.37
14	200	10.0	6270	0.6237	3910.60
15	300	10.0	14120	0.3642	5142.50
16	300	20.0	7040	0.7376	5192.70
17	400	20.0	12530	0.2816	3528.45

LOCATION: OCHIGI
TOWN: OCHIGI VES 15
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^{0}04'. 103''
LATITUDE: N07^{0}00'. 538''
ELEVATION: 349 m

S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	16.22	191.10
2	3	0.5	27.5	8.716	239.69
3	6	0.5	112.3	2.609	292.99
4	9	0.5	254	1.239	314.71
5	9	2.0	60.5	3.530	213.57
6	15	2.0	173.6	1.098	190.61
7	25	2.0	488	0.601	293.29
8	40	2.0	1253	0.348	436.04
9	50	2.0	1960	0.256	501.76
10	75	2.0	4410	0.120	529.20
11	75	10.0	868	0.802	696.14
12	100	10.0	1555	0.558	867.69
13	150	10.0	3520	0.343	1207.36
14	200	10.0	6270	0.298	1868.46
15	300	10.0	14120	0.162	2287.44
16	300	20.0	7040	0.530	3731.20
17	400	20.0	12530	0.338	4235.14

LOCATION:OLAJI
TOWN: OLAJI VES 16
L.G.A: OFU
STATE: KOGI
LONGITUDE: E007^{0} 04'. 317''
LATITUDE: N07^{0} 01'. 487''
ELEVATION: 305 m

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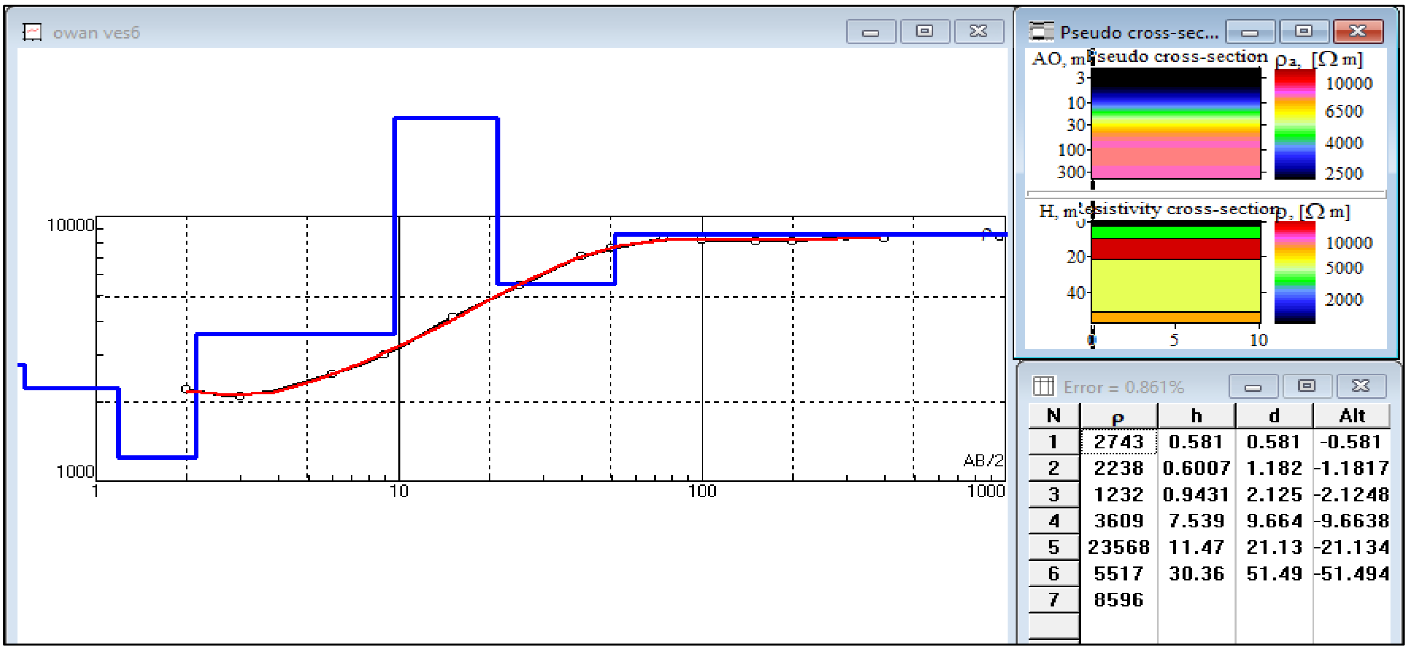
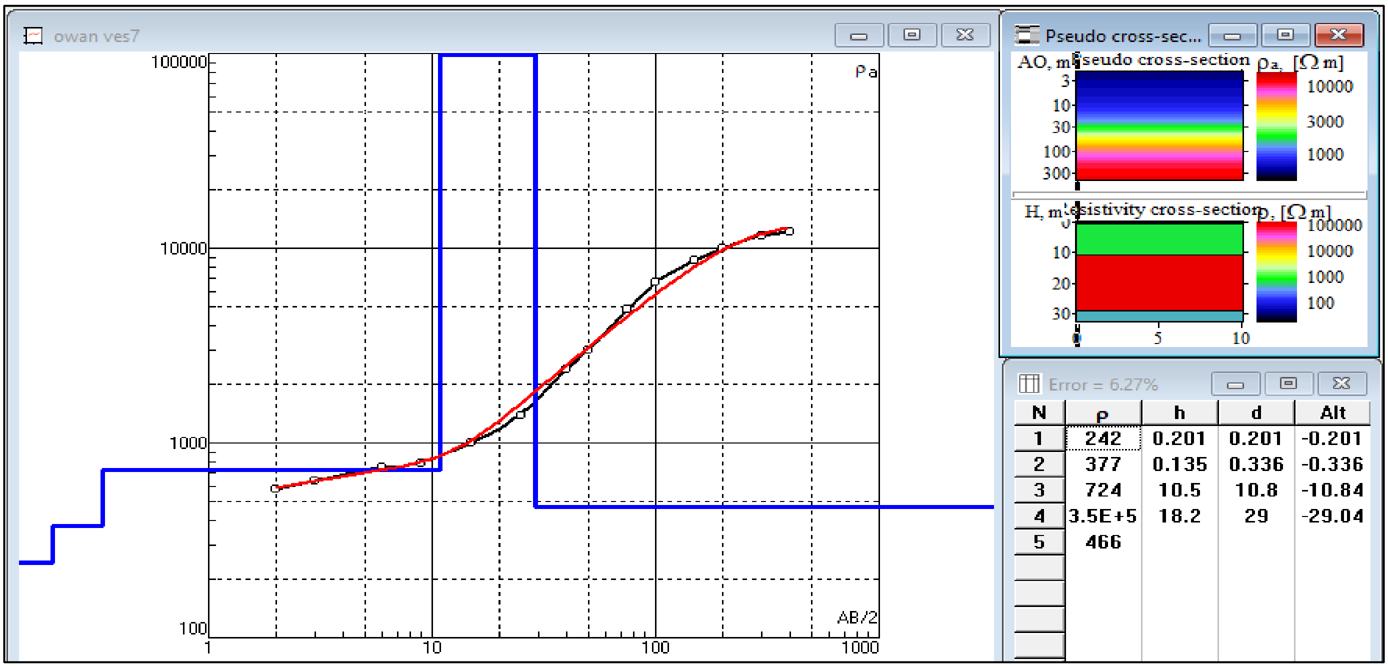


