



(RESEARCH ARTICLE)



Investigation of groundwater iron using electrical resistivity tomography in Yenagoa, Bayelsa State, Nigeria

Eniye Mienye *, Amakiri A. R.C, Tamunubereton-ari I and Amonieah J

Department of Physics, Faculty of Science, Rivers State university, Port Harcourt, Nigeria.

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Abstract

This study attempted using electrical resistivity tomography in investigating groundwater iron. A lot of studies have been conducted in the area with different approaches such as 1D resistivity and hydrogeochemical approaches which, off course, led to the adoption of this method of investigating groundwater iron. Wenner configuration was used in the field and a minimum spread of 100m was employed. The data interpretation was done with Res2divn software. The value of resistivity has a range of 14.2Ωm to 37.9Ωm in the topsoil, figure 2. Below this layer, the resistivity increased equal to 100Ω or more and a further depth to more than 296Ωm suggestive of sandy material and aquiferous layer. However, in other location figure 7, the resistivity was very high right from the topsoil with a range of 118Ωm to 498Ωm suggestive of sandy material overlying the aquifer and meaning less concentration of groundwater iron. The 2-D resistivity tomography was able to depict the variability of iron concentration within a given locality. This was identified from the high heterogeneity of the subsurface.

Keywords: Electrical Resistivity Tomography; Wenner Configuration; Hydrogeochemical Approaches; 1D Resistivity; Res2divn software

1. Introduction

In Bayelsa State over 90% of residents depend on groundwater. It is widely reported that there is prevalence of high concentration of dissolved iron in the groundwater (Okiongbo *et al*, 2019).

Similar empirical studies have been carried out in the study area (Okiongbo *et al*, 2017; 2019; Akpofure *et al*, 2019; Ogini *et al*, 2019). These studies reported that the high iron concentration is pervasive in Bayelsa State, similar to the conclusion of (Okiongbo, *et al* 2019).

Okiongbo *et al*, (2019) put serious effort in looking at the problem of iron concentration in the study area by integrating geophysical and geochemical approaches to decipher the stratigraphic layers in order to identify the controlling factors for high concentration of iron.

Geochemical study was carried out to probe into the chemical composition in ground water in parts of Yenagoa and its environs. It was opined that oxidation/reduction reactions, silicate weathering and reverse ion exchange are the controlling factors of ground water chemistry or hydrochemistry (Okiongbo *et al*, 2019)

Okiongbo *et al* (2017), carried out a study of iron concentration from the perspective of aquifer sediment colour and chemical characteristics of sediment from drilled boreholes. The colours of the sediment were being utilized to determine the concentration of iron in the study area.

* Corresponding author: Eniye Mienye

Location of low iron concentration had been shown in the study area to be underneath top thin silty sand having higher permeability and hydraulic conductivity. Finer materials above the aquifer tend to block the percolation and infiltration of oxygenated water and consequently control aquifer iron enrichment (Okiongbo *et al*, 2015).

Ganiyu *et al* (2022), from 2D electrical resistivity study carried out to pinpoint that aquiferous layer is related to geological structures of the subsurface after delineating the various layers and was of the opinion that sandy weathered layer was the aquiferous layer due to its capacity to transmit and store groundwater.

This is also peculiar to the Niger Delta Region as conducted by researchers, notable among them (Okiongbo *et al*, 2015, 2019).

The degree of saturation of groundwater can be evidenced by the study carried out (Bamidele *et al*, 2022) as conductivity was observed to be related to saturation and greater depth of penetration. In other words, greater depth penetration also means ground water saturation.

Micaela *et al*, (2021) adopted electrical resistivity to map stratigraphy and salinity of aquifer-aquitard system. They were able to establish strong correlation between resistivity and grain size in the aquifer-aquitard system where low resistivity corresponds to clay. They also observed resistivity was also a function of porewater.

From electrical resistivity tomography studies, depth of penetration of groundwater contaminants increased with time. Seasonal variation of physico-chemical parameters had high increase during dry season and reduction of Fe, Pb, Mn and others in the wet season. This increase of mineral elements in the dry season was related to evaporation and concentration of groundwater while the reduction was said to be due to dilution from rainfall (Samuel *et al*, 2018).

The hydrochemical composition of groundwater in Yenagoa and its environs correspond with specified standards for potable drinking water. That is, the ions from samples collected in the study area. The only exception is iron which exceeds the acceptable limit in some areas, (Akpofure, *et al* 2019)

All the studies are pointing out the prevalence of iron concentration in the study area.

