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INVESTIGATION OF GROUNDWATER AQUIFER USING ELECTRICAL RESISTIVITY METHOD AT MULERUWA VILLAGE, SOUTH WEST, NIGERIA.

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ABSTRACT

Groundwater is an important natural resource and constitutes our environment. Groundwater can be found in geological formations which exist below the ground surface. Differences exist in groundwater systems all over the world due to differences in their geological make up and climate.Groundwater resource assessment has been carried out using hydro-geophysical techniques (Vertical electrical maximum spread of 350m sounding and 2-D Wenner profile (a=10m) ,maximum spread of 230 m was modelled with the corresponding depth of 30 to 50 m was investigated) in Muleruwa Ogun State, Southwestern Nigeria. The 2D data was interpreted with WinPRO while VES data curve matched and interpreted results of the VES data were presented as Geo-electric sections. Six geo-electric layers were delineated which correspond to the Topsoil, Clayey sand, Lateritic clay sand, clay and sand. The Topsoil has layer thickness of 0.5m - 0.8m and Resistivity values within the range of 69.3Ωm-423.6Ωm. The Clay has a layer thickness of 1.2m - 29.9m and resistivity values within the range of 17.7Ωm - 35.0Ωm. The lateritic clayey sand has a layer thickness of 5.5m - 74.2m and resistivity value within the range of 1054.5Ωm - 9319.2Ωm.The Clayey sand has a layer thickness of 1.7m - 13.3m and resistivity value within the range 63.9Ωm - 824.9Ωm. The sand has a layer thickness of 2.2m - 58.6m and resistivity values within the range of 118.2Ωm - 940.3Ωm, this layer is not a Groundwater reservoir. Groundwater reservoirs are found between the depths 67.2m -115.8m, thickness of 23.0m – 54.5m and above in saturated sand.The physical properties of the water in this community was also seen to contradict the normal properties of water. The water was seen to be slightly coloured in appearance, had a particular taste and an unpleasant odour.

KEYWORDS: Resistivity, Aquifer, Groundwater, physical properties, Geo-electric section.

INTRODUCTION

Muleruwa village is located after Ogijo community, Sagamu local Government, Ogun state. It is an industrialized area with a large concentration of industrial wastes from different companies such as the Nigeria National Petroleum Corporation (NNPC), Iron and Steel companies and the Metal Recycling Industry. Huge masses of wastes are produced daily from the companies as a result of industrial and commercial activities, when not properly disposed could affect the groundwater aquifer present in the study area. Groundwater is an important natural resource and constitutes our environment. Groundwater can be found in geological formations which exist below the ground surface. Differences exist in groundwater systems all over the world due to differences in their geological make up and climate

The contamination of groundwater with Industrial pollution is of great concern in many countries globally due to its potential impact on health and environmental quality. (Olayinka, 2019).

Leachate generated from industrial and domestic landfill during the rain may eventually percolate and contaminate groundwater. Consequently, pollution from landfills leads to potentially communicable diseases. Groundwater is the subsurface transporting agent for dissolved chemicals including contaminants. Materials dissolved from the wastes areas are contaminated, they commonly remain so for decades or longer. (Ofomala, 2015). Groundwater resources poses a greater risk to the domestic user and also the natural environment. The site is located at Muleruwa Community, Ogijo, Ogun State. The area is accessible via major road from Maryland Bus stop to Ikorodu Garage, from Ikorodu - Garage, board a bus going to Ogijo. Then from Ogijo Bus stop, take to Igbaga and stop at Muleruwa Community.

