APPLICATION OF 2-DIMENSIONAL TOMOGRAPHY FOR SUBSURFACE LITHOLOGY IMAGING AND AQUIFER DETERMINATION IN ETIM EKPO, SOUTHERN NIGERIA.

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**UMOH, E. E.[1] AKANKPO A. O.[1] UMOREN, E. B.[1]
ATAT, J. G.[1] AND ADENIRAN, A. O.[*1]**
Department of Physics, University of Uyo, Nigeria.
*Correspondence: *adeniranadebayo@uniuyo.edu.ng*

ABSTRACT

In recent times, surface water has been seen not to be a good source of domestic water because of impurities from physical, biological and chemical contaminants. The use of geophysical techniques for groundwater exploration and water quality evaluations has increased over the past few years due to the rapid advances in computer software and associated numerical modeling solutions. A 2D electrical resistivity tomographic method was adopted in this study using the Werner electrode arrangement in determining the variation of subsurface resistivity distribution in Etim Ekpo, southern Nigeria. Ten soundings were carried out in the area. The RES2DINV software was used to transform the measured ERT data to an approximate picture of the subsurface resistivity distribution and geometry of the subsurface features. The resistivity values in the area for layer 1(topsoil) range from 34.60 Ωm to 2311Ωm while the thickness ranges from 0 to 12 m. For layer 2 (lateritic sand), the resistivity values range from 213 Ωm to 3982 Ωm while the thickness ranges from 5 to 20 m. The resistivity values in the area for layer 3(coarse-grained sand) range from 1237 Ωm to 6964 Ωm while the thickness ranges from 17 to 57 m. Three geo-electric layers were delineated (topsoil, lateritic sand and coarse-grained sand). This study shows that the groundwater potential within the area is of economic volume.

KEYWORDS: layers, groundwater, electrical resistivity tomography, soil.

INTRODUCTION

Water, an essential element is most needed by man for daily living ((Falowo *et.al*., 2016). In view of this important role played by water in man's survival, the government of Nigeria has made a good number of investments in ensuring that there is availability of good water for Nigerians. In spite of this considerable effort, large population of Nigerians still do not have access to good domestic water. According to the national water supply policy, 2000, it is estimated that only 48% of those living in the urban and semi-urban areas of Nigeria and 39% of those living in the rural areas have access to portable water supply. Most of the people living in the rural areas depend on surface water as their source of domestic water supply (Akpan *et al*., 2007).

In recent times, surface water has been seen not to be a good source of domestic water because of impurities from physical, biological and chemical contaminants (Okorie *et al*., 2020). Groundwater defined as fresh water (from rain, melting of ice and snow) that soaks into the soil is stored between pore-spaces, fractures and joints found within rocks and other geological formations (Salako and Adepelumi, 2018). It is an important natural commodity that is needed for domestic, agricultural and industrial use and its suitability is of great worry for its sustainability and efficient use (Ibuot *et al*., 2019). The characteristics of groundwater is determined by the properties of the immediate geologic formations (Atakpo, 2009; Akankpo and Igboekwe, 2011). The nature of the aquifer is a function of subsurface geological composition that plays an important role in determining the circulation of water from the surface (infiltration) to subsurface water through recharge processes (Bashir *et al*., 2014).

The use of geophysical techniques for groundwater exploration and water quality evaluations has increased over the past few years due to the rapid advances in computer software and associated numerical modeling solutions (Chinwuko, *et al.*, 2016). Some of these geophysical methods include; vertical electrical sounding (VES), electrical resistivity tomography (ERT), self-potential method, etc. The electrical resistivity tomography is now frequently used as both reconnaissance and confirmatory studies (Olorunfemi and Oni, 2019; Olorunfemi *et al*., 2020). 2D resistivity structures derivable from the inversion of 2D resistivity data are close approximations of images of horizontal layers that are three-dimensional in nature (Shemang and Chaoka, 2003; Owen *et al.*, 2006).