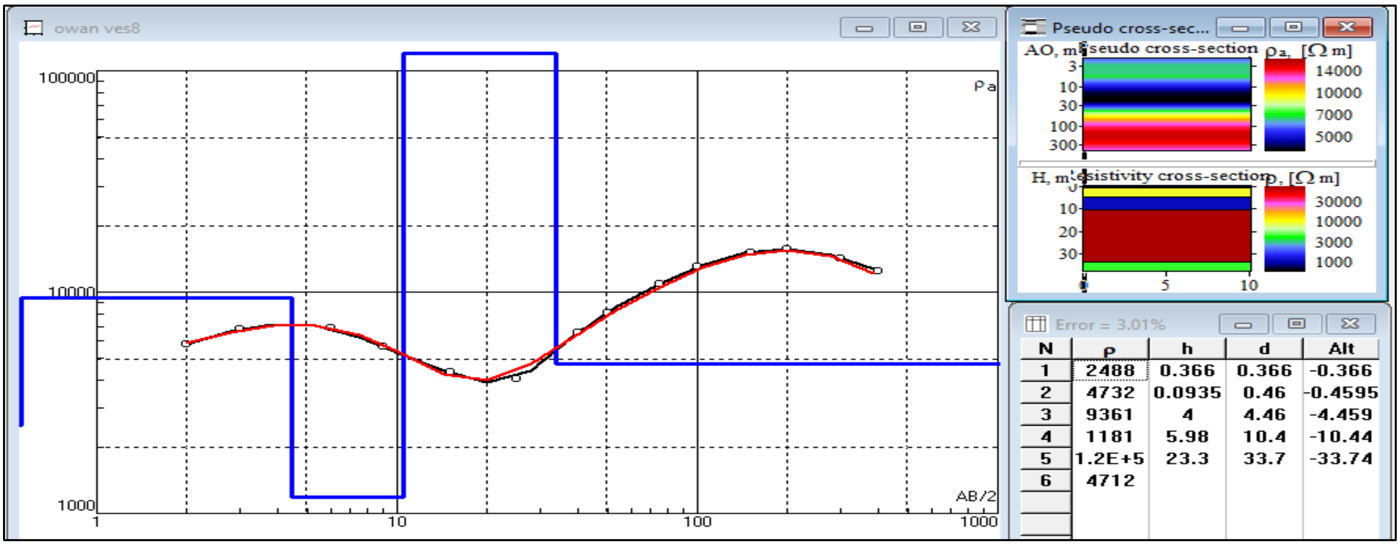
S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	46.80	551.30
2	3	0.5	27.5	24.72	679.8
3	6	0.5	112.3	7.132	800.92
4	9	0.5	254	2.950	749.3
5	9	2.0	60.5	24.92	1507.66
6	15	2.0	173.6	9.757	1693.82
7	25	2.0	488	4.415	2154.52
8	40	2.0	1253	2.279	2855.59
9	50	2.0	1960	1.638	3210.48
10	75	2.0	4410	0.870	3836.7
11	75	10.0	868	6.766	5872.89
12	100	10.0	1555	4.222	6565.21
13	150	10.0	3520	2.167	7627.84
14	200	10.0	6270	1.241	7781.07
15	300	10.0	14120	0.428	6043.36
16	300	20.0	7040	0.737	5188.48
17	400	20.0	12530	0.510	6390.3

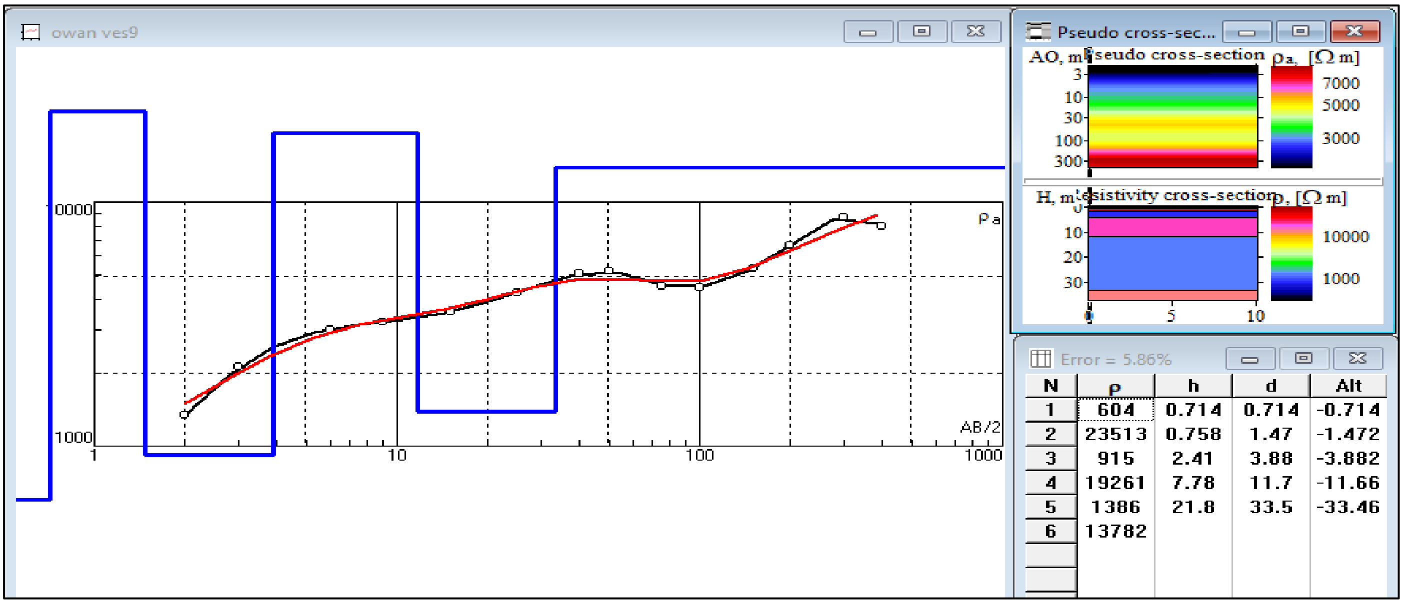
LOCATION: CHIKARO
TOWN: CHIKARO VES 19
L.G.A: OFU
STATE: KOGI
LONGITUDE: E006^{0}01'. 148''
LATITUDE: N06^{0}59'. 447''
ELEVATION: 296 m

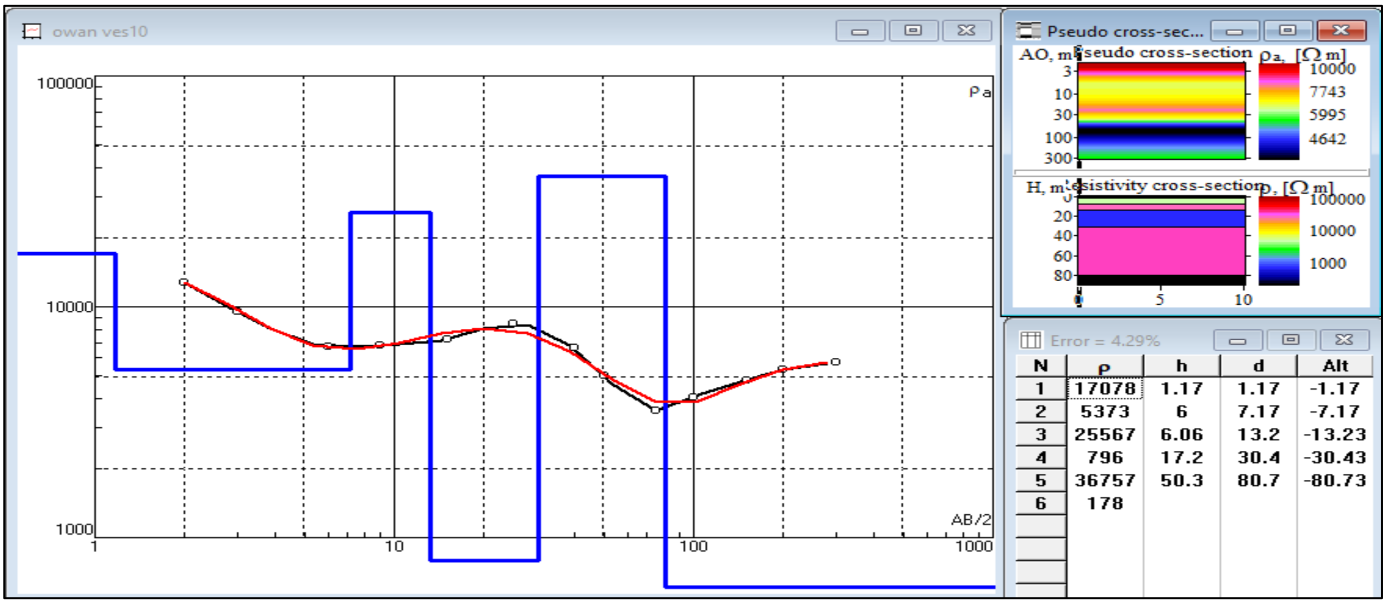
S/NO.	ELECTRODE SPACING (M)		GEOMETRIC FACTOR "K"	RESISTANCE (OHMS)	APPARENT RESISTIVITY (OHMS M)
	AB/2	MN/2			
1	2	0.5	11.78	63.78	751.33
2	3	0.5	27.5	50.26	1382.15
3	6	0.5	112.3	25.31	2842.31
4	9	0.5	254	12.68	3220.72
5	9	2.0	60.5	19.94	1206.37
6	15	2.0	173.6	11.49	1994.66
7	25	2.0	488	7.946	3877.65
8	40	2.0	1253	4.361	5464.33
9	50	2.0	1960	3.581	7018.76
10	75	2.0	4410	1.866	8229.06
11	75	10.0	868	8.201	7118.47
12	100	10.0	1555	5.647	8781.09
13	150	10.0	3520	2.279	8022.08
14	200	10.0	6270	1.668	10458.36
15	300	10.0	14120	1.098	15503.76
16	300	20.0	7040	0.6430	4526.72
17	400	20.0	12530	1.180	14785.4