Site Description, Geology and Hydrogeology of the study area

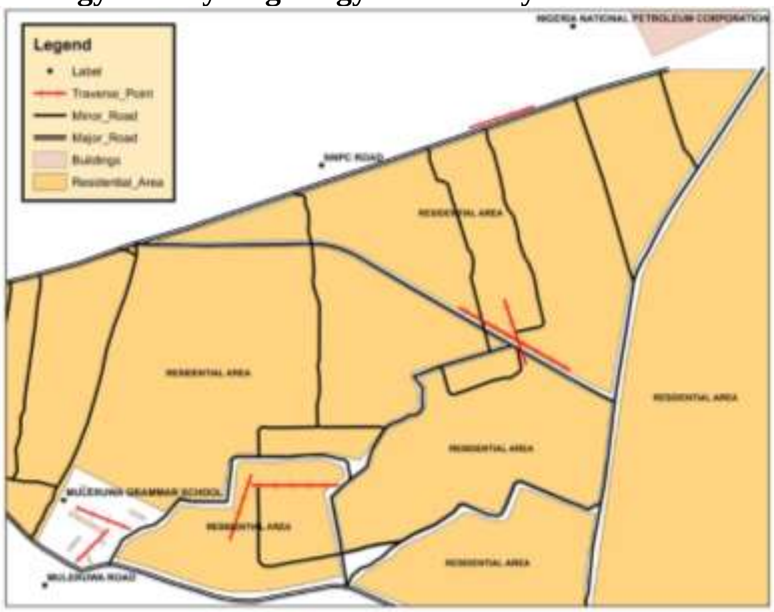

Fig 1: Base Map of the study area

The study area is located in Muleruwa and Igbaga village, Ogijo community, Sagamu local government area within Ogun state, Southwestern Nigeria. The study area is located along Ikorodu - Sagamu Expressway. It is situated along geographic coordinates of Latitude 6.6994°N and Longitude 3.5155°E. It falls within the eastern dahomey basin of Southwestern Nigeria. The study area possesses Savanna vegetations which are described with crystalline basement complex rocks. The dominant rocks are gneisses and quartzite. (Abdulaziz, 2003).

The major climatic seasons of the area are rainy and dry seasons. The rainy season rus from April to October which is characterized by heavy downpours in June/July while the remaining months constitute the dry season with little rainfall or none at all. The mean annual rainfall which is about 1270mm makes up the major source of groundwater recharge in the area with a mean annual temperature of about 27°C - 28°C. (Ojo, 1997).

The vegetation which exists within the study area is largely influenced by climate and relief though the present day vegetation cover can be said to be scarce owing to residential and commercial activities within the town.

The geological setting of the study area is that of a sedimentary terrain Easstern Dahomey basin which include; Abeokuta, Ewekoro, Ilaro, Akinbo, Oshosun and Benin formations. The local geology of the study area was observed to be one which comprises of sedimentary rocks with Shale and Clayey lithology being predominant belonging to the

Akinbo formation. (Oyeyemi and Aizbeokhai, 2015).

The major aquifer zones delineated in the study area are the shale and clay. The shale and clayey deposits are the major aquifers in the study area. Boreholes in residential buildings around the area serve as a major source of portable water for the inhabitants. With the increasing activities of industries such as Petroleum Industry, Iron and Steel Industry and Metal Recycling Industry, the groundwater may be rendered unsuitable for domestic and agricultural purposes.

The occurrence of groundwater in crystalline rocks majorly depends on the fracturing and weathering of rocks. The groundwater is primarily contained in the fractured and weathered formations which is basically recharged through surface precipitation.

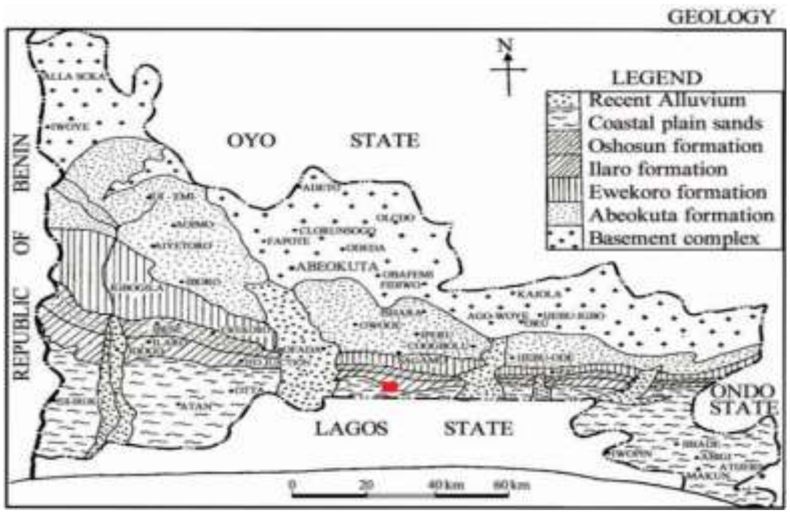

Fig 2 : Geological Map of study area. Oladunjoye,et al. (2013)

MATERIALS AND METHODS

FIELD WORK PROCEDURE

In 1D resistivity survey Fig 3, the Centre point of the electrode remains fixed and unchanged but the spacing between the electrodes are varied to obtain more information about the depth of the subsurface. (Loke, 2001). These surveys assume that the geological layers are horizontal and homogenous.

The measured apparent resistivity values are normally plotted on a log-log graph paper. To interpret the data from such a survey, it is normally assumed that the subsurface consists of horizontal layers. In this case, the subsurface resistivity changes only with depth, but does not change in the horizontal direction. This method has given useful results for geological situations (such the water-table) where the one-dimensional model is approximately true. (Loke, 2001).