The study would make use of electrical tomographic method in the investigation of ground water iron in the study which would give a clearer picture of the subsurface. The subsurface is made up of high heterogeneity and this is very vivid from 2 D models both from the vertical and horizontal direction in the subsurface.

1.1. Location and Geological Setting of The Study Area

Yenagoa is the state capital of Bayelsa State (fig 1). The state is surrounded by creeks, rivers and streams which make the state to be influenced by the issues of seasonal flooding. The state is located in the coastal plain area of the recent Niger Delta. At the extreme south of the state is the Atlantic Ocean which is the outlet of discharge of the surrounding water. The area has the characteristics of flat topography and moderate undulation in some areas. The elevation range is between 6m and 10m above sea level. Yenagoa is located in the rainforest region characterized by seasonal rainfall of wet and dry season. The wet season starts from march to october with a short dry period in august. The dry season has a period of four months from november to march. The range of temperature is 25⁰ -32⁰c. Mean annual rainfall could be considered to be 300mm and about 85% drops in the wet season. Rainfall is the most important source of groundwater supply in the area. In the dry season, hamattan wind is noticed which is dry, dusty and cold while southern winds are noted in the wet season.

The geology of the Niger Delta comprises of Quaternary deposits on thick tertiary sandy and clayey deltaic deposits. Three lithologies were noted in the Niger Delta from top to bottom as Akata, Agbada and Benin form (Okiongbo, 2015).

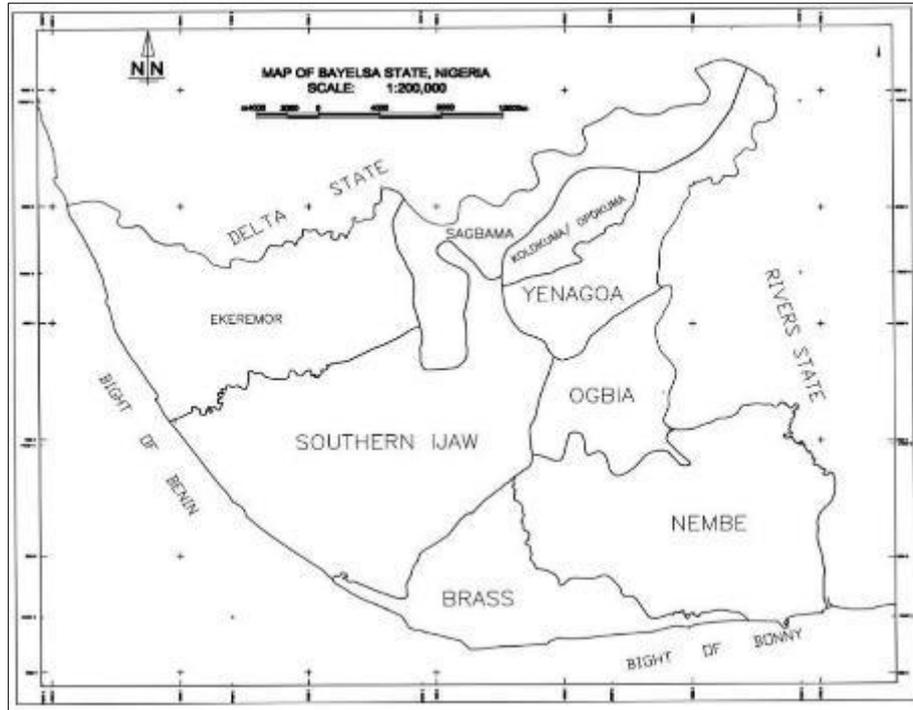


Figure 1 Map of Bayelsa State showing the study Area (Yenagoa)

2. Materials and Methods

Data acquisition was made by means of a resistivity meter called Hero Jat. Four stainless steel electrodes were used made up of two potential electrodes and two current electrodes. The equipment was made up of two connections for current electrodes namely c1 and c2. There were also two connections for potential electrodes. 2-D resistivity imaging technique was used in the study area. The 2-D imaging was done manually by using Wenner configuration. In this paper, each measurement was five metres for $n=1$ up to $n=6$. This means that the measurement profile length was done six times from $n=1$ to $n=6$. The profile length was taken to be 100 metres. The spacing of the electrodes in the first set of measurements was 5m. The electrodes were positioned 1,2,3,4 as c1, p1, p2, c2 respectively. For the second set of measurements, the first electrode which was c1 would occupy position 2 and the electrodes would be in the order 2,3,4,5 and this process was continued till c2 occupied the last position which is, in this case, the position of 100m. The measurement continued after getting to the 100m and the next sets of measurements started at 1 which is c1 but the spacing of the electrodes was 5 multiplied by 2. In this situation, the electrode spacing would be 10m while the movement of the electrodes would still be maintained at 5m. These measurements were done to get to 100m position after which the electrode spacing would start at 15m spacing while the movements of the electrodes would still be maintained at 5m. In this case, 3 is multiplied by 5 (15m electrode spacing) and the process continued to the end of the profile.