LOCATION: MAMAREBO
TOWN: MAMAREBO VES 20
L.G.A: OFU
STATE: KOGI
LONGITUDE: E006^0 59'. 393''
LATITUDE: N07^0 01'. 143''
ELEVATION: 320 m

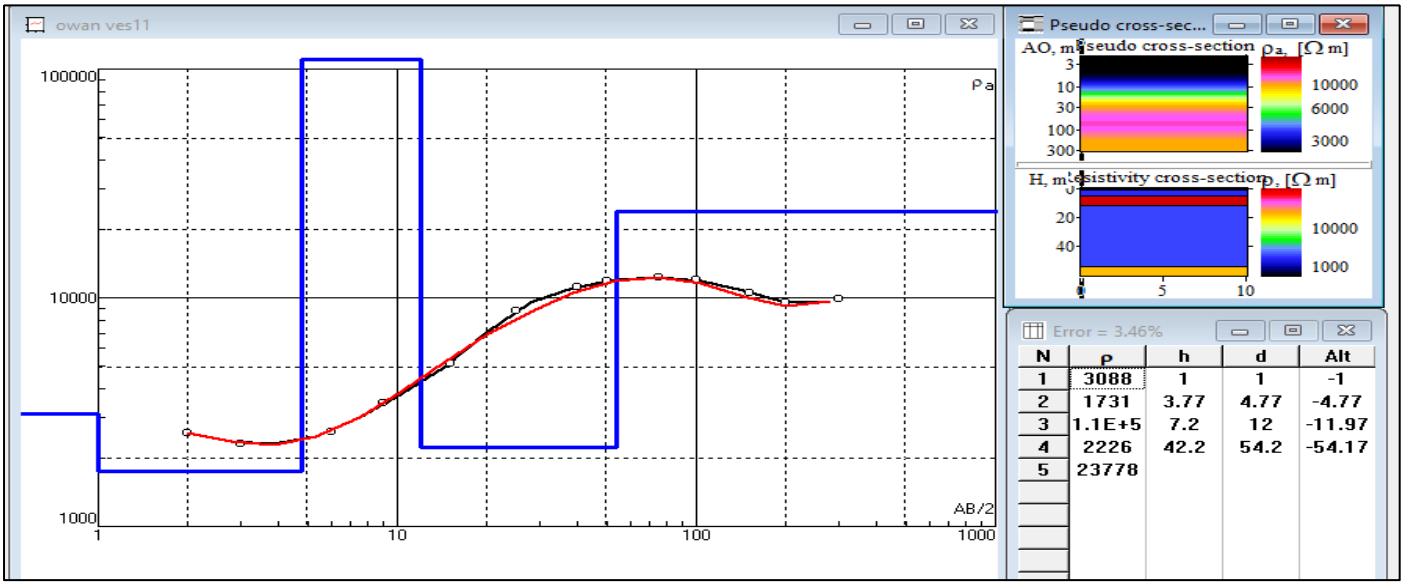

owan ves7
Pseudo cross-sec...
AO, m Pseudo cross-section ρa, [Ω m]
10000
3000
1000
H, m Resistivity cross-section ρ, [Ω m]
100000
10000
1000
100
Error = 6.27%
N ρ h d Alt
1 242 0.201 0.201 -0.201
2 377 0.135 0.336 -0.336
3 724 10.5 10.8 -10.84
4 3.5E+5 18.2 29 -29.04
5 466
AB/2


owan ves8
Pseudo cross-sec...
AO, m Pseudo cross-section ρa, [Ω m]
14000
10000
7000
5000
H, m Resistivity cross-section ρ, [Ω m]
30000
10000
3000
1000
Error = 3.01%
N ρ h d Alt
1 2488 0.366 0.366 -0.366
2 4732 0.0935 0.46 -0.4595
3 9361 4 4.46 -4.459
4 1181 5.98 10.4 -10.44
5 1.2E+5 23.3 33.7 -33.74
6 4712
AB/2

