

Geoelectrical Evaluation of Groundwater Occurrence in Anwai, Delta State, Nigeria

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Abstract
The purpose of carrying out this survey is to determine the groundwater occurrence in Anwai, Nigeria. Eight geoelectric soundings were conducted using the Schlumberger configuration. The data obtained were interpreted using two layer model. The result revealed the presence of five geoelectric layers made up of topsoil laterite, clay-clayey sand, fine-medium grain sand, coarse sand, medium coarse sand and very coarse sand. The fifth layer with a depth range of 33.4 to 47.2 m and resistivity range of between 1512 and 3294 Ωm is identified as the aquifer layer from which groundwater can be sourced. It is deduced from this survey that groundwater development is viable in the area.
Keywords: Groundwater, Geoelectric, Aquifer, Electrical Resistivity, Schlumberger Configuration

1. Introduction

Groundwater is the most widely valuable natural resources in the world. It is known to occur within the earth sediments, rocks or sand formation. The occurrence and distribution of this natural resource are restricted to some geological formations and structures called aquifers. An aquifer is explained as a subsurface formation which is capable of storing and transmitting water at a pace fast enough to provide sufficient quantity to wells (Fetter, 2007). The presence of water in a formation does not in any way imply that the water quality is good enough for domestic consumption. However, groundwater that occurs in formations which are properly sealed by a non porous formation is known to provide good quality water (Todd, 2004).

Sometimes a confining layer of less porous rock might occur above and below the aquifer layer. When this happens, the aquifer is referred to as a confined aquifer. In such a situation, the rocks surrounding the aquifer confine the pressure in the porous rock and its water. The pressure inside the aquifer might just be enough to move the water to the surface if a borehole is sank into the aquifer. When this occurs, the well is called an artesian (Todd, 2004).

The depth to the groundwater aquifer varies and sometimes could be as deep as 50m and above. Therefore, exploring this resource requires proper planning and technique. Some of the techniques that have been used to source groundwater includes aerial, surface, subsurface and esoteric (Fetter, 2007). The most common procedures are the surface and subsurface methods (Anomohanran, 2014). The surface methods are made up of geophysical, geological, geomorphological, hydrogeological, geobotanical and geochemical methods.

The role of geophysical method particularly the electrical techniques in the exploration of groundwater has been widely acclaimed as being the most common and time tested technique (Anomohanran, 2013). It involves investigating the electrical fields of the earth formation generated by nature or artificially using an external power source. The intensity of the electric fields depends on the origin, the electrical properties and the geological construction of the area. The electrical properties vary in response to the lithology, presence of water and the quality of the water (Nwosu et al., 2013).

It is important to have good enough information that will enable the drilling of successful wells that will not dry up during certain period of the year and that will not yield poor quality water. This is why this study is carried out to determine the potential water bearing formation. This will help the people in the area to assess quality water from the groundwater resource.

2. Theory

If we consider the surface of the earth to be a uniform half space with a source electrode supplying current to the ground (Fig. 1), it will be observed that the electric field lines will spread radially outward (Lowrie, 2004). If the current flowing through the electrode is I and r the radius of the hemisphere, then the current density J is the current divided by the surface area. Hence the electric field E, according to ohms law is given as

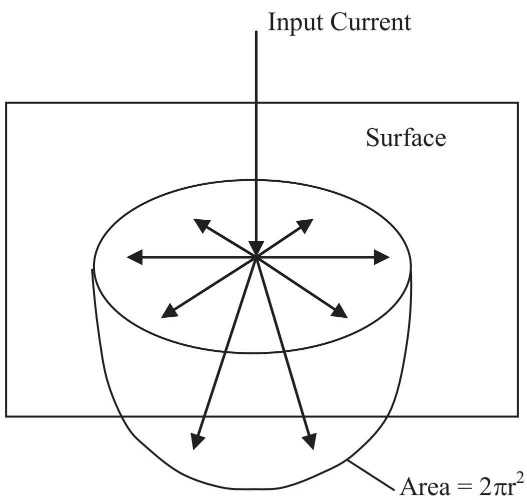

Fig. 1: Electric Field Lines around a Single Electrode

$$E = \rho J = \rho \frac{I}{2\pi r} \qquad (1)$$

where
ρ = Resistivity of the medium
The electric potential U at distance r is obtained as