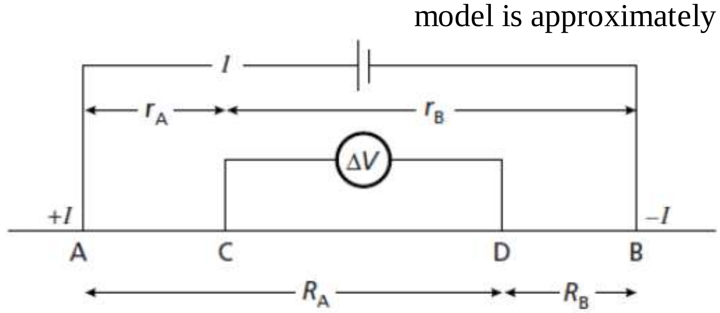

Fig 3: The generalized form of the electrode configuration used in resistivity measurements (Keary et al., 2002).

Considering the case where the current sink is a finite distance from the source. The potential VC at an internal electrode C is the From equation above

sum of the potential contributions VA and VB from the current source at A and the sink at B: VC = VA + VB

$$V_C = \frac{\rho I}{2\pi}\left(\frac{1}{r_A} - \frac{1}{r_B}\right) \quad (1)$$

Thus

$$\rho = \frac{2\pi\Delta V}{I\left\{\left(\frac{1}{r_A} - \frac{1}{r_B}\right) - \left(\frac{1}{R_A} - \frac{1}{R_B}\right)\right\}}$$

2D is one of the most recent technique in electrical resistivity method to map out areas with moderately complex geology. The surveys are usually carried out using a large number of electrodes and connected to a multi core cable. At present, field techniques and equipment to carry out 2-D resistivity surveys are well developed. Normally, a constant spacing between the adjacent electrodes is used. The multi core cable is then attached to the electronics switching unit which is then connected to the instrument. In a typical survey, most of the field work is in laying out cables and the electrodes. After that, the survey time is spent waiting for the resistivity meter to complete the set of measurements. For a good 2-D picture of the subsurface to be obtained, the coverage of the measurement must be 2-D as well.

For instance, the figure below shows the possible sequence of measurements for a zenner electrode array for a system with 20 electrodes.

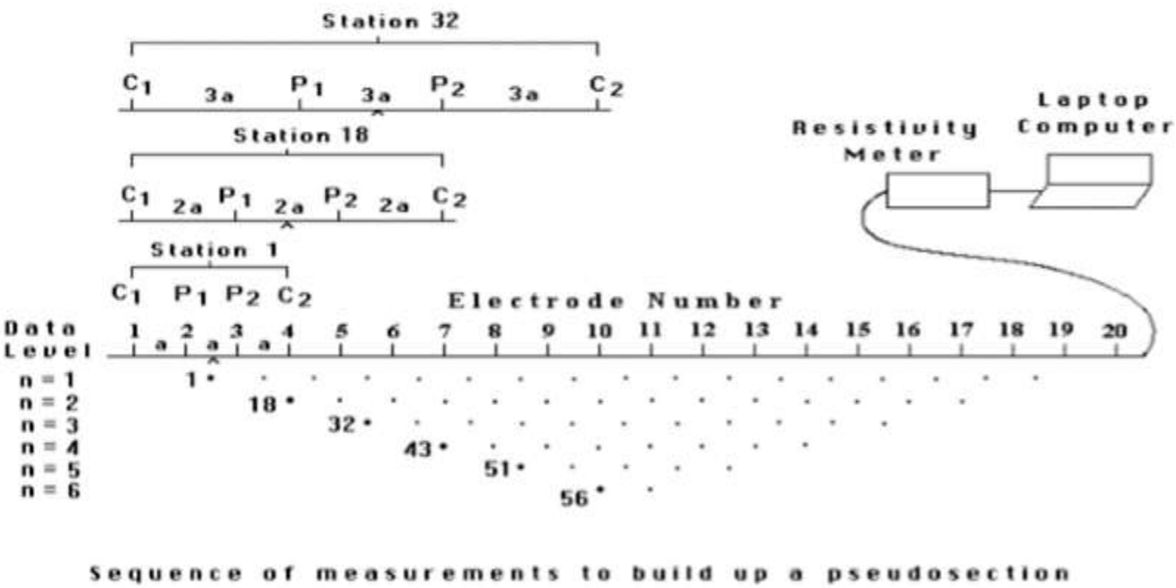

Fig 4: The arrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build up a pseudo section (Loke, 2001).