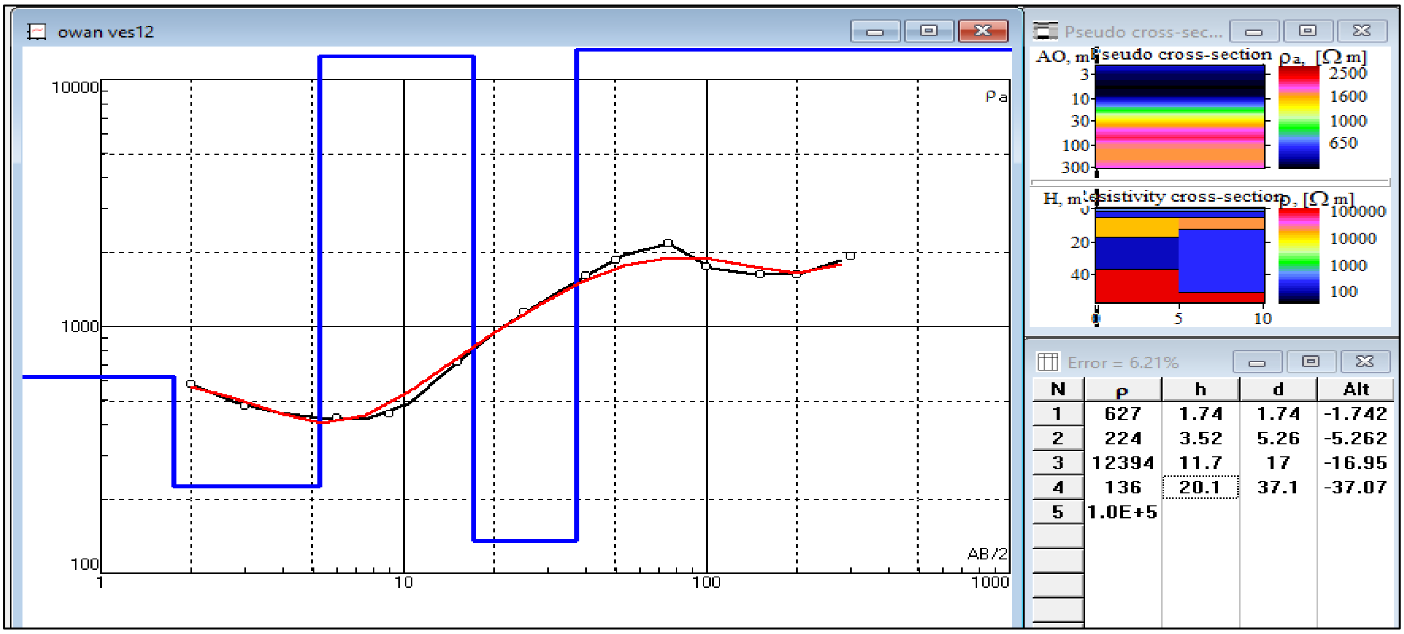

owan ves9
Pseudo cross-sec...
AO, m Pseudo cross-section ρa, [Ω m]
7000
5000
3000
H, m Resistivity cross-section ρ, [Ω m]
10000
1000
Error = 5.86%
N ρ h d Alt
1 604 0.714 0.714 -0.714
2 23513 0.758 1.47 -1.472
3 915 2.41 3.88 -3.882
4 19261 7.78 11.7 -11.66
5 1386 21.8 33.5 -33.46
6 13782
AB/2



N	ρ	h	d	Alt
1	17078	1.17	1.17	-1.17
2	5373	6	7.17	-7.17
3	25567	6.06	13.2	-13.23
4	796	17.2	30.4	-30.43
5	36757	50.3	80.7	-80.73
6	178			



N	ρ	h	d	Alt
1	3088	1	1	-1
2	1731	3.77	4.77	-4.77
3	1.1E+5	7.2	12	-11.97
4	2226	42.2	54.2	-54.17
5	23778			



N	ρ	h	d	Alt
1	627	1.74	1.74	-1.742
2	224	3.52	5.26	-5.262
3	12394	11.7	17	-16.95
4	136	20.1	37.1	-37.07
5	1.0E+5			

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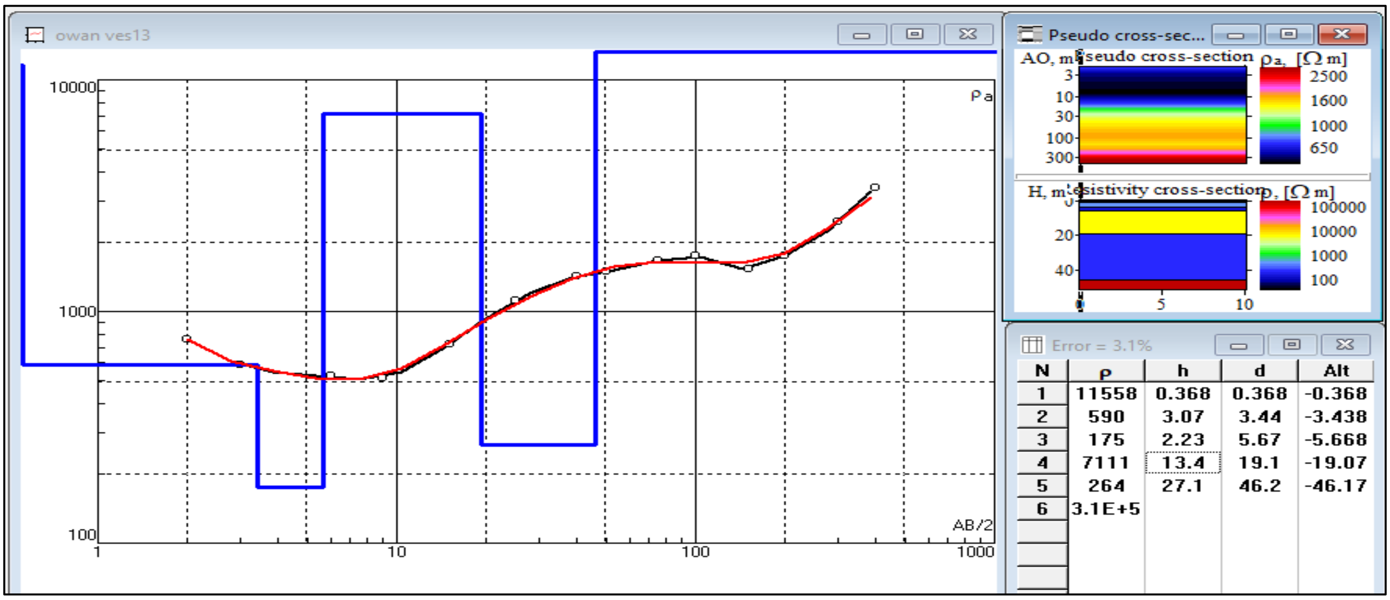
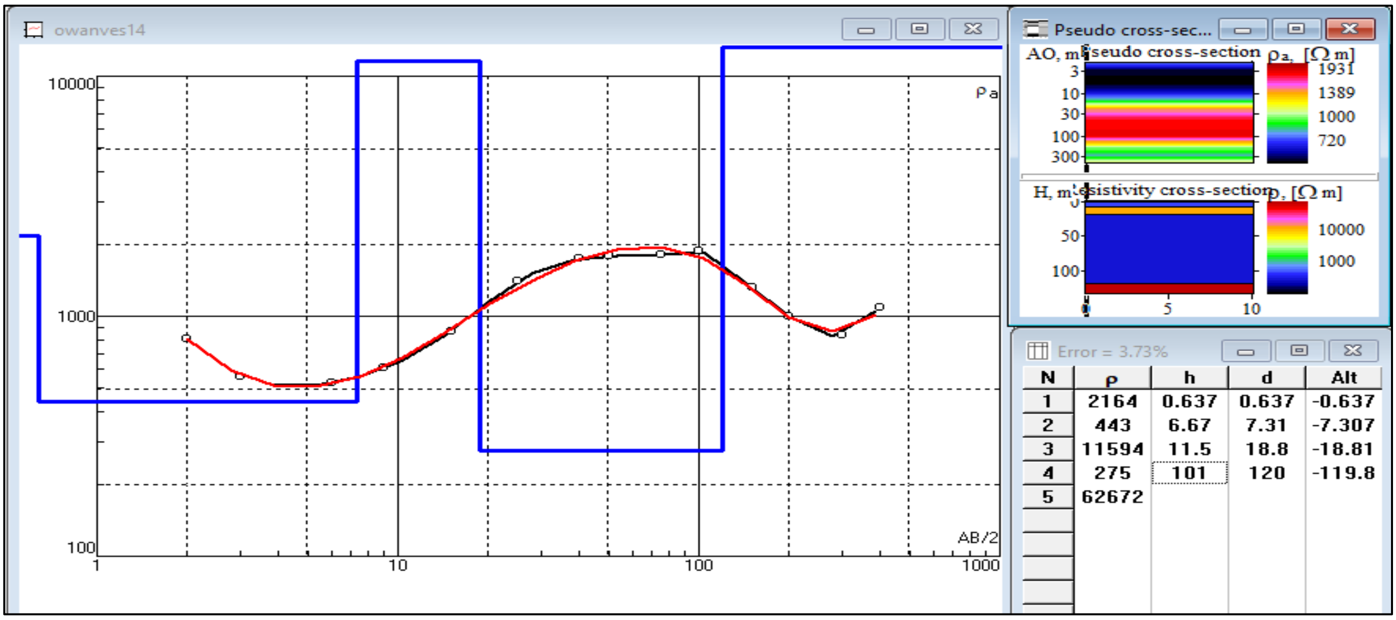
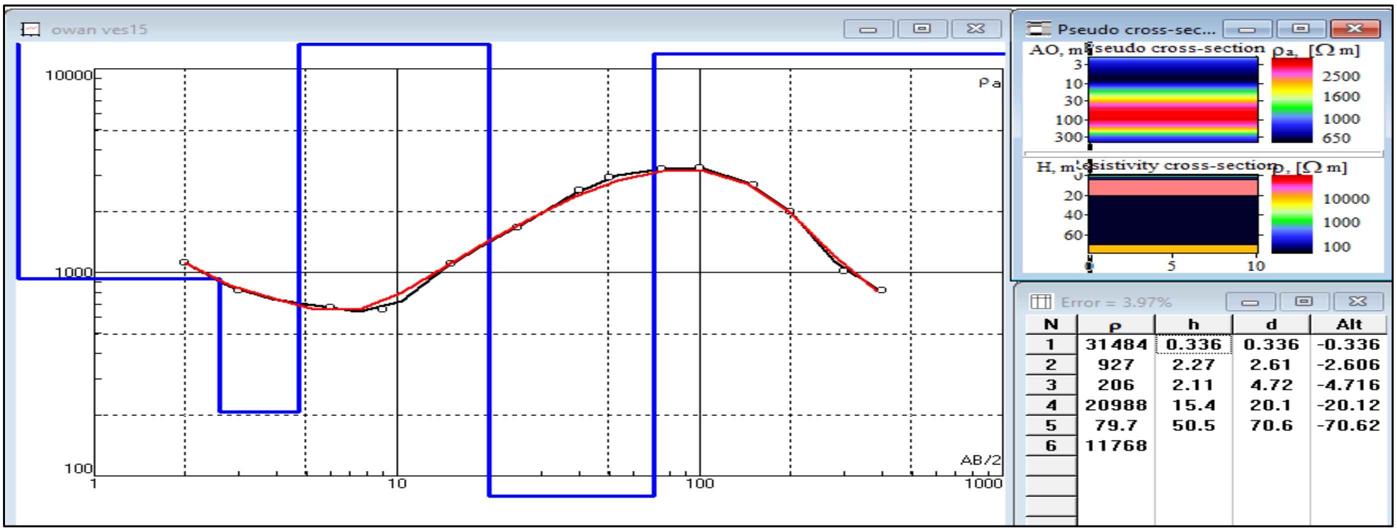