$$\frac{dU}{dr} = -\rho \frac{I}{2\pi r^2} \qquad (2)$$

Therefore,

$$U = \rho \frac{I}{2\pi r} \qquad (3)$$

For an arrangement consisting of two current electrodes as shown in Fig. 2, the potential due to C is

$$U_c = \frac{\rho I}{2\pi}\left[\frac{1}{r_{AC}} - \frac{1}{r_{CB}}\right] \qquad (4)$$

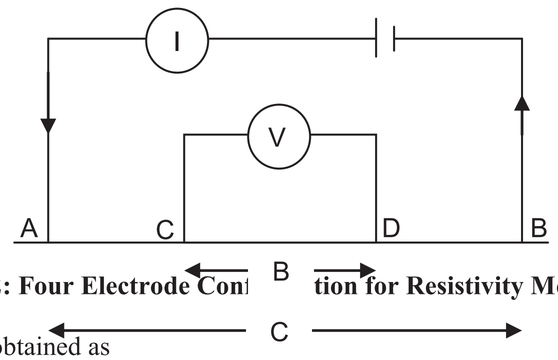

Fig. 2: Four Electrode Conf tion for Resistivity Measurement

while the potential at D is obtained as

$$U_D = \frac{\rho I}{2\pi}\left[\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right] \qquad (5)$$

The potential difference (V) between the points C and D is obtained as

$$V = \frac{\rho I}{2\pi}\left[\left(\frac{1}{r_{AC}} - \frac{1}{r_{CD}}\right) - \left(\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right)\right] \qquad (6)$$

Therefore,

$$\rho = \frac{2\pi V}{I}\left[\frac{1}{\left(\frac{1}{r_{AC}} - \frac{1}{r_{CD}}\right) - \left(\frac{1}{r_{AD}} - \frac{1}{r_{DB}}\right)}\right] \qquad (7)$$

Considering a Wenner electrode arrangement in which the distance AC = CD = DB = a, we have the apparent resistivity as

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$$\rho_a = \frac{2\pi V a}{I} \quad (8)$$

However, for a Schlumberger arrangement in which distance between AB = L, CD = a and AC = DB ≠ CD, the apparent resistivity is obtained as

$$\rho_a = \frac{\pi V}{4I}\left(\frac{L^2 - a^2}{a}\right) \quad (9)$$

3. Materials and Methods

3.1 Location and Geology of the Study Area.

The study was carried out in Anwai located within longitude 6.65° and 6.72° N and latitude 6.18° and 6.25° E (Fig. 3). The landscape of the area is rough and dominated by alternating hills and valleys. It has steady rainfall which occurs between the months of April and October. It is situated on the Ogwashi-Asaba formation (Ogala et al., 2012). The area is generally made up of an older terrace alluvium. This terrace alluvium is an elongated strip that borders the River Niger west bank. The upper horizon of the underlying Ogwashi-Asaba formation and the terrace alluvium are classified as the water bearing horizon which have been exploited extensively to obtain potable water supply (Akpoborie et al., 2011; Chinyem, 2013).