Both Vertical Electrical Sounding (VES) and the 2-D geoelectrical survey were carried out using both Schlumberger and Wenner array configurations respectively. The basic field equipment for this survey is the PASI Earth Resistivity metre which is accompanied by other instruments such as; metal electrodes, conducting cables, hammers e.t.c. in the VES, the Schlumberger electrode configuration was adopted with four electrodes being positioned symmetrically along a straight line with the current electrode on the outside and the potential electrodes on the inside. To change the depth, the range of measurements of the current electrodes are displaced outwards while the potential electrodes are left fixed. Measurement of current and potential electrodes position are marked such that $AB/2 \geq MN/2$.

Where:

AB/2 = Current electrode spacing

MN/2 = Potential electrode spacing

One of the major advantages this method has is that only the current electrodes need to be shifted to a new position for most readings.
The Wenner arrays were used on seven traverse lines, Traverse AA - Traverse GG with a maximum length spread of 230m and minimum electrode spacing of 10m. The data were generated along the traverses. Two people manned each current electrode, marked out the required length with the tapes and hammered the electrodes connected to the cables into the ground and rewound them when each traverse was completed. Communication between the field crew and the operator were made possible with the aid of a GSM phone. By the end of the field work, a total number of seven traverses were run.
The Wenner array was used for 2-D resistivity imaging acquisition. These electrode configuration are well suited for constant separation data acquisition systems so that many data points can be recorded simultaneously for each current injection. A third party software package, Surfer 12 and RES2DINV were used for the resistivity data processing. Before processing with the RES2DINV software, the data was converted into CSV -file extension with Surfer 12 software. This conversion was done to enable the RES2DINV software to read the Wenner data. In the RES2DINV software program, each of the apparent resistivity data files was read and inverted with the user model. The inverted data was printed and saved in word file format. The result is an inverse model resistivity section which is referred to as pseudo section. The data obtained and results of interpretation from the Wenner array survey are presented below as inverse model resistivity section.

The Schlumberger configuration was used in carrying out vertical electrical soundings for the delineation of possible subsurface layers of the earth. The electrodes were moved in steps further out from a fixed center in order to achieve greater current penetration into the ground.
This method involves the use of a geophysical software called WinResist Field data are input and then modeled. Curve matching gets cumbersome where there are many layers, hence the computer iteration makes the interpretation of such problems easier. A fast observation is allowed based on the iteration intense of the program. The layer parameter are altered until a good fit is achieved between the observed and the calculated values. The iteration process of a curve can go as far as 30 times of achieving an effect match, after which the computer displays the final result of the iteration and the layer parameters. This method is the most effective method of all the interpretation method in terms of speed and accuracy

RESULTS AND DISCUSSION

Some typical resistivity curves are shown in Figure 5(a - c). A summary of the interpreted VES results with inferred lithology is presented as Table 1. The geo-electric sections are displayed in Figures 6(a – b). The 2D Electrical Resistivity models are shown in Figures 7

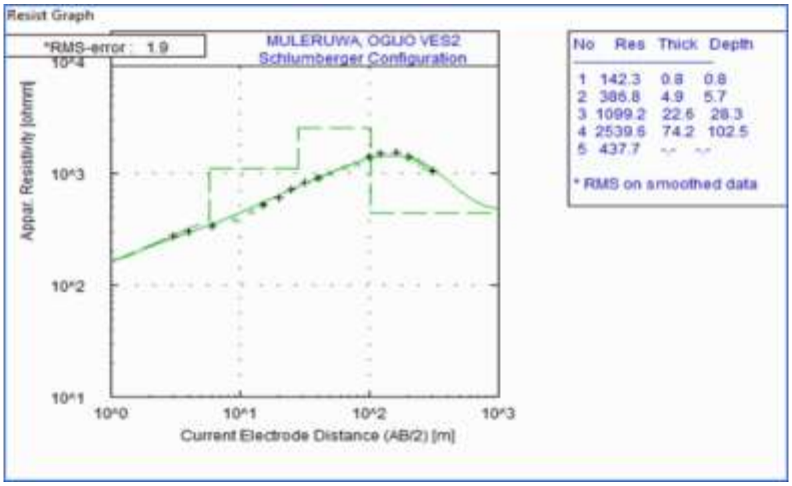

Figure 5: Resistivity Curve of VES 2 (AA)