N	ρ	h	d	Alt
1	11558	0.368	0.368	-0.368
2	590	3.07	3.44	-3.438
3	175	2.23	5.67	-5.668
4	7111	13.4	19.1	-19.07
5	264	27.1	46.2	-46.17
6	3.1E+5			



N	ρ	h	d	Alt
1	2164	0.637	0.637	-0.637
2	443	6.67	7.31	-7.307
3	11594	11.5	18.8	-18.81
4	275	101	120	-119.8
5	62672			



N	ρ	h	d	Alt
1	31484	0.336	0.336	-0.336
2	927	2.27	2.61	-2.606
3	206	2.11	4.72	-4.716
4	20988	15.4	20.1	-20.12
5	79.7	50.5	70.6	-70.62
6	11768			

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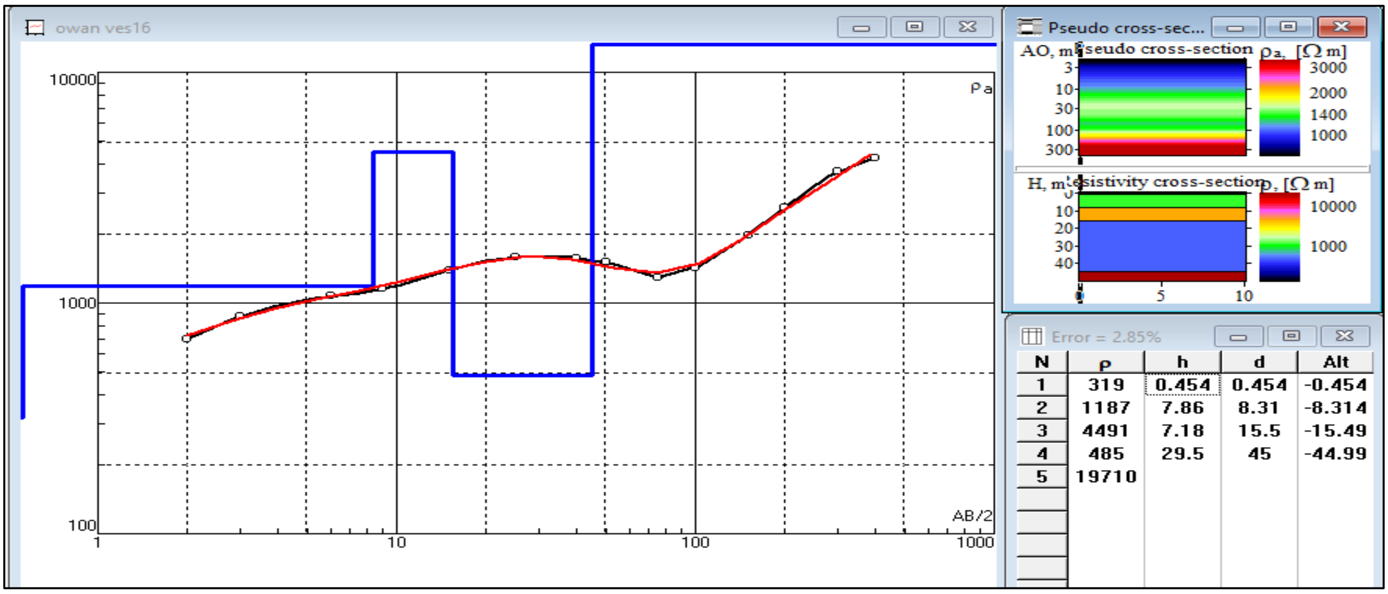
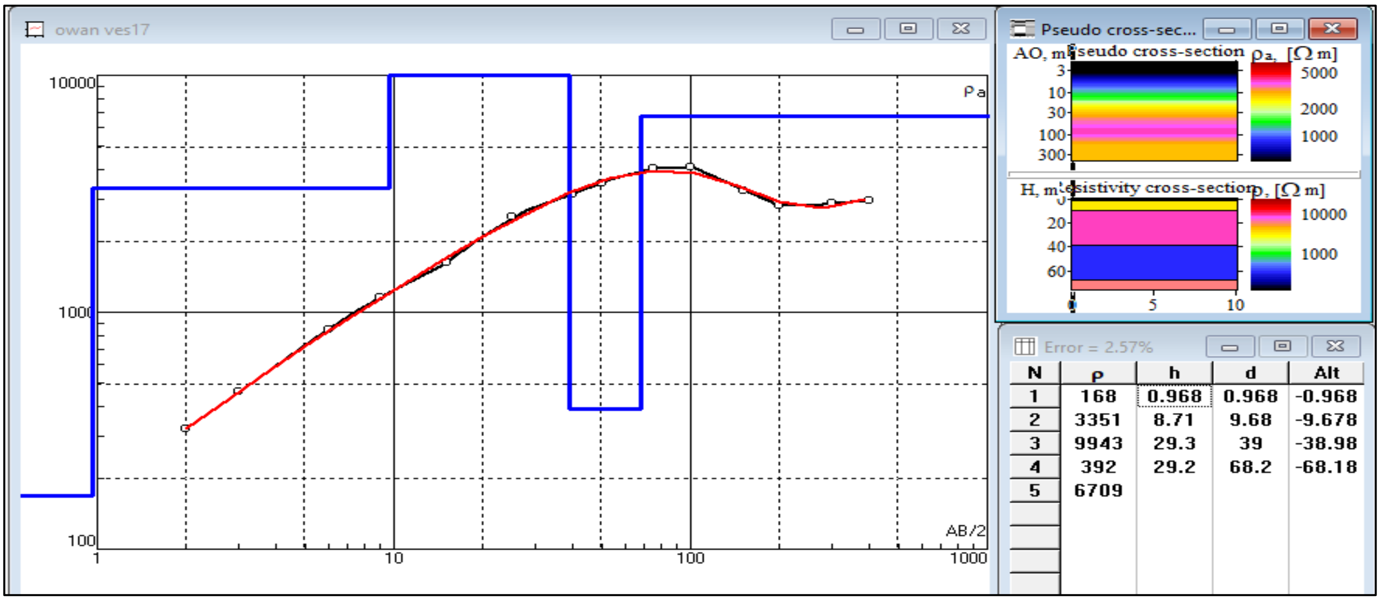
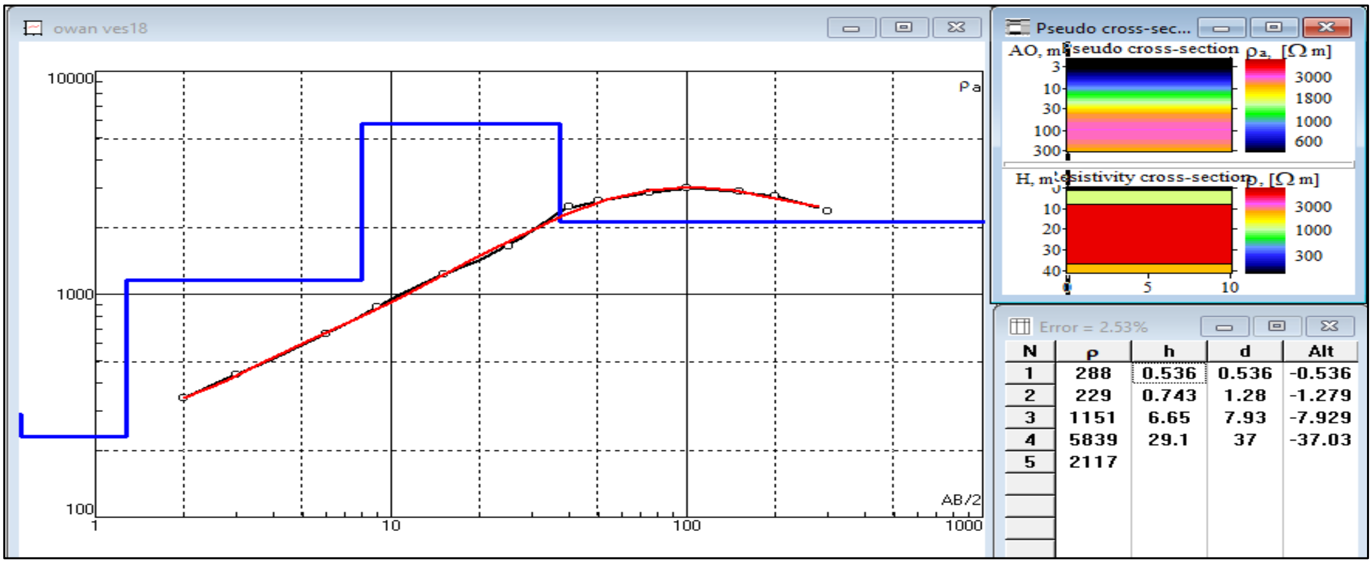
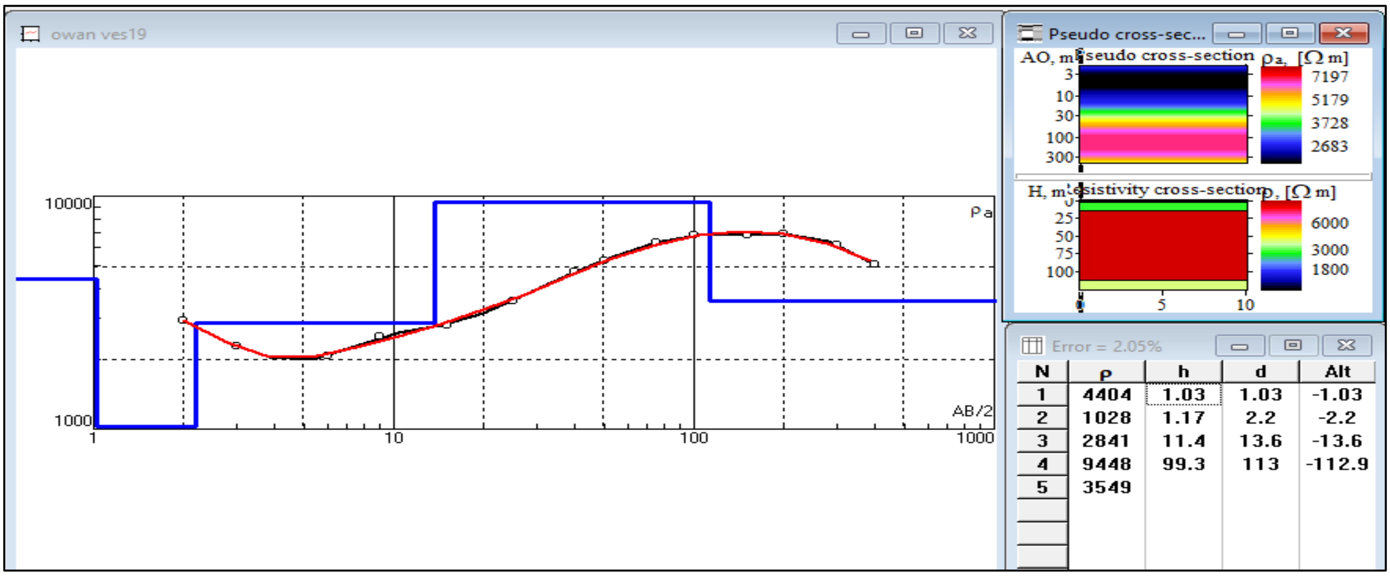
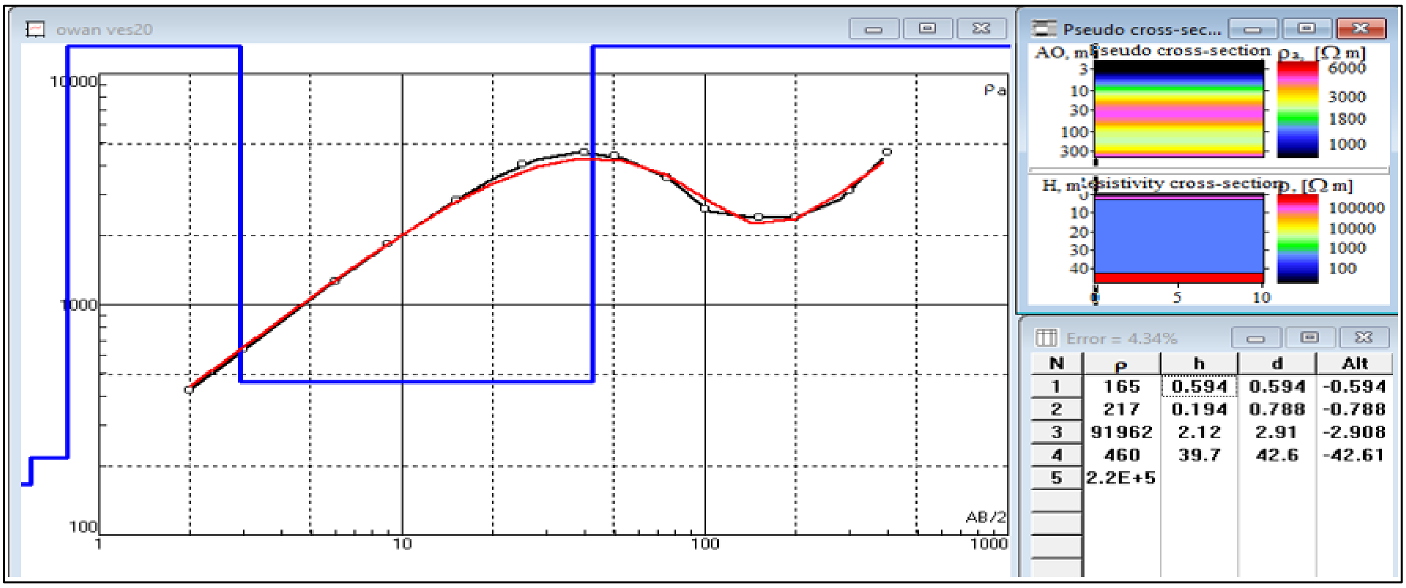