2.1. Ground Truthing

At the time of carrying out this study, one borehole was drilled in order to gain access to lithological and stratigraphic information. Ground truthing was obtained at other locations from previous studies conducted close to the locations of this study. Physicochemical information was also obtained from previous study which ultimately served as a guide in the process of interpretation of the tomograms. In essence interpretation was based on correlation between what was observed in the tomograms and those of other studies in terms of stratigraphy and geochemical parameters (in this case ground water iron).

2.2. Data Processing

Data processing was dependent on computer software. The resistance values were computed to apparent resistivities using geometric factor. Since wenner configurations was used its geometric factor is $k= 2\pi aR$ where a = electrodes spacing and R =resistance.

The formula $\rho_a = kR$ was used in obtaining the apparent resistivity. The resistivity values and other parameters were utilized in getting the true resistivity from the computer software. The computer made use of the information given in it to carry out inversion processes by means of the observed model with that of the reference model iteratively until the residual was within acceptable limit.

3. Results and discussion

The resistivity values increase with increase in depth from figure 2. If there is (from VES results carried out in the study area) an increase in resistivity going deeper into the subsurface and the increase gets to a maximum before reducing, it is a pointer to the fact that the area is of less concentration of iron. This observation has been utilized in the interpretation of the 2D results. From borehole information around the surveyed area, the topsoil is made up of sand material and going down the soil material becomes coarser. the concentration of iron is not impactful. Tomographic information is pointing to less concentration of iron supported by bore hole information got close to the site of investigation from figure 2. This interpretation is obtained from the lithological arrangement of the soil material as confirmed by previous study done in the area (okiongbo et al, 2019).The subsurface is predominantly made up of coarser material.