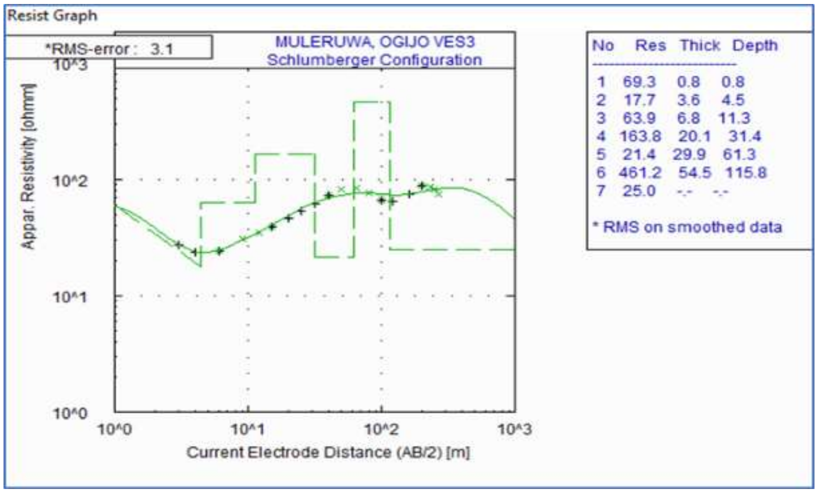

Figure 5b: Resistivity Curve of VES 3 (AAK)

Figure 5: Resistivity Curve of VES 3 (HAKHK)

Table 1: Lithology of the study area

VES Number	Possible Layers	Resistivity (Ωm)	Thickness (m)	Depth (m)	Curve Type	Lithology
VES 1	1	71.3	0.7	0.7		Topsoil
	2	491.8	3.7	4.3		Clayey Sand
	3	738.4	13.3	17.3	**AAK**	Clayey Sand
	4	1674.1	41	58.6		Lateritic Clayey Sand
	5	277.5	---	---		Sand
VES 2	1	142.3	0.8	0.8		Topsoil
	2	386.8	4.9	5.7		Clayey Sand
	3	1099.2	22.6	28.3	**AAK**	Lateritic Clayey Sand
	4	2539.6	74.2	102.5		Lateritic Clayey Sand
	5	437.7	---	---		Sand
VES 3	1	69.3	0.8	0.8		Topsoil
	2	17.7	3.6	4.5		Clay
	3	63.9	6.8	11.3	**HAKHK**	Clayey Sand
	4	163.8	20.1	31.4		Sand
	5	21.4	29.9	61.3		Clay
	6	461.2	54.5	115.8		Sand
	7	25	---	---		Clay
VES 4	1	123.3	0.7	0.7		Topsoil
	2	1174.2	3.8	4.5		Lateritic Clayey Sand
	3	171.2	11.9	16.4	**KHK**	Sand
	4	2866.6	56.2	72.7		Lateritic Clayey Sand
	5	193.9	---	---		Sand
VES 5	1	150.1	0.7	0.7		Topsoil
	2	1275.7	5.2	5.9		Lateritic Clayey Sand
	3	259.4	7.9	13.8	**KHK**	Sand
	4	1428	57.1	70.9		Lateritic Clayey Sand
	5	281	---	---		Sand
VES 6	1	316.4	0.7	0.7		Topsoil
	2	705.2	3.3	4		Clayey Sand
	3	1340.5	3.1	7.1	**AKHK**	Lateritic Clayey Sand
	4	283.9	7.6	14.7		Sand
	5	2307	54.9	69.8		Lateritic Clayey Sand
	6	362.9	---	---		Sand
VES 7	1	423.6	0.6	0.6		Topsoil
	2	527.8	1.7	2.3		Clayey Sand
	3	97.8	1	3.4	**KHAKH**	Sandy Clay
	4	543.1	7.7	11		Clayey Sand
	5	2831.1	28.3	39.4		Lateritic Clayey Sand
	6	163.6	50.5	89.9		Sand
	7	1938.4	---	---		Lateritic Clayey Sand

VES 8	1	213.1	0.8	0.8		Topsoil
	2	774	4.4	5.2		Clayey Sand
	3	8261.5	10.8	16	**AKH**	Lateritic Clayey Sand
	4	940.3	54.7	70.7		Sand
	5	9319.2	---	---		Lateritic Clayey Sand

Geoelectric Section along BB'

