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ORIGINAL RESEARCH

Delineation of Aquiferous Zones Using Geoelectrical Resistivity Techniques in Oworoshonki, Lagos, Nigeria.

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Abstract:
The 2D Electrical Resistivity Imaging (ERI) and Vertical Electrical Sounding (VES) techniques were deployed for groundwater extraction at a school located in Oworoshoki, Kosofe, local government area, Lagos. This becomes necessary due to two failed existing hand dug wells within the school premises. 2D ERI data and thirty VES data were acquired along five profiles. The results revealed four to five geoelectric layers which correspond to the topsoil, clay, clayey sand, sandy clay and sand. The topsoil is characterized by resistivity values ranging from 42.5 to 3798.4 Ωm. The clay has resistivity values ranging from 7.9 to 48.1 Ωm. The sandy clay has resistivity values ranging from 21.0 to 59.0 m. The clayey sand in VES (16, 17 and 26) has resistivity values between 72.9 to 96.5 Ωm. The sand identified at the VES (1 to 18 and 22 to 30) has resistivity values of 116.7 to 1531.3 Ωm at the shallow layer which is suspected to be the seasonal aquifer where most of the existing hand dug wells were situated. The sand at the fourth to fifth layer across VES (1, 2, 3, 6, 7, 8, 11, 12 to 15, 18 and 25) with the resistivity values between 107.2 to 450.0 Ωm represents a good aquifer where groundwater could be tapped. The 2D resistivity structures were able to delineate the shallow aquifer thereby complementing the VES results. Hence, the study recommends that borehole could be sunk at depth range (39.5 to 90.3 m) in the study area.

Keywords: Groundwater, 2D Electrical resistivity imaging, Vertical electrical sounding, Aquifer, Extraction

1. INTRODUCTION

Water is necessary for human consumption, its availability and accessibility is crucial to human life. It is an essential resource for humanity and the environment, as it supports ecosystems, agriculture, and human activities [1]. Water exists in the form of surface water and groundwater, surface water is vulnerable to contamination, hence the use is limited while groundwater is located beneath the earth's surface in soil crevices, fractures, and other types of geological structures, though could be contaminated at times due to human activities such as indiscriminate dumping of refuse and waste from industrial, mining or agricultural activities [2,3]. Groundwater accumulates over time from precipitation, snowmelt, and surface water sources, the recharge process involves the infiltration of water into the ground, where it is stored in porous rocks and sediment layers called aquifers. These aquifers can be found at various depths beneath the earth's surface, and their characteristics can vary depending on the geology of the area [4]. It is important to deploy integrated geophysical methods to delineate an aquifer and to determine the depth for extraction [4, 5, 6, 7, 8, 9]. When geophysical survey is not conducted prior to drilling of boreholes often times, most drilled wells or boreholes are abandoned for reasons such as bore hole drying, low yield and contamination [10].

The application of geophysical techniques in groundwater extraction depends largely on the relationship between the physical parameters such as conductivity/resistivity, acoustic velocity, magnetic permeability and density [5, 11, 12] and the host. Likewise, properties of the geologic formations such as porosity and permeability are very important [13, 14]. The vertical electrical sounding (VES) and constant separation traversing (CST) of electrical resistivity method have proven effective in groundwater studies due to their non-invasive nature and simplicity of the techniques. [15] established that 82% failure rate of boreholes recorded for rural water supply in Northern Nigeria was dramatically reduced to less than 20% failure due to the deployment of electrical resistivity method. Studies have shown that geophysical methods such as electrical resistivity method, electromagnetic method and seismic refraction method are effective in delineating location for boreholes in both sedimentary and crystalline basement in sub-Saharan Africa [14, 16].

In this study geophysical survey was conducted in a compound at Oworonshoki which comprises of five schools with inadequate supply of portable water. Though there exist three hand dug wells within the school premises. Two have been abandoned while only one produces and it is seasonal; it gives high yield during rainy season and low yield during dry season. This informed the application of electrical resistivity method to delineate the aquiferous unit(s) for groundwater extraction so as to meet the pupils' demand within the school compound.