Sounding Curves



Estimated Table of Geologic Formation of the Study Area

VES5(OJIRI) (RMS:1.58%)				**CURVE TYPE AAK((ρ1< ρ2< ρ3< ρ4>ρ5)**
1	155.9	0.6208	0.6208	Topsoil
2	135.8	0.5915	1.212	Clay
3	2377	30.18	31.39	Sandyclay
4	44731	28.47	59.86	Sandstone
5	2100	Undetermined	88.33	Water-SaturatedSand
VES6(AKPOPO) (RMS:0.861%)				CURVE TYPE HAK(ρ1>ρ2< ρ3< ρ4>ρ5)
1	2743	0.581	0.581	Toplayer/Laterite
2	2238	0.6007	1.182	Clayeysand
3	1232	0.9431	2.125	Clay
4	3609	7.539	9.664	Sandyclay
5	23568	11.47	21.13	Sandstone
6	5517	30.36	51.49	Water-SaturatedSand
7	8596	Undetermined	81.85	Sandstone
VES7 (EJIKOLU) (RMS: 6.27%)				CURVE TYPE HAK((ρ1>ρ2< ρ3< ρ4>ρ5)
1	242	0.201	0.201	Toplayer/Laterite

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2	377	0.135	0.336	Clay
3	724	10.5	10.8	Sandyclay
4	350000	18.2	29	Sandstone
5	466	Undetermined	47.2	Water-SaturatedSand
VES8(ALOKURA) (RMS:3.01%)				CURVE TYPE KHK((ρ1<ρ2>ρ3< ρ4>ρ5)
1	2488	0.366	0.366	Toplayer/Laterite
2	4732	0.0935	0.46	Sandyclay
3	9361	4	4.46	Sandstone
4	1181	5.98	10.4	Clayeysand
5	120000	23.3	33.7	Sandstone
6	4712	Undetermined	57.0	Water-SaturatedSand
VES 9(ASADAM) (RMS:5.86%)				CURVE TYPE KHK((ρ1<ρ2>ρ3< ρ4>ρ5)
1	604	0.714	0.714	Toplayer/Laterite
2	23513	0.758	1.47	Sandstone
3	915	2.41	3.88	Clay
4	19261	7.78	11.7	Sandstone
5	1386	21.8	33.5	Water-SaturatedSand
6	13782	Undetermined	55.3	Sandstone
VES10(SANIOKO) (RMS:4.29%)				CURVE TYPE HKH((ρ1>ρ2< ρ3> ρ4<ρ5)
1	17078	1.17	1.17	Toplayer/Laterite
a2	5373	6	7.17	Sandyclay
3	25567	6.06	13.2	Sandstone
4	796	17.2	30.4	Clay
5	36757	50.3	80.7	Sandstone
6	178	Undetermined	131.0	Water-SaturatedSand
VES11(EJULE) (RMS:3.46%)				CURVE TYPE HKH((ρ1>ρ2< ρ3> ρ4<ρ5)
1	3088	1	1	Toplayer/Laterite
2	1731	3.77	4.77	Clayeysand
3	1.1E+5	7.2	12	Sandstone
4	2226	42.2	54.2	Clayeysand
5	23778	Undetermined	96.4	Water-SaturatedSand
VES 12(IBOKO) (RMS:6.21%)				CURVE TYPE HKH((ρ1>ρ2< ρ3> ρ4<ρ5)
1	627	1.74	1.74	Toplayer/Laterite
2	224	3.52	5.26	Clayeysand
3	12394	11.7	17	Sandstone
4	136	20.1	37.1	Clay
5	100000	Undetermined	57.2	Water-SaturatedSand
VES 13(AGOJEJU) (RMS:3.1%)				CURVE TYPE HKH((ρ1>ρ2< ρ3> ρ4<ρ5)
1	11558	0.368	0.368	Toplayer/Laterite
2	590	3.07	3.44	Clayeysand
3	175	2.23	5.67	Clay
4	7111	13.4	19.1	Sandyclay
5	264	13.4	19.1	Water-SaturatedSand
6	310000	Undetermined	32.5	Sandstone
VES14 (EFAKU) (RMS:3.73%)				CURVE TYPE HKH((ρ1>ρ2< ρ3> ρ4<ρ5)
1	2164	0.637	0.637	Toplayer/Laterite
2	443	6.67	7.31	Clayeysand
3	11594	11.5	18.8	Sandstone
4	275	101	120	Water-SaturatedSand
5	62672	Undetermined	221	Sandstone
VES15(OCHIGI) (RMS:3.97%)				CURVE TYPE HKQ(ρ1>ρ2< ρ3> ρ4>ρ5)

1	31484	0.336	0.336	Toplayer/Laterite
2	927	2.27	2.61	Sandyclay
3	206	2.11	4.72	Clayeysand
4	79.7	50.5	70.6	Water-SaturatedSand
5	11768	Undetermined	121.1	Sandstone
VES 16(OLAJI) (RMS:2.85%)				CURVE TYPE AKH($\rho_1<\rho_2<\rho_3>\rho_4<\rho_5$)
1	319	0.454	0.454	Toplayer/Laterite
2	1187	7.86	8.31	Clayeysand
3	4491	7.18	15.5	Sandyclay
4	485	29.5	45	Water-SaturatedSand
5	19710	Undetermined	74.5	Sandstone
VES 17(OCHANJA) (RMS:2.57%)				CURVE TYPE AAH($\rho_1<\rho_2<\rho_3<\rho_4<\rho_5$)
1	168	0.968	0.968	Toplayer/Laterite
2	3351	8.71	9.68	Clayeysand
3	9943	29.3	39	Sandstone
4	392	29.2	68.2	Water-SaturatedSand
5	6709	Undetermined	97.4	Sandstone
VES18 (ALLOMO) (RMS: 2.53%)				CURVE TYPE AAK($\rho_1<\rho_2<\rho_3<\rho_4>\rho_5$)
1	288	0.536	0.536	Toplayer/Laterite
2	229	0.743	1.28	Clayeysand
3	1151	6.65	7.93	Sandyclay
4	5839	29.1	37.0	Sandstone
5	2117	Undetermined	56.1	Water-SaturatedSand
VES19(CHIKARO) (RMS:2.05%)				CURVE TYPE HKH(($\rho_1>\rho_2<\rho_3>\rho_4<\rho_5$)
1	4404	1.03	1.03	Topsoil
2	1028	1.17	2.2	Clayeysand
3	2841	11.4	13.6	Sandyclay
4	9448	99.3	113	Sandstone
5	3549	Undetermined	212.3	Water-SaturatedSand
VES 20(MAMARESO) (RMS: 4.34%)				CURVE TYPE AAH(($\rho_1<\rho_2<\rho_3<\rho_4<\rho_5$)
1	165	0.594	0.594	Toplayer/Laterite
2	217	0.194	0.788	Clay
3	91962	2.12	2.91	Sandstone
4	460	39.7	42.6	Water-SaturatedSand
5	22000	Undetermined	82.3	Sandstone