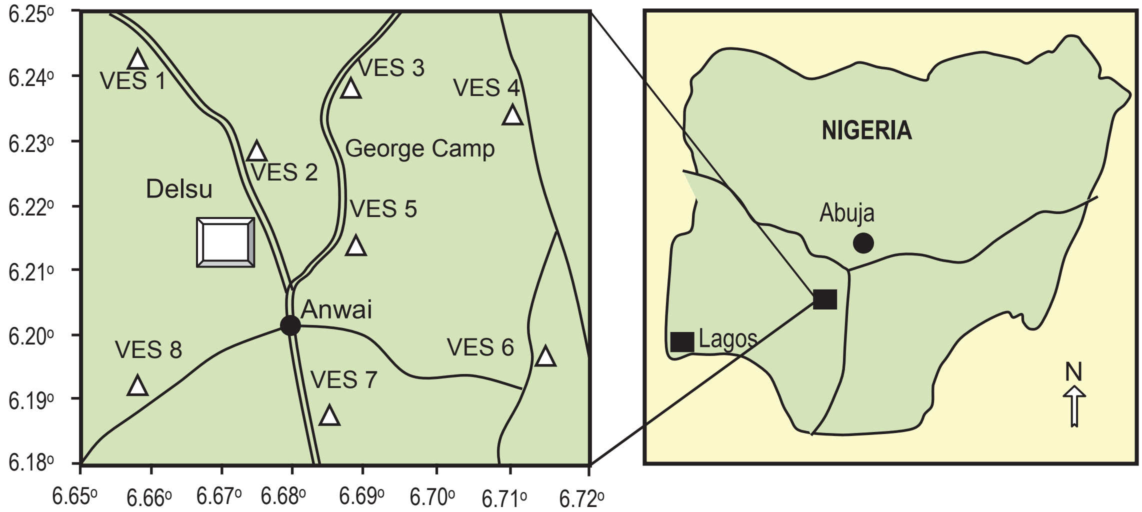

Fig. 3: Location Map Showing the Sounding positions

3.2 Field Survey

This work was done using the electrical sounding method with the vertical electrical sounding as the field process. This is because the study area suits the use of this method and it is reckoned to be convenient. An ABEM SAS 1000 Terrameter was used. The Schlumberger configuration was adopted using a current electrode separation of 300 m. A reference point was first marked from which all measurements were made. Two current electrodes were each inserted into the ground at a distance of 1 m on either side of the reference point. The potential electrodes were also inserted at a distance of 0.5 m each from the reference point. The electrodes were connected using various cables to the appropriate terminals of a terrameter. The current was induced into the ground and the potential obtained. The current electrode was then increased in steps each time and potential generated determined. At a time when the current spread is considered too wide to impact on the potential electrode, the potential electrode was increased. The apparent resistivity was determined and was plotted against half electrode separation. The data obtained was interpreted first by partial curve matching and later by computer iteration procedure using the Resist software to determine the depth and the resistivity of the various formations encountered.

4. Results

The result of the interpreted field data is presented as shown in Figs. 4 and 5. Figure 4 represent the resistivity of the various formations while Fig. 5 shows the depth of the formations from the surface. The result of the geoelectric interpretation was compared with the generalized lithologic log from the area and the result presented as shown in Fig. 6. The contour map showing the depth to the top of the aquifer layer is as shown in Fig. 7 while the resistivity of the aquifer layer is presented as shown in Fig. 8.