Figure 6b consist of VES 3 to 7. The section reveals five to seven geoelectric layers which varies from topsoil, clay, clayey sand, lateritic clayey sand, sandy clay and sand. The topsoil is characterized by resistivity values ranging from 69.3 to 150.1 Ohm-m and layer thickness of 0.7 to 0.8 m. The second identified layer in VES 3 is representative of clay having resistivity value of 17.7 Ohm-m and layer thickness of 3.6 m while the clay is replaced with lateritic clayey sand in VES (4 and 5) with resistivity and layer thickness values ranging from 1174.2 to 1275.7 Ohm-m and 3.8 to 5.2 m respectively. However, the second layer in VES (6 and 7) denotes clayey sand with resistivity values ranging from 527.8 to 705.2 Ohm-m and layer thickness of 1.7 to 3.3 m. The third geoelectric unit in VES 3 depicts clayey sand with resistivity and layer thickness value of 63.9 Ohm-m and 6.8 m respectively. While the clayey sand is replaced with sand in VES (4 and 5) having resistivity values ranging from 171.2 to 259.4 Ohm-m and layer thickness of 7.9 to 11.9 m. However, the third layer in VES 6 is representative of lateritic clayey sand with resistivity value of 1340.5 Ohm-m and layer thickness of 3.1 m. More so, the third geoelectric layer in VES 7 represent sandy clay having resistivity and layer thickness value of 97.8 Ohm-m and 1.0 m respectively. The fourth horizon beneath VES (3 and 6) is indicative of sand with resistivity values ranging from 163.8 to 283.9 Ohm-m and layer thickness of 7.6 to 20.1 m while the sand is replaced with lateritic clayey sand in VES (4 and 5) with resistivity values ranging from 1428.0 to 2866.6 Ohm-m and layer thickness of 56.2 to 57.1 m. However, the fourth layer in VES 7 revealed clayey sand with resistivity and layer thickness of 543.1 Ohm-m and 7.7 m respectively. The fifth substratum layer beneath VES 3 is diagnostic clay with resistivity value of 21.4 Ohm-m and layer thickness of 29.9 m while the clay is replaced with sand in VES (4 and 5) with resistivity values ranging from 193.9 to 281.0 Ohm-m but their layer thickness could not be determined due to current terminated within this region. The sand in this zone represents an aquifer unit where groundwater could be tapped. However, the fifth geoelectric layer in VES (6 and 7) signify lateritic clayey sand with resistivity values ranging from 2307.0 to 2831.1 Ohm-m and layer thickness of 50.5 to 54.9 m. The sixth geologic units in VES (3, 6 and 7) is symptomatic of sand with resistivity values ranging from 163.6 to 461.2 Ohm-m. The layer thickness in VES (3 and 7) ranges from 50.5 to 54.5 m but the layer thickness in VES 6 could not be determined due to current terminated within this zone. The sand in this region represents an aquifer unit where groundwater could be tapped. The seventh geoelectric layer in VES 3 connotes clay with resistivity value of 25.0 Ohm-m but the layer thickness could not be determined due to current terminated within this region. While the clay is replaced with lateritic clayey sand in VES 7 with resistivity value of 1938.4 Ohm-m but the layer thickness could not be determined due to current terminated within this horizon.

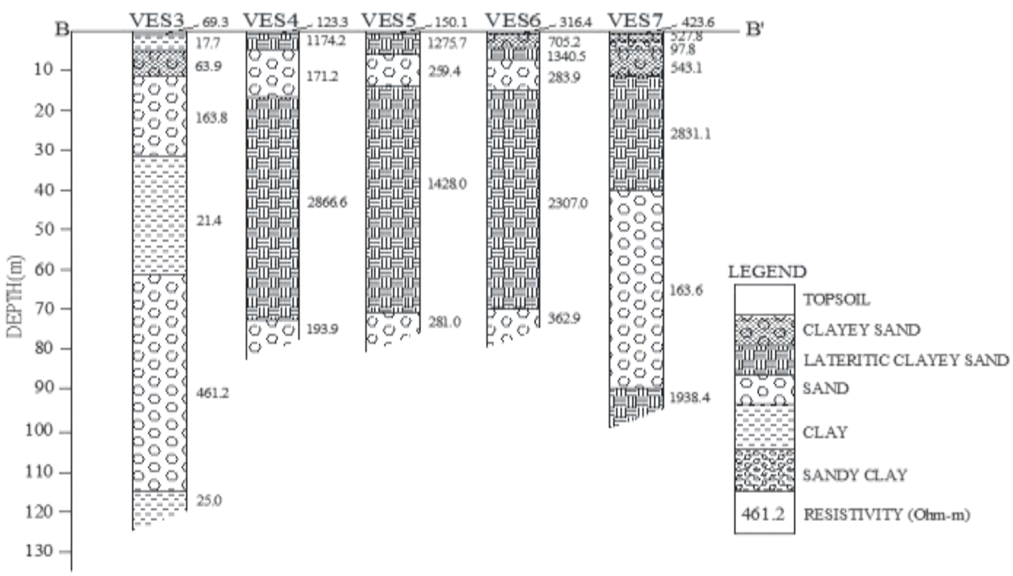

Figure 6a:Geo-electric section of traverse BB'