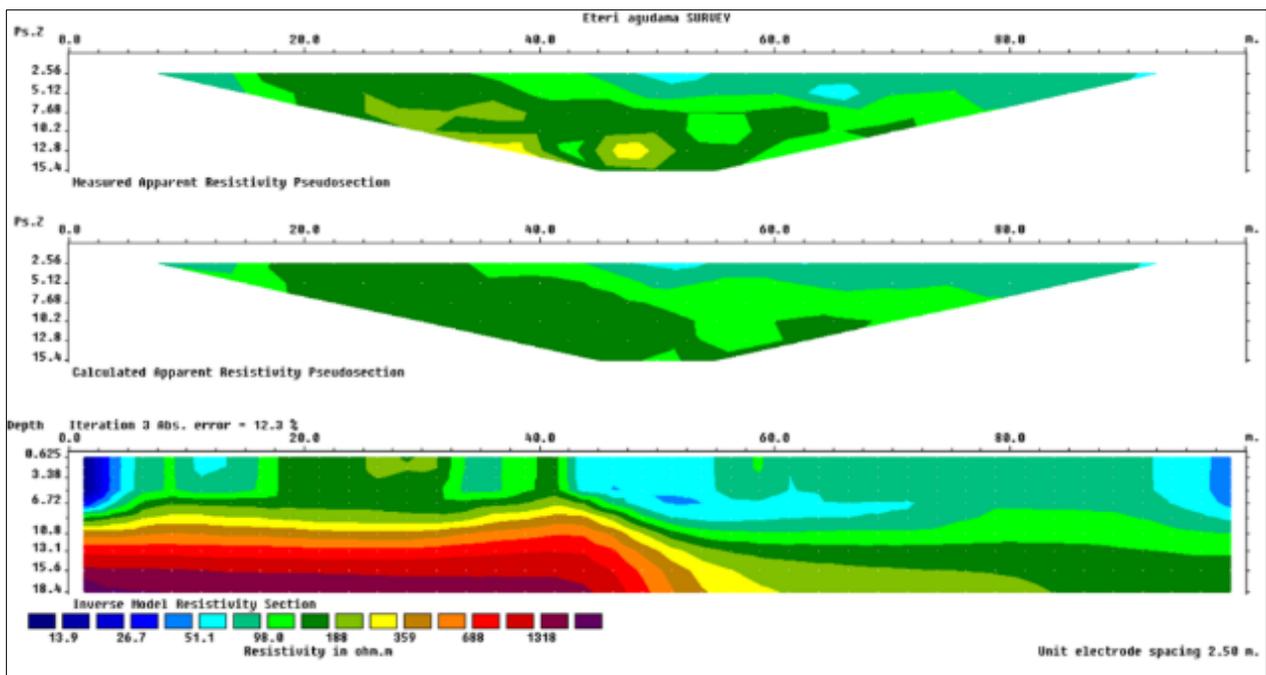


Figure 2 Eteri Agudama

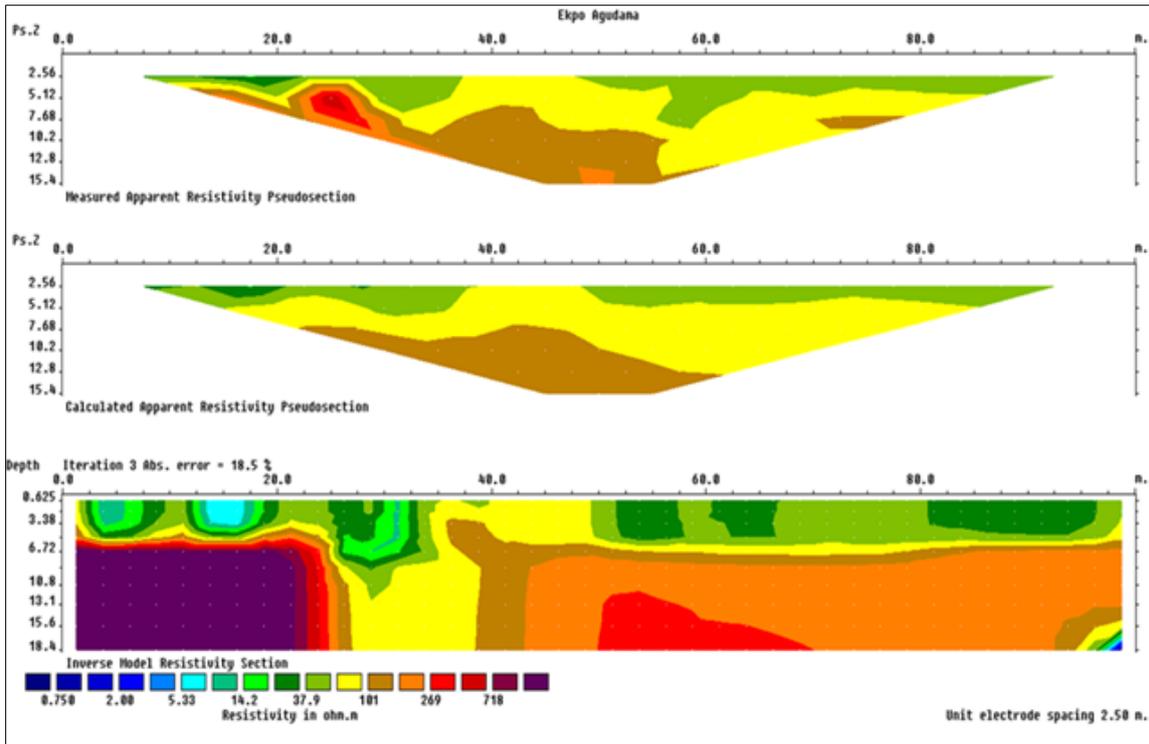


Figure 3 Ekpo Agudama

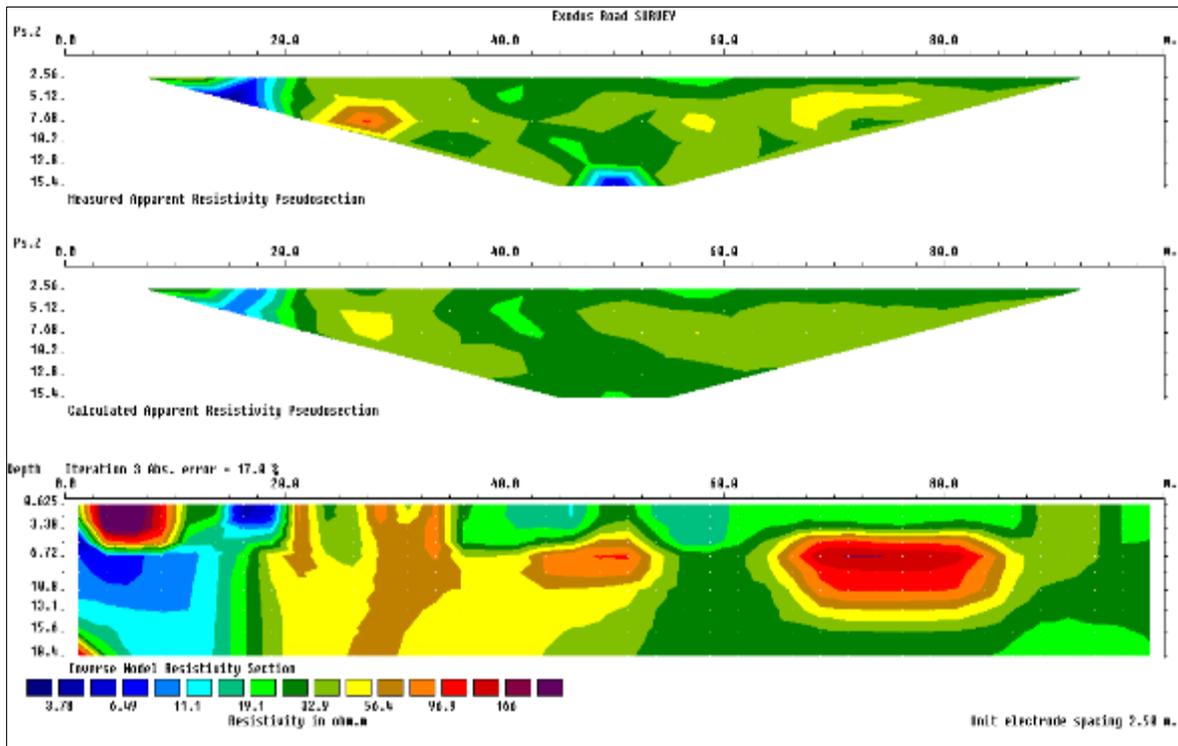