LOCATION AND GEOLOGY OF THE STUDY AREA

Etim Ekpo lies on coordinate $5^0\ 1^1$N 7^0 37" E of Akwa Ibom State of Nigeria (Figure 1). It is a tertiary sediment belonging to the Benin formation and the youngest geologic unit in the Niger-Delta sedimentary basin. This formation comprises continental sands and gravel deposited in an upper deltaic plain environment. The sands are poorly sorted from coarse to fine texture, and they have a mixture of clay, silt, and sandstone. This mixture forms different types of aquifers in some areas in the region (Edet *et al.*, 2003; Edet and Okereke, 2002 and Esu *et al*., 1999). These multiple aquifer formations have been found to be a combination of different sands. The Kwa Ibo river drains the study area that sits on a relatively flat terrain. It has a humid tropical climate which are two seasons: wet and dry season (Akpan *et al*., 2007).

MATERIALS AND METHOD

The Werner array was used for the ERT survey and ten soundings were carried out in the area. Figure 1 shows the locations where soundings were done. In Werner array while the electrode spacing was progressively increased, the center part of the electrode was fixed. (Olasehinde and Taiwo, 2000). If small electrode spacing is used, the current electrode spacing is nearly equivalent to resistivity of the surface materials. Therefore, as the current electrode spacing increased, the current penetrated deeper into the ground (Figure 1b).

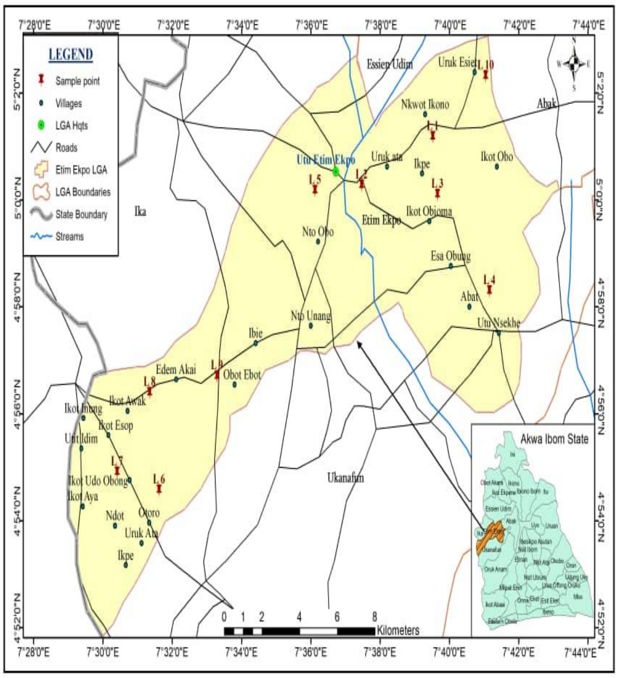

Figure 1: Map of the study area showing different locations of the data point.

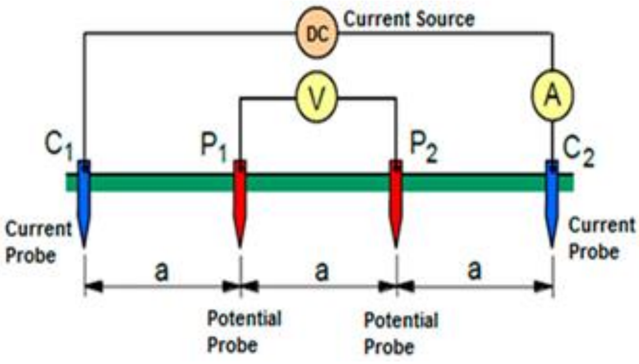

Figure 1b: Wenner Array

The spacing in Wenner array is usually referred to as 'a'. The resistance measured from the meter was recorded for each point; this resistance was converted to apparent resistivity using geometric factor which is constant for Wenner array (2πaR), where R is the resistance measured from the field which can also be known as the ground resistance, and 'a' is the spacing between the electrodes.