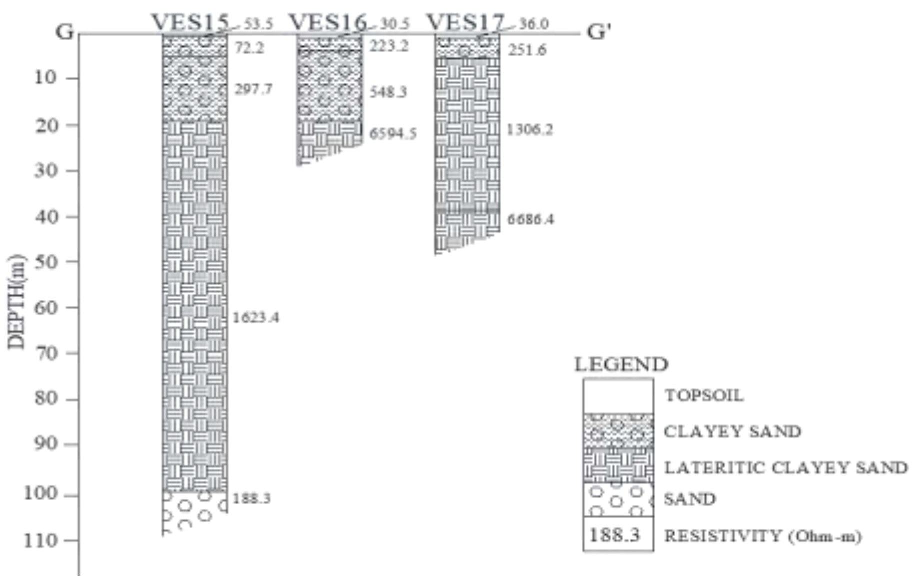

Figure 6b:Geo-electric section of traverse EE'

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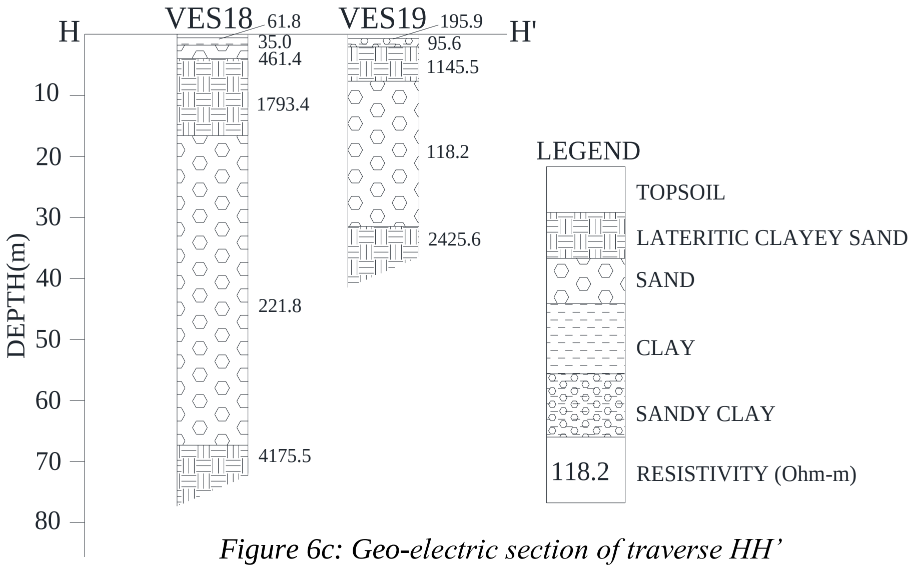

Figure 6c: Geo-electric section of traverse HH'

2-D ELECTRICAL IMAGING

In this model, the results are presented in a colour coded format Fig 7.0(a-f) consisting of the Inverted 2-D Resistivity structure. The horizontal scale on the section is the lateral distance while the vertical scale is the depths which are both in meters. A minimum and maximum spread of 130 to 230 m was modelled with the corresponding depth of 30 to 50 m investigated on all the profiles Fig 6.0 (a - f).

2-D Resistivity Section along Traverse One

A total spread of 200 m was surveyed and a depth of 50 m was probed with resistivity values ranging from 188 to 848 Ohm-m as shown in Figure 7(a-d). The VES 1 and 2 were along the 2-D profile in Figure 7(a) at lateral distance of 40 m and 120 m respectively. At depth below 20 m is indicative of clayey sand and lateritic clayey sand having a resistivity values ranging from 223 to 848 Ohm-m across the profile. The depth above 20 m to the subsurface signifies lateritic clayey sand with resistivity in the range of 718 to 848 Ohm-m across the profile in Figure (7a) at VES 2.