2. MATERIAL AND METHODS

2.1 Location and the Geology of the Study Area

Oworonshoki is located in Kosofe, Lagos State, South-Western Nigeria. It lies between longitude E 003°24'13.31" to E 003°24'19.0" and latitude N 06°32'41.97" to N 06°32'53.4". It falls within the sedimentary basin (Figure 1). The sedimentary basin is classified under five major formations according to their geological formation age [14]. They are the Littoral and the Lagoon deposits, Coastal Plain sands, the Ilaro formation, the Ewekoro formation and the Abeokuta formation overlying the crystalline basement complex with their ages ranging from Recent to Cretaceous. Four of these formations, excluding Ilaro, constitute aquifers in the Dahomey Basin, from which the geological section of Lagos was drawn. The Ilaro formation is composed predominantly of shaley clay (argillaceous sediments). Limestone forms the aquifer material in the Ewekoro formation while sands and gravels constitute the materials in aquifers of the recent sediments, Coastal plain sands and Abeokuta formations which contain brackish water.

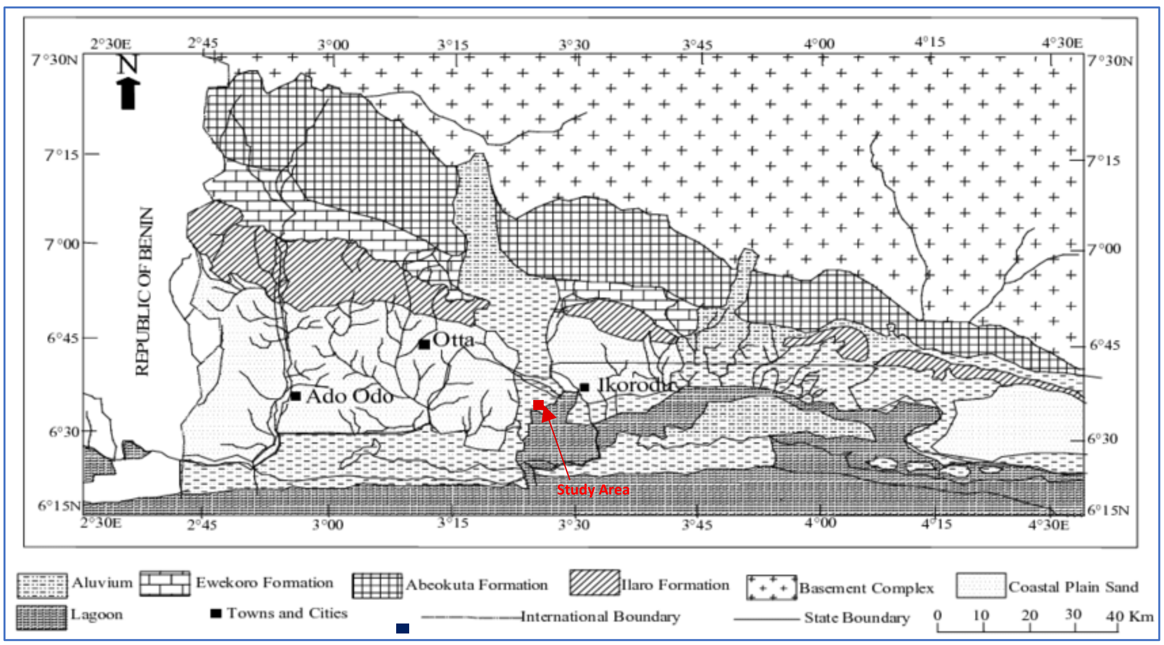


Fig. 1: Geological map of Nigeria showing the major Formations and the location of study area [12]

2.2 Data Acquisition

2D ERI data was acquired along five (5) traverses using Wenner electrode array while thirty (30) VES data was acquired along same profile via Schlumberger electrode array with current electrode spread varied from 0 - 400 m (Figure 2). The resistivity data was acquired using the Pasi Terrameter. The other accessories were four (4) electrodes, measuring tape, four reels of cables, Garmin Global Positioning

System (GPS). This was carried out to reveal the lateral and vertical variation of resistivity values of the subsurface which could help to delineate aquiferous zone for groundwater exploitation in the study area.