The apparent resistivity was then inputted in a computer software (RES2DINV) to get the calculated apparent resistivity and then inversion was carried out to have the ERT imaging. According to Olayinka and Yaramanci (2000), the RES2DINV software transformed the measured ERT data to an approximate picture of the true subsurface resistivity distribution and geometry of the subsurface features.

THEORETICAL BACKGROUND

One of the most commonly used electrode configurations is the Wenner array. In the Wenner array, while the electrode spacing is progressively increased, the center part of the electrode is fixed. (Olasehinde and Taiwo, 2000). If small electrode spacing is used, the current electrode spacing is nearly equivalent to the resistivity of the surface materials. Therefore, as the current electrode spacing is increased, the current penetrates deeper into the ground. The apparent resistivity reflects the resistivity of the deeper layers.

Mathematically,

$$\rho=\left(\frac{2\pi}{G}\right)R \quad \text{ii}$$

$$G=\frac{1}{C1P1}-\frac{1}{C2p1}-\frac{1}{C1P2}+\frac{1}{C2p2} \quad \text{iii}$$

$$G=\frac{1}{a}-\frac{1}{2a}-\frac{1}{2a}+\frac{1}{a} \quad \text{iv}$$

$$=\frac{1}{a} \quad \text{v}$$

Apparent Resistivity for Wenner array

$$\rho=\left(\frac{2\pi}{1/a}\right)R \quad \text{vi}$$

$$\rho=(2\pi \times a)R$$

$$\rho=2\pi aR \quad \text{vii.}$$

RESULTS AND DISCUSSION

The 2D resistivity images obtained from the study area are shown in Figures 2 to 11. The inversion of traverse 1 is as displayed in Figure 2. The image shows three geoelectric zones beneath the profile. These include the topsoil (laterite fine grain sand) with resistivity ranging from 1646 Ωm to 2311 Ωm. It extends from the top to a depth of about 12 m. The second subsurface geoelectric layer has resistivity ranging from 2311 Ωm to 3838 Ωm. The third geoelectric layer extends from a depth of about 22.8 m to beyond 44.9m, with resistivity ranging from 3838 Ωm to 5382 Ωm. This layer could serve as aquifer where groundwater could be tapped. The 2D resistivity image in location two is presented in the Figure 3. Three distinct resistivity layers indicating sandy clay topsoil, laterite fine grain sand and coarse sand are revealed. The sandy clay topsoil is fairly continuous with the thickness varying from 0 to 4 m and resistivity values ranging from 835 – 1371 Ωm. The laterite sand thickness varies from 5 to 15 m and resistivity values vary from 1372 – 2886 Ωm. The coarse sand thickness varies from 22 to 44 m and the resistivity values vary from 2889 – 4739 Ωm. The third layer is suspected to host the aquifer. The 2D resistivity imaging for location 3 is shown in the Figure 4. It presents a three-layer lithology amongst are the top soil which ranges from 546-1006 Ωm with the maximum depth of 0-3 m. The top soil is suspected to be sandy clay. The second layer ranges from 1008- 2513 Ωm in resistivity and 5-10 m in depth. It is suspected to be coarse grained sand. The last layer ranges from 2513-4642 Ωm in resistivity and is more permeable than others, as such may contain the aquifer. The depth is from 17-57 m and it is a saturated medium and coarse grained sand.