CONCLUSION AND RECOMMENDATIONS

The potential of groundwater at Muleruwa area was approached by establishing both 2-D Wenner array and 1- D Schlumbeger technique. The analysis of the data in 2D and 1D revealed that the water-bearing formation exist below the third and fourth layers with thickness ranging from 40.0m – 110.5m.The 2-D revealed lateral variations with depth though sand could not be delineated while 1D only shows vertical depth at which ground water could be tapped .

Further Geophysical techniques should be employed like induced polarization and Electromagnetic method to determine the level of pollution of the groundwater in the study area.It is also recommended that Physicochemical Techniques should also be employed to determine the Total Dissolved Solids (TDS), heavy metals and organic compounds present in the boreholes in the study area

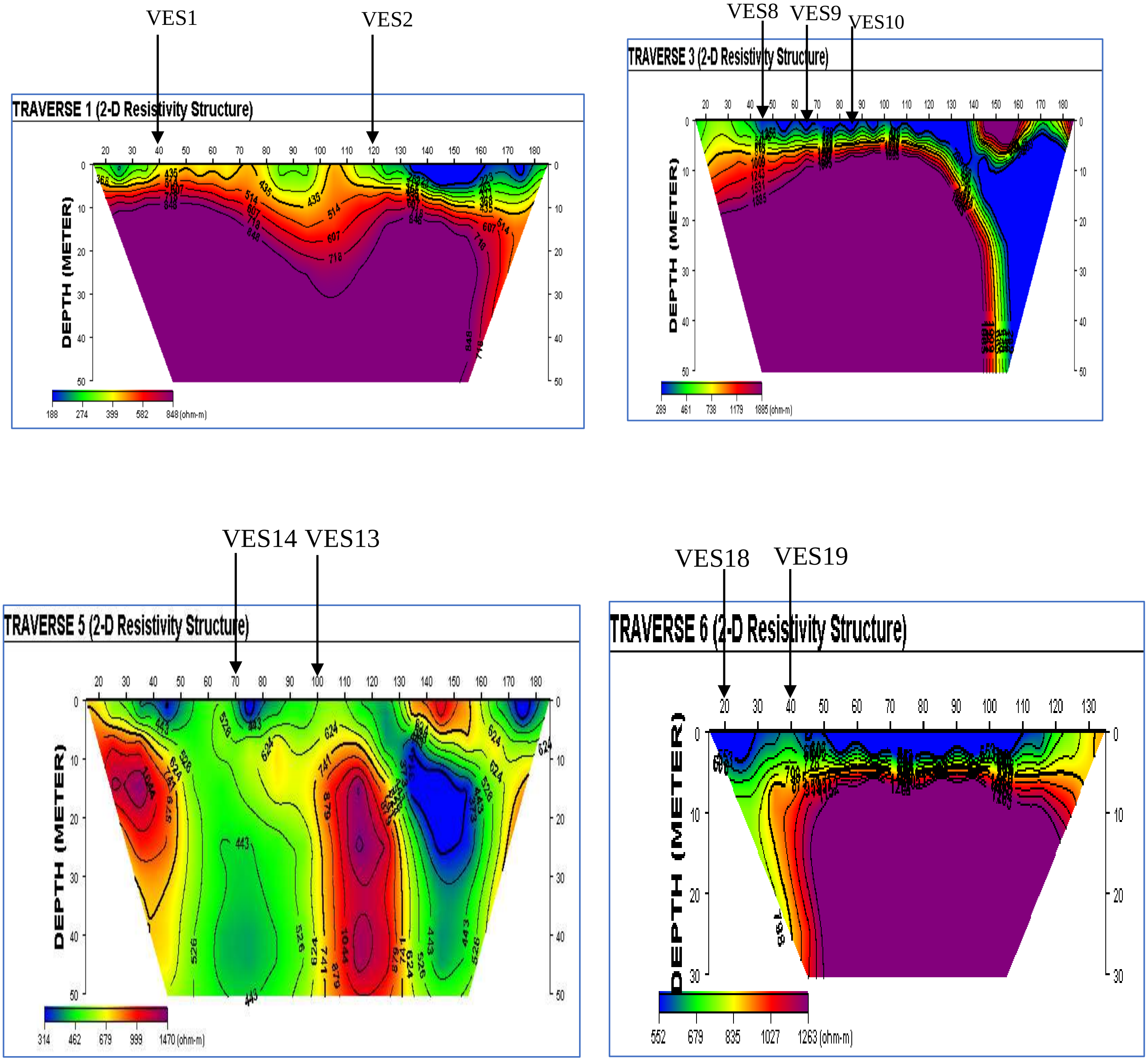

Figure 7 (a-d) ; 2D Geoelectric structure of the study area.

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