Figure 4 Exodus Road Edepie

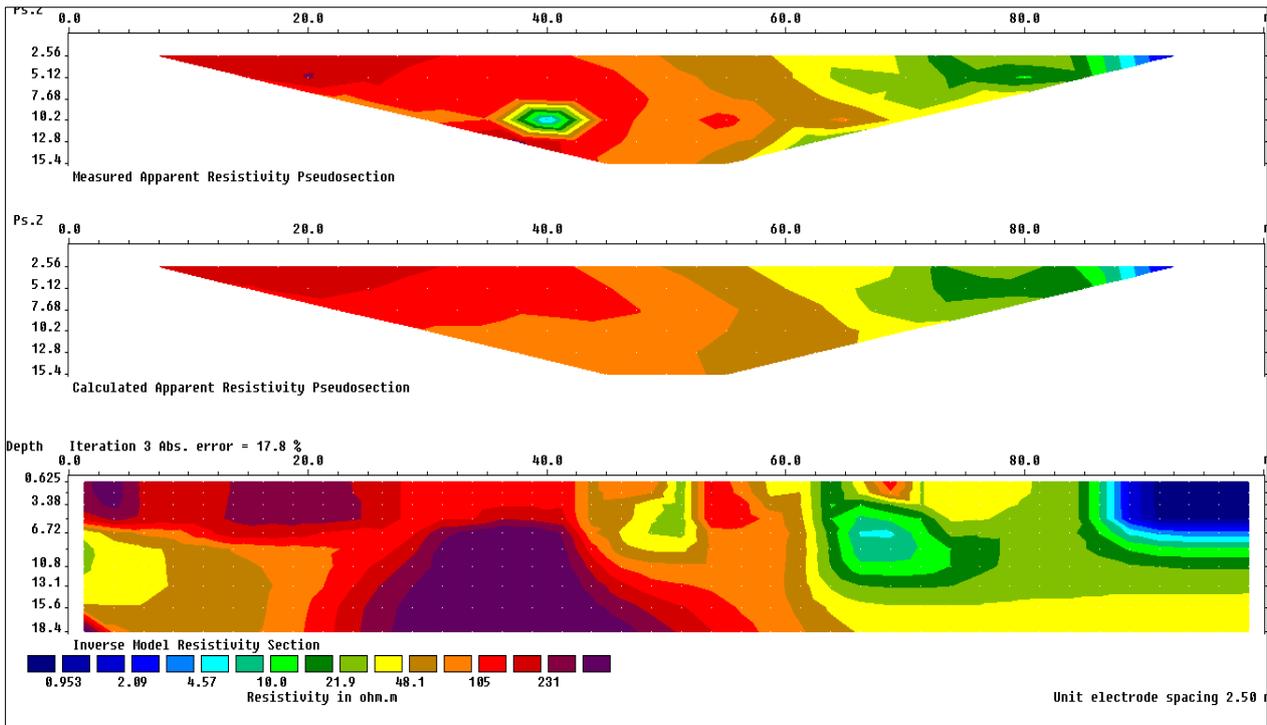


Figure 5 Elebele Road

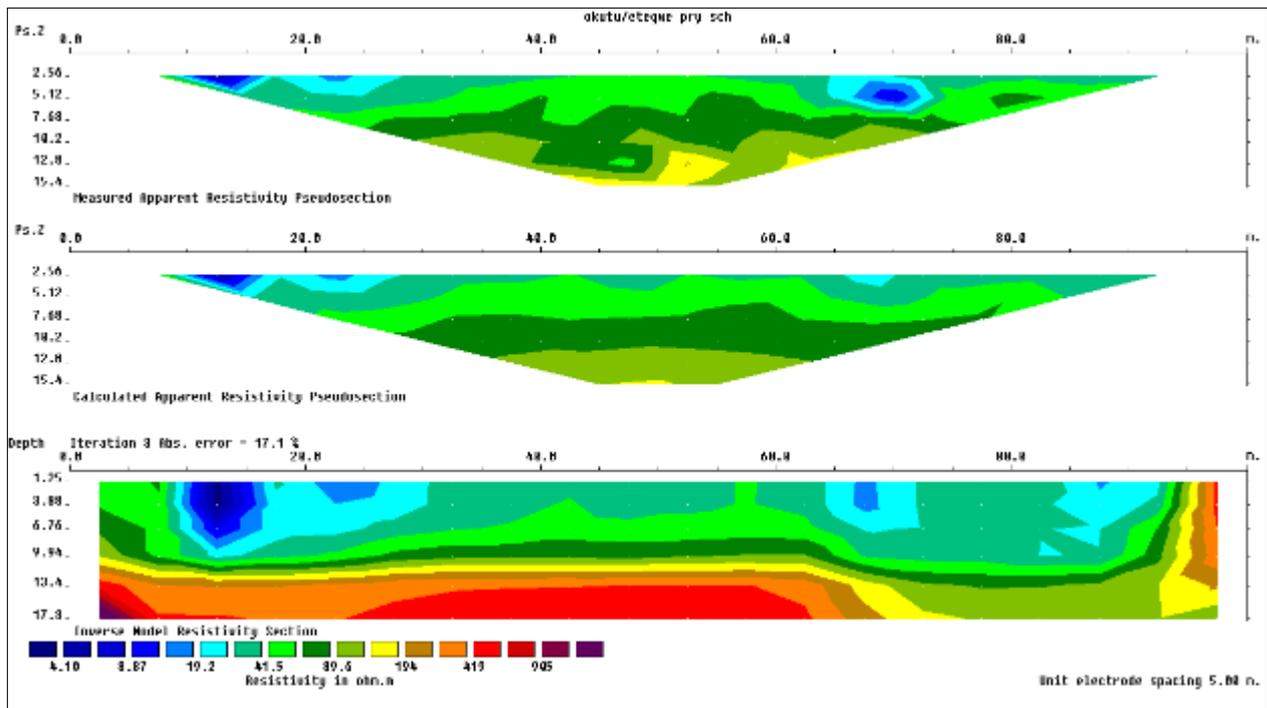


Figure 6 Okutukutu/Etege primary school

At a depth range of 15.6m to 18.4 from the distance 0m to 60m of the survey profile the values of resistivity are very high suggestive of very coarser material.