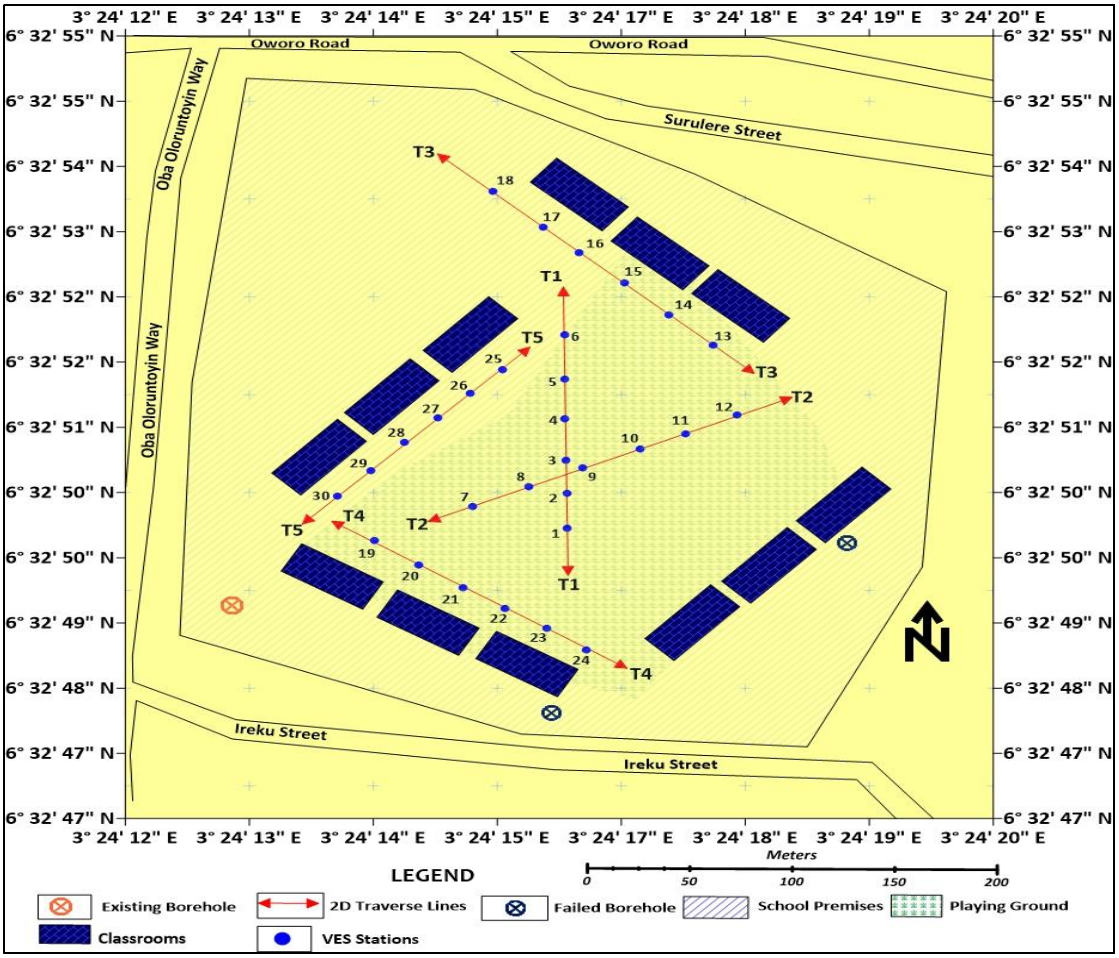


Fig. 2: Base map of the study area

2.3 Data Processing

The apparent resistivity values for Wenner and Schlumberger electrode arrays were obtained using basic equations 1 and 2

$$\Delta V = \rho a * \frac{I}{2\pi} * a \qquad (1)$$

Where a = AB (potential electrode spacing) = MN (current electrode spacing), ΔV is the potential difference and I is the current injected and π is 3.142. The obtained apparent resistivity values were inverted using the Dipro software **[15]** to generate 2D resistivity structures which were then interpreted qualitatively. The apparent resistivity (ρa) values for the VES data were computed using equation 2