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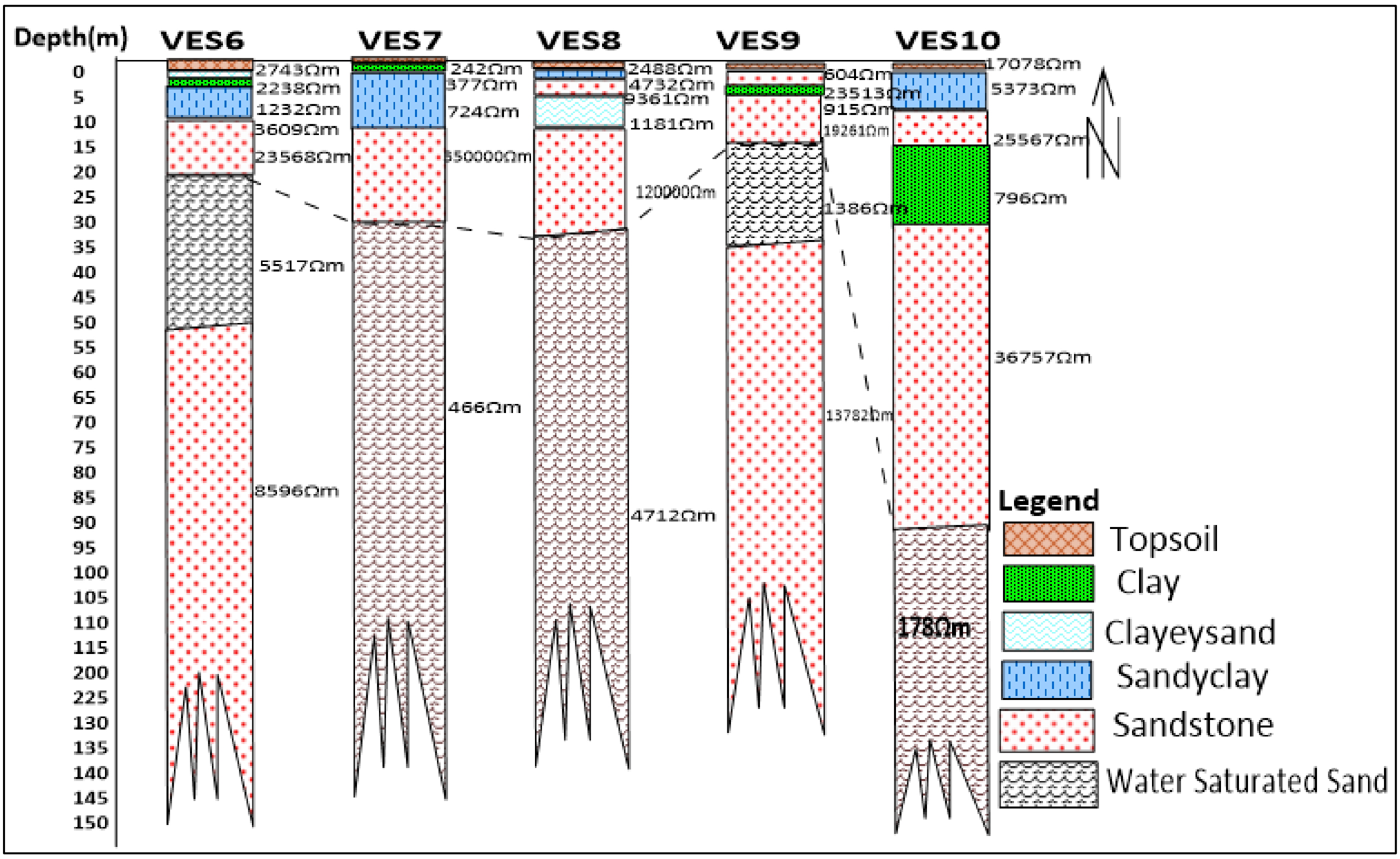

Lithologic Table of the Study Area

VES NO	Aquifer App.Res (Ωm)	Depth to Groundwater (m)	Depth of Overburden (m)	Thickness of Overburden Layers(m)
VES 5	2100	88.33	59.86	59.86
VES 6	5517	51.49	21.13	21.13
VES 7	466	47.2	29	29
VES 8	4712	57	33.7	33.7
VES 9	1386	33.5	33.5	11.3
VES 10	178	131	80.7	80.7
VES 11	23778	96.4	54.2	54.2
VES12	100000	57.2	37.1	37.1
VES 13	264	19.1	19.1	19.1
VES 14	275	120	26.1	18.8
VES 15	79.7	70.6	7.33	4.72
VES 16	485	45	15.5	15.5
VES 17	392	68.2	39	39
VES 18	2117	56.1	37	37
VES 19	3549	212.3	113	113
VES 20	460	42.6	42.6	3.5

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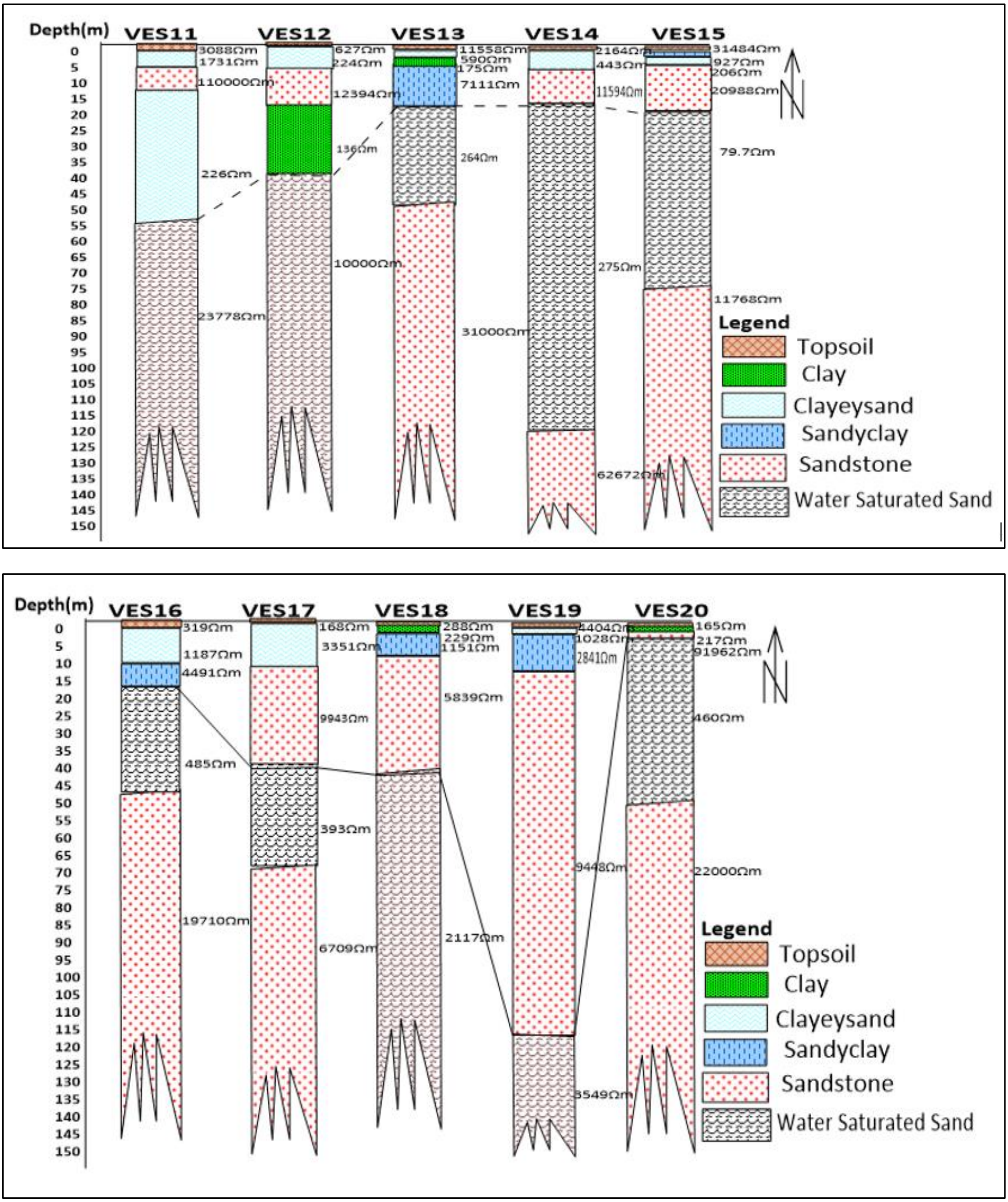

Resistivity Depth(s) of the Study Area