At a distance range 0m to about 25m on the survey profile from figure 3, the resistivity values increase with depth. The top soil has resistivity range of 14.2Ωm to 37.9Ωm. The value of resistivity below increases suggestive of sand greater

or equal to $101\Omega\text{m}$. The values of resistivity also increase going deeper into the subsurface suggestive of coarser material or greater degree of compaction and the resistivity range is $269\Omega\text{m}$ to $718\Omega\text{m}$. It is expected that the iron concentration is low. This can also be seen around boreholes drilled close to the site of investigation. From a distance of 40m to 50m range in the survey profile, the pattern of resistivity takes a different outlook, the resistivity also increases with depth. However, the material might not be as coarse as the previous area as seen in figure 2. The aquifer is from 10m below supported by information got from drilled boreholes close to the site of investigation. The treatment of iron concentration should be less rigorous.

From figure 4, between 0m and about 12.5m on the survey profile, the values of resistivity decrease with depth and the value begins to rise at depth of 15.6m. The depth to the aquifer is slightly spotted at 18.4m depth. the top layers of soil are dominated by clay and a reason why the iron content is more from evidence got from a bore hole drilled close to the site. The whole top layers are predominantly dominated by clay suggestive of higher concentration of iron content. This information is supported by a borehole close the site of investigation.

From figure 5, top layers are dominated by clay. This is seen from very low resistivity values. The water content is expected not to be as good as in figure 2 and 3. The depth to the aquifer is estimated to be at depth below 18.4m. The depth to the aquifer might be less than this value taking a view at a profile distance of 20 to 40m.

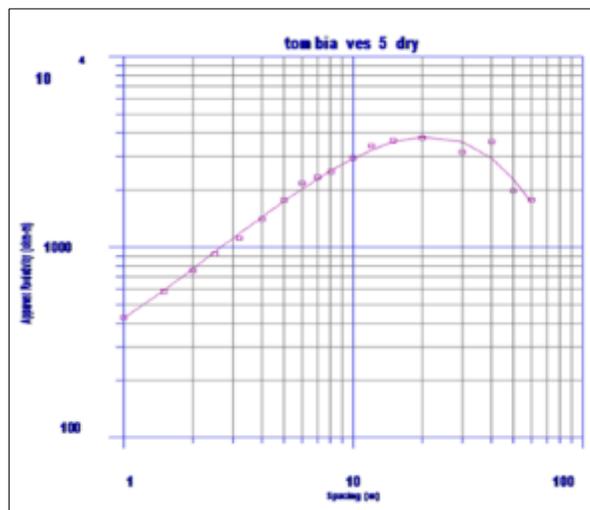
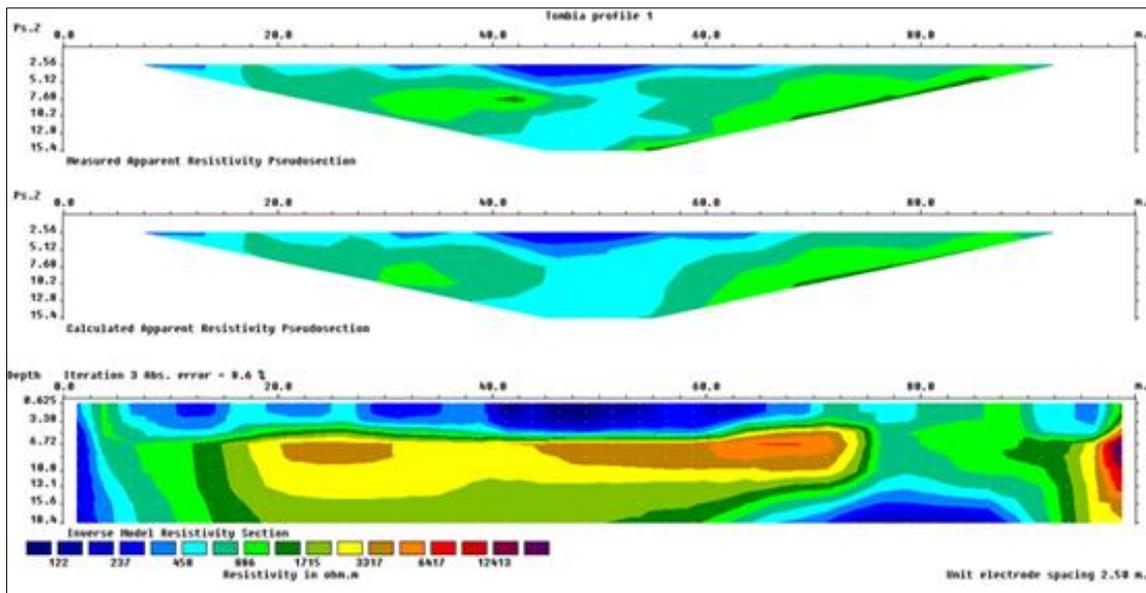


Figure 7 Tombia

Table 1 Tombia (VES)

Resistivity	thickness	Depth	Error
274.82	0.65103	0.65103	3.3706
5452.1	0.86284	1.5139	
16179	5.3065	6.8193	
403.68			

It is evident from figure 7 that iron concentration is minimal in this location due to the lithological/stratigraphic arrangement of earth material. The top soil is observed to be made up of sandy material and the aquifer is underlain by it. The resistivity values increase with depth. The depth to the aquifer is about 7 to 8 meters deep. The resistivity becomes very high at greater depth which could be indicative of more stony material.