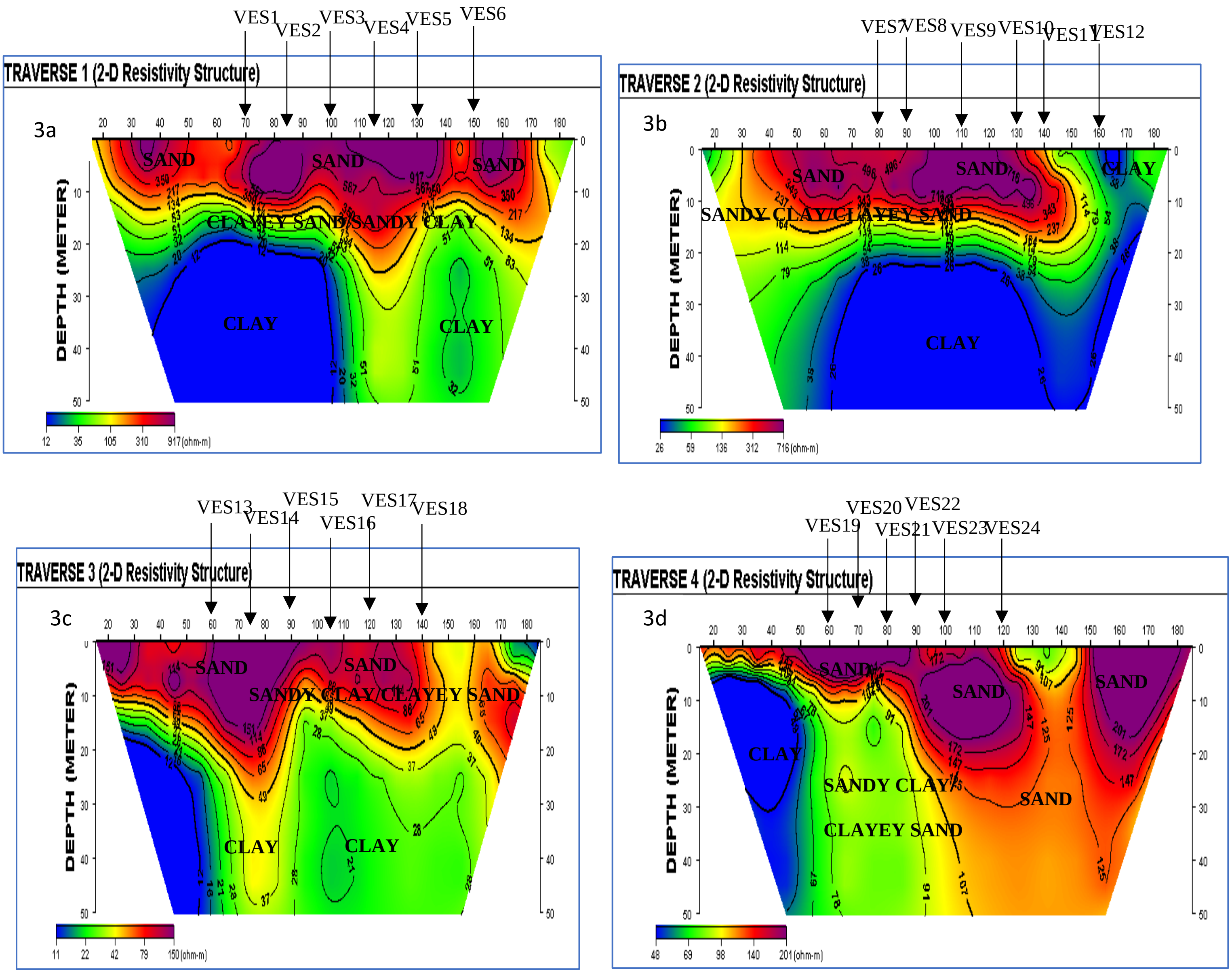
$$\rho a = \pi \left[\frac{\left(\frac{AB}{2}\right)**2 - \left(\frac{MN}{2}\right)**2}{MN}\right]\left(\frac{\Delta V}{I}\right) \quad (2)$$

Where AB is the potential electrode spacing, MN is the current electrode spacing, ΔV is the potential difference and I is the current injected and π is 3.142. The apparent resistivity data acquired were interpreted qualitatively and quantitatively. The apparent resistivity values were plotted against half of the current electrode spacing (AB/2) using transparent paper overlaid on log-log graph. The plotted field data curves were matched with standard and auxiliary curves to determine the true resistivity and thickness of successive layers. These estimated parameters were put into the Winresist software for inversion to produce true resistivity distribution [1]. The model parameters were further used to generate geo-electric sections using AutoCAD software.

3. RESULTS AND DISCUSSION

3.1 2D ELECTRICAL RESISTIVITY IMAGING (ERI)

The 2D ERI covered the spread of 200 m and probed to a depth of about 50 m, Figures 3 (a - e) is the display of the 2D sections with location of the VES points. The 2D sections across the five traverses TR (1 - 5) revealed lateral resistivity variation (12 - 917) Ωm at depth range of 0 to 20 m, delineating topsoil, clay, clayey sand/sandy clay and sand. The identified lithologies with resistivity range (12 - 83) Ωm at depth 20 to 50 m are clay and clayey sand/sandy clay. The shallow sand with resistivity values (134 - 917) Ωm was identified along TR1 at the depth of 0 to 12 m (Figure 3a) with lateral distance of 20 to 170 m, along TR 2 (Figure 3b) the sand covers lateral distance of 20 to 150 m with resistivity values (114 - 716) Ωm while at TR (3 - 5) Figures 3 (c - e) the sand delineated extended to a depth of about 50 m with resistivity values (125 - 560) Ωm. The shallow sand in this region is suspected to be the sand where most failed hand dug wells were situated. This aquifer is however suspected to be seasonal aquifer that oscillates in groundwater saturation.