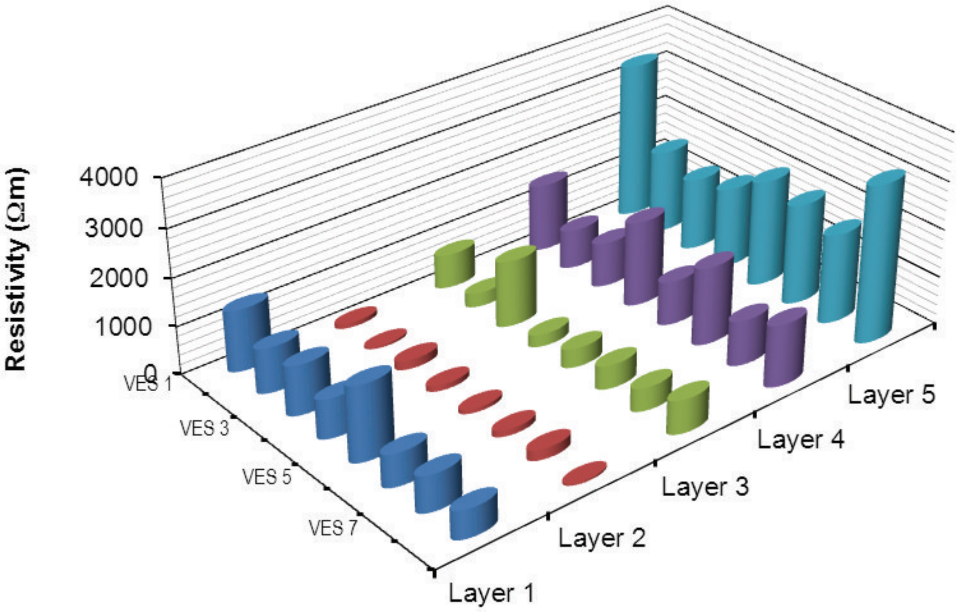

Fig. 4: Result of the geophysical interpretation showing the resistivity values of the various layers

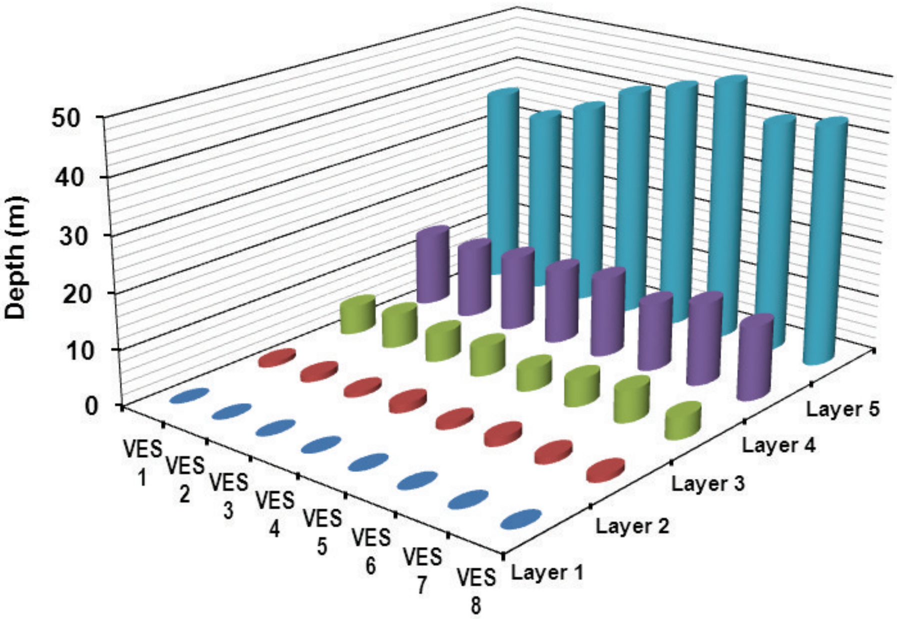

Fig. 5: Result of the geophysical interpretation showing the depth of the various layers from the surface