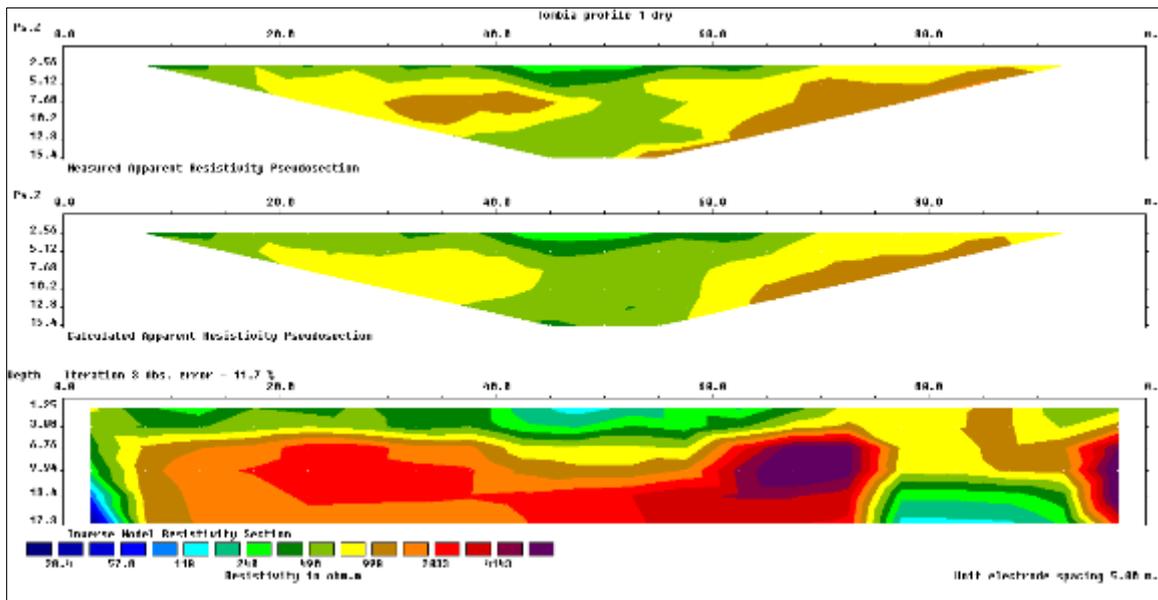


Figure 8 Tombia 1 dry

In the area (Tombia Town) figure 8, the iron concentration is observed to be low and following the pattern of k-curve, the resistivity values tend to increase with depth. It is expected that the nature of the water at the start of the profile would have to be similar to other areas in this location. From the topsoil, there is sandy material meaning less concentration of iron.

4. Conclusion

The level of iron concentration is variable even within the same location. This could be due to high heterogeneity of the subsurface as seen from the 2D survey. In the area where the iron is less concentrated, the depth to the aquifer is less and this interpretation is considered within these study areas. It is expected to carry out 2D resistivity survey because it is possible to easily detect perched aquifer which could dry up with time. This kind of survey could easily give the right spot to drill in order to get iron free or less concentration of iron within a given locality. The 2 D survey has the capacity to represent pictorially the subsurface heterogeneity. The topsoil, clay soil, sandy soil, gravels and others are vividly seen in the results of 2D survey. Despite the cost and rigour that are involved in the survey, it is still advisable for more of its use in carrying out groundwater study.

Recommendation

It is recommended that there should be continuous geophysical and hydrogeophysical study in the area because of environmental changes which could be majorly due to anthropogenic factors. Geophysical measurement be carried out for every drilling activities of groundwater to ensure that good quality water is got, high groundwater potential is

accessed, to avoid incessant drilling effort at a given location and a host of other factors. The government should pay more attention to groundwater as the major source of potable water in the State.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict-of-interest to be disclosed.

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