VES1 VES2 VES3 VES4 VES5 VES6
TRAVERSE 1 (2-D Resistivity Structure)
3a
SAND
SAND
SAND
CLAYEY SAND/SANDY CLAY
CLAY
CLAY
DEPTH (METER)
12 35 105 310 917 (ohm-m)
VES7 VES8 VES9 VES10 VES11 VES12
TRAVERSE 2 (2-D Resistivity Structure)
3b
SAND
SAND
CLAY
SANDY CLAY/CLAYEY SAND
CLAY
DEPTH (METER)
26 59 136 312 716 (ohm-m)
VES13 VES14 VES15 VES16 VES17 VES18
TRAVERSE 3 (2-D Resistivity Structure)
3c
SAND
SAND
SANDY CLAY/CLAYEY SAND
CLAY
CLAY
DEPTH (METER)
11 22 42 79 150 (ohm-m)
VES19 VES20 VES21 VES22 VES23 VES24
TRAVERSE 4 (2-D Resistivity Structure)
3d
SAND
SAND
SAND
CLAY
SANDY CLAY/
CLAYEY SAND
SAND
DEPTH (METER)
48 69 98 140 201 (ohm-m)

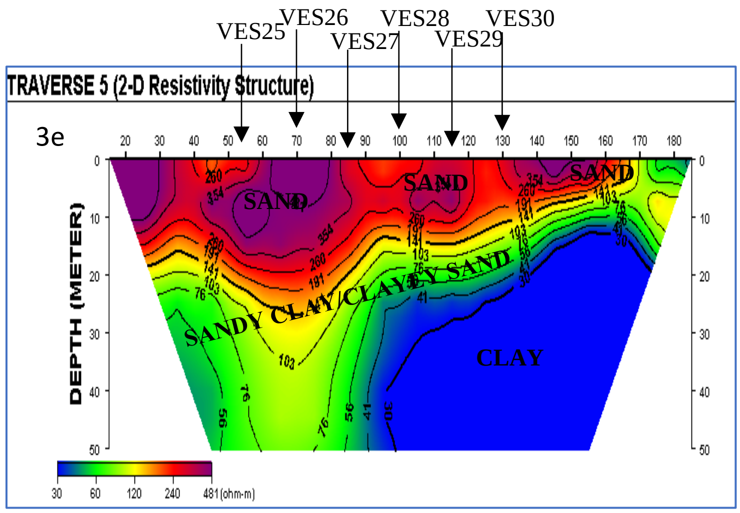


Fig. 3(a - e): 2D Electrical resistivity imaging along TR (1 - 5)

3.2 VERTICAL ELECTRICAL SOUNDING

Figures 3 (f and g) are the samples of the resistivity curves generated. Figures 3 (h - l) are the geoelectric sections for the five traverses TR (1 - 5) consisting of VES (1 - 30). The geoelectric sections revealed four to five geolectric layers which are topsoil, clay, sandy clay, clayey sand and sand.