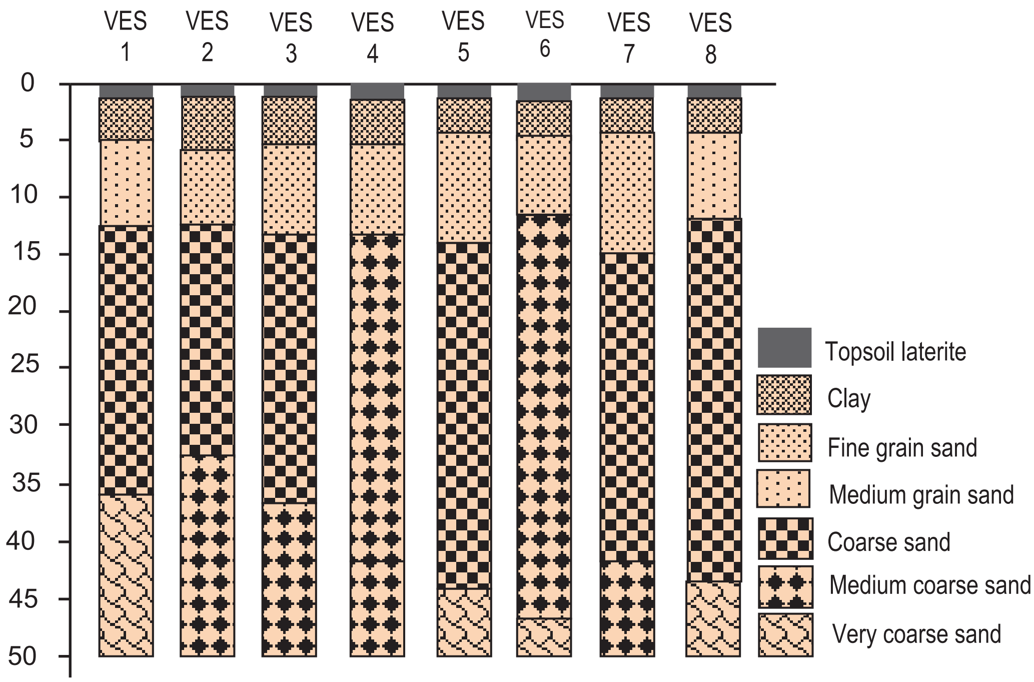

Fig. 6: Geoelectric profile of the survey area showing a five layer model

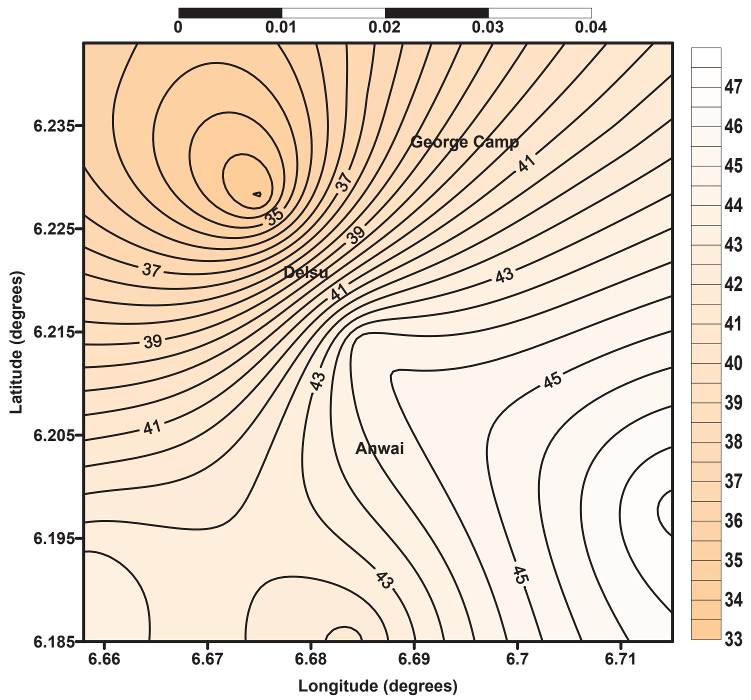

Fig. 7: Contour map showing the depth from the surface to the aquifer layer

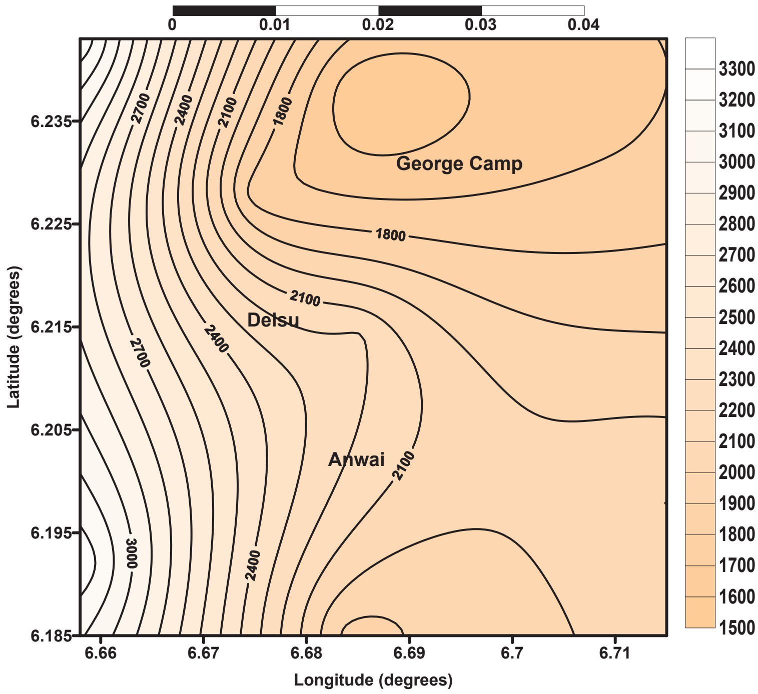

Fig. 8: Contour map showing the resistivity values of the aquifer layer

5. Discussion

The interpreted result as shown in Figs. 4 and 5 were analyzed and the outcome shown in fig. 6. Figure 6 reveals that five geoelectric formations exist in the survey area. The identified formations are topsoil laterite, clay-clayey sand, fine sand, medium coarse sand, coarse sand and very coarse sand.

The result shows that the first layer is made of topsoil laterite with resistivity which spread from 581 Ωm in VES 8 to 1558 Ωm in VES 5. The thickness of this layer falls in the range of 0.9 and 1.6 m. This topsoil lateritic formation is underlain by a fairly impermeable formation made of clay, sandy clay and clayey sand. The resistivity of this formation ranges between 44 Ωm in VES 8 and 215 Ωm in VES 7. The thickness range between 2.9 m in VES 7 and 5.0 m in VES 2. This stratum is very essential to the groundwater aquifer as it constitutes a confining bed preventing the down flow of contaminant into the groundwater table.

The third formation according to the result is made up of fine grain sand in VES 2-7 while it is medium grain sand in VES 1 and 8. The resistivity of this layer range between 254 and 712 Ωm, while the thickness range is between 6.8 and 10.4 m. This layer is a wet formation, but the pore space is considered too small to accommodate adequate quantity of underground water.