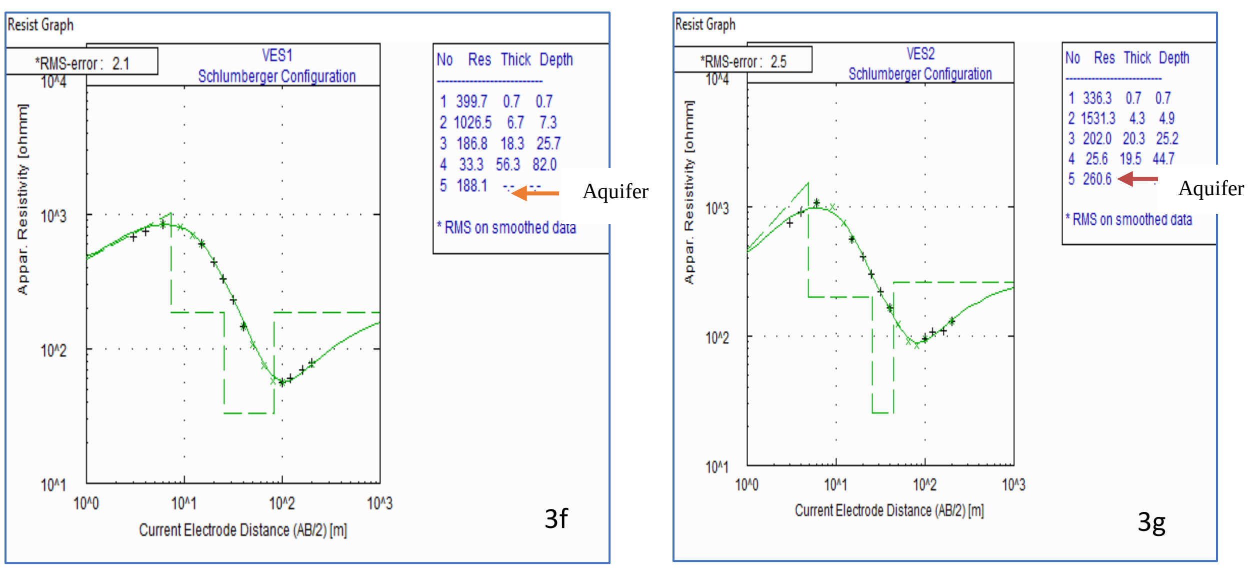
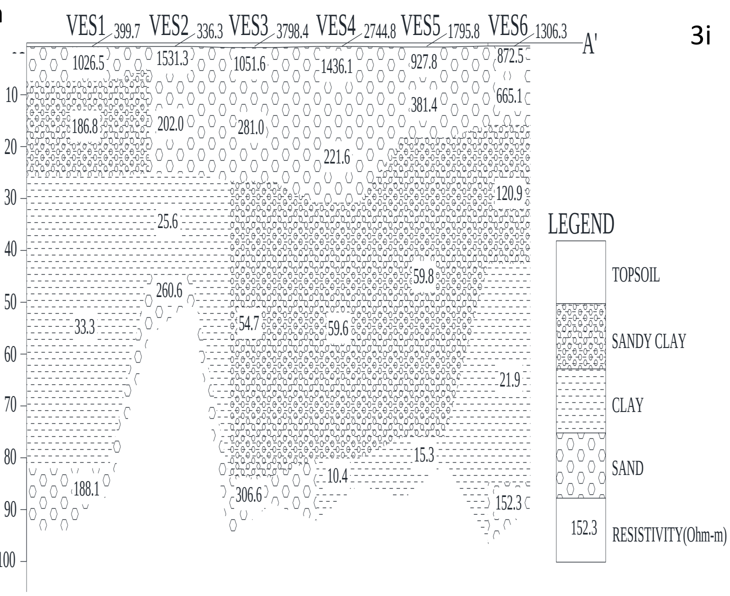


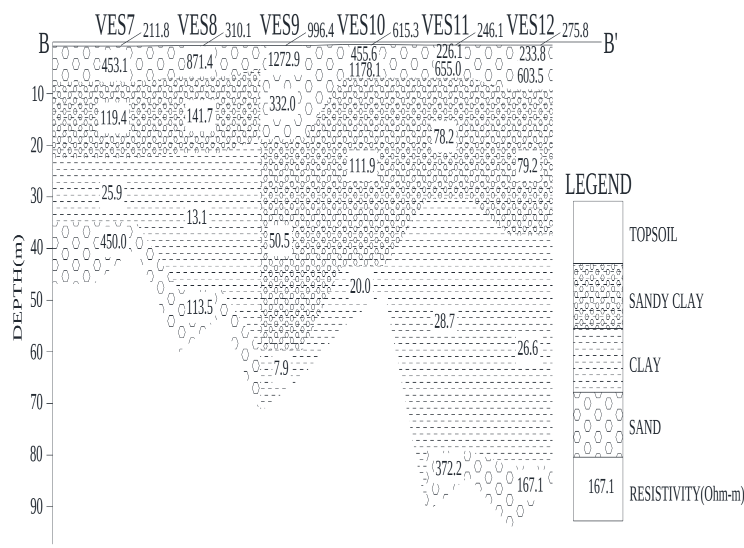
Fig. 3 (f and g): Samples of resistivity curves generated from the VES data

The topsoil is characterized by resistivity values ranging from 42.0 to 3798.4 Ωm and layer thickness of 0.7 to 0.9 m along TR (1 - 5) as displayed in Figures 3 (h – l). The identified sand in the second layer across VES (1 - 6) and at the third layer of VES (7 - 12, 14 - 18) is characterized with resistivity and thickness values ranging from 144.8 to 1531.3 Ωm and 2.3 to 9.5 m respectively. This sand (shallow aquifer) gives low yield of groundwater; the associated high resistivity is an indication of dry sand. Sandy clay is identified across VES (1, 7, 8, 10, 11, 12, 13, 16 17, 22, 24, 28, 29, 30) at the third geoelectric layer with resistivity values ranging from 50.5 to 120.9 Ωm and layer thickness of 12.0 to 22.4 m. The fourth horizon across VES (1, 2, 7, 8, 13 - 18, 19, 20, 25, 26) is indicative of clay with resistivity values ranging from 25.6 to 33.3 Ωm and layer thickness of 19.5 to 56.3 m while the clay is replaced with sandy clay in VES (3 - 6, 9 -12) with resistivity and layer thickness values ranging from 54.7 to 120.9 Ωm and 26.7 to 57.6 m respectively. The fifth layer in VES (1 - 3, 7 - 8, 13 - 15 and 25 - 27) is representative of sand with resistivity values ranging from 188.1 to 306.6 Ωm but their layer thickness could not be determined because the current terminated within this zone. The sand in this region represents the deep aquifer unit where groundwater could be tapped. However, the sand is replaced with clay in VES (4 - 6) with resistivity values ranging from 10.4 to 21.9 Ωm and with clayey sand in VES (16 - 18) with resistivity 80 - 92 Ωm. The sixth geoelectric layer beneath VES 6 is symptomatic of sand having resistivity value of 152.3 Ωm while this was replaced with clay in VES (21 - 22). The sand in this region represents an aquifer unit where groundwater could be tapped.