The fourth layer is composed of coarse sand in VES 1, 2, 3, 5, 7 and 8 while it is medium coarse sand in VES 4 and 6. The resistivity range between 816 and 1771 Ωm while the thickness ranged between 20.4 and 34.9 m. The result shows that the pore space in this layer is capable of holding more water than the layer above it. The fifth layer is composed of medium coarse sand in VES 2, 3, 4 and 7 while it is very coarse sand in VES 1, 5, 6 and 8. The resistivity range between 1512 and 3294 Ωm while the depth to this layer range between 33.4 and 47.2 m. This layer is considered the best formation to source groundwater as it is more prolific and the water from this layer is expected to be of better quality than the layers above it.

The depth contour map as shown in Fig. 7 indicates that the aquifer deepens towards the south eastern portion of the survey area. With this depth map, the era of drilling failed well is over in the area. The resistivity contour map of the fifth layer aquifer as shown in Fig. 8 can help identify areas of the survey that can yield more groundwater. In the event that a public water scheme is considered for the area, the southwestern area will be the site of choice.

6. Conclusion

This study to investigate the groundwater occurrence in the area has been carried out using the vertical electrical sounding method and employing the Schlumberger configuration. The results of interpretation delineated five layers consisting of topsoil laterite, clay-clayey sand, fine-medium grain sand, coarse sand, medium coarse sand and very coarse sand. The fifth layer was identified as the aquifer layer suitable to source good and prolific groundwater in the area. The depth range of this aquifer layer lies between 33.4 and 47.2 m while the resistivity range between 1512 and 3294 Ωm. It is recommended that boreholes to supply potable water for domestic use should be sourced from the depth in excess of 33.4 m while boreholes for public water scheme should be sited in the southwestern part of the survey area.

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