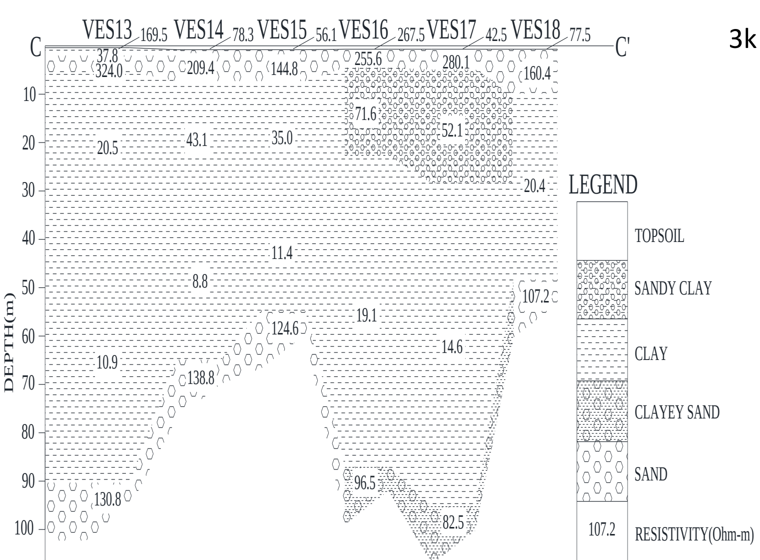
3h



3i



3j



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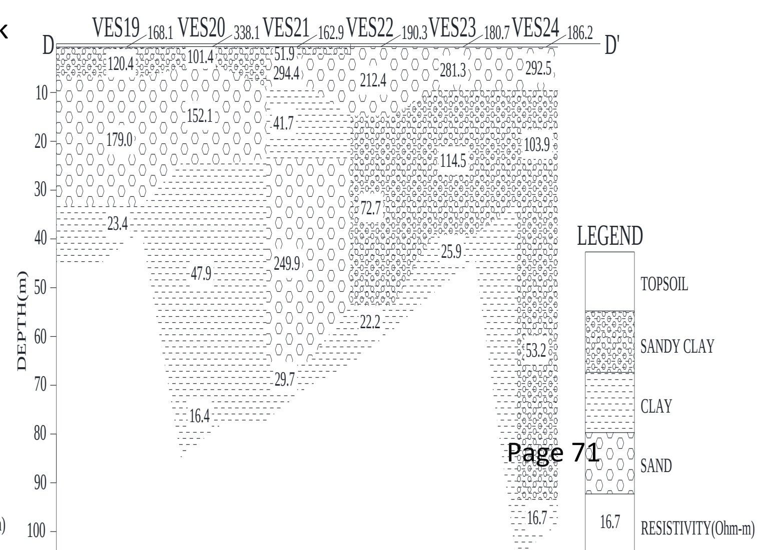
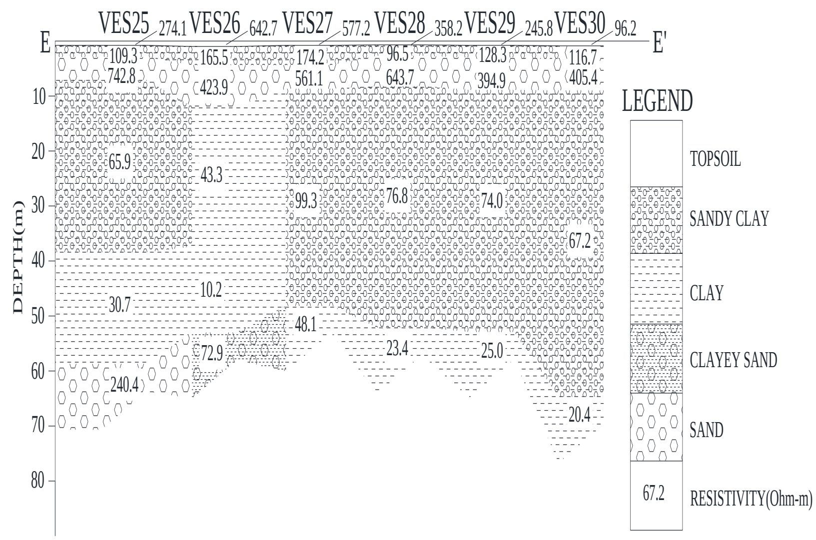


3l



Figures 3(h – l): Geoelectric sections along TR (1 - 5)

3.3 Correlation of 2D ERI and VES

The geoelectric sections across TR (1 - 5) revealed topsoil with resistivity values ranging from 42.5 to 3798.4 Ωm with depth range of 0.4 to 0.9 m, while the 2D sections delineated topsoil with resistivity values ranging from 38 to 917 Ωm with depth range of 0 to 5 m. Both results show that the topsoil is composed of clay, clayey sand, sandy clay and sand. The second layer across the geoelectric sections reflected clay, sandy clay and sand having resistivity values ranging from 37.8 to 1531.3 Ωm with depth range of 1.9 to 14.7 m which agreed with the 2D results which revealed clay, clayey sand/sandy clay and sand having resistivity values ranging from 38 to 716 Ωm at depth of 15 m. The third geoelectric layer delineated clay, sandy clay and sand having resistivity values ranging from 20.4 to 1178.1 Ωm with depth range of 5.4 to 53.7 m which also coincided with the 2D results representing clay, clayey sand/sandy clay and sand with depth range of 15 to 30 m with resistivity values ranging from 12 to 172 Ωm. The fourth geologic layer is described to consist of clay, sandy clay and sand having resistivity values ranging from 8.8 to 120.9 Ωm with depth range of 34.9 to 95.2 m which agreed with the 2D results indicating clay, clayey sand/sandy clay and sand with depth range of 35 to 50 m having resistivity values ranging from 12 to 147 Ωm. The fifth horizon across the geoelectric sections delineated clay, clayey sand and sand with resistivity values ranging from 7.9 to 450.0 Ωm with depth range of 52.8 to 90.3 m. The sixth layer across the five geoelectric sections revealed clay, clayey sand and sand having resistivity values ranging from 29.7 to 372.2 Ωm but the depth could not be determined due to current termination within this region.

4. CONCLUSION

The study revealed two aquiferous zones; the shallow aquifer with resistivity values ranging from 116.7 to 1531.3 Ωm at depth range 5 m - 20 m. This is where most of the failed hand dug wells must have been situated. The deep aquifer was delineated at depth range of 39.5 - 90.3 m with resistivity range of 107.2 to 450.0 Ωm, it represents a good aquifer where groundwater could be exploited depending on the chosen VES point. The shallow sand delineated is suspected to be seasonal aquifer that oscillates in groundwater saturation. Hence, the study recommends the deep aquifer for exploitation so as to ensure sustainable water supply within the school premises.

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COMPETING INTERESTS

The authors have no conflicts of interest to declare that are relevant to the content of this article.

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