In ERT 4, three distinct layers was presented as shown in Figure 5. The first layer which is the top soil has resistivity value ranging from 34.6 – 213 Ωm and depth of 0- 4 m. It is sandy clay. The second layer ranges from 213-1237 Ωm in resistivity while the depth ranges from 6 m – 15 m. It is fine grained sand. The third layer has the highest resistivity values. The resistivity ranges from 1237 – 2465 Ωm and the depth ranges from 26 – 52 m; it is saturated medium and coarse grained sand. The ERT imaging for point 5 is shown in figure 6. This image shows a three-layer lithology composition. This include, the top soil which is sandy clay with resistivity range of 1268-1688 Ωm and depth of 0-6 m. The second layer is coarse grained sand with resistivity range of 1948 -2592 Ωm and depth of 10 -17 m. The third layer has higher resistivity values, ranging from 2592 - 3451 Ωm, and depth ranging from 26 – 52 m. It is a saturated medium and coarse grained sand. Figure 7 shows the ERT imaging for location 6. Three layers are identified. Layer 1 is the top soil (lateritic fine grained sand) with resistivity values ranging from 765-1251 Ωm and depth of 0 - 7m. The second layer is sandy clay with resistivity values ranging from 1251-2688 Ωm and depth of 10 - 17 m, while the third layer is the aquifer zone having high resistivity values, ranging from 2688- 4254 Ωm, and the depth range of 26-52 m. The aquifer zone is a saturated medium with coarse grained sand.

The ERT imaging for location 7 is shown in the figure 8. This image shows a three-layer lithology composition. This include, the top soil which is lateritic fine grained sand with resistivity range of 845-1267Ωm and depth of 0-7m. The second layer is sandy clay with resistivity range of 1267-2812Ωm and depth of 10-20 m, and the third layer having resistivity values ranging from 2812- 4550 Ωm, and the depth range of 26-52 m. The 2D resistivity image obtained from location 8 is displayed in figure 9. It comprises of three geoelectric zones beneath the profile. These include the topsoil (laterite fine grained sand) with resistivity values ranging from 1412 Ωm to 1678 Ωm. It extends from the top to a depth of about 12 m. The second subsurface geoelectric layer has resistivity values ranging from about 1994 Ωm to about 2174 Ωm. This subsoil encloses the third geoelectric material whose resistivity ranges from 2174 Ωm to 2583 Ωm and it extends from a depth of about 22.8 m to beyond 44.1m. The 2D resistivity image in location 9 is presented in Figure 10. Three distinct resistivity layers indicating sandy clay topsoil, lateritic fine grained sand and coarse sand are revealed. The sandy clay topsoil is fairly continuous with the thickness varying from 0 to 4 m and resistivity values ranging from 998 – 1728 Ωm. The laterite sand thickness varies from 5 to 15 m and resistivity values which vary from 1728 – 3982 Ωm. The coarse sand thickness varies from 22 to 44 m and the resistivity values vary from 3982 – 6964 Ωm. The third layer is suspected to host the aquifer. The ERT imaging for point 10 is shown in the figure 11. This image shows a three-layer lithology composition. This include, the top soil which is laterite fine grained sand with resistivity range of 534 to 995 Ωm and depth of 0-7 m. The second layer is sandy clay with resistivity range of 995-2532 Ωm and depth of 8-20 m, and the third layer is the aquifer layer because of the high resistivity values ranging from 2532- 4719 Ωm and the depth range of 26-52 m. It is a saturated medium and coarse grained sand.

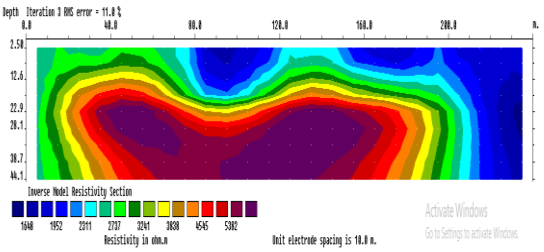

Figure 2: 2 D resistivity image for location 1

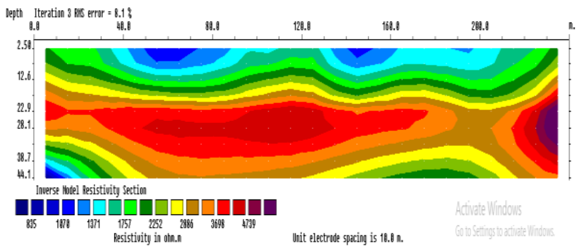

Figure 3: 2 D resistivity image for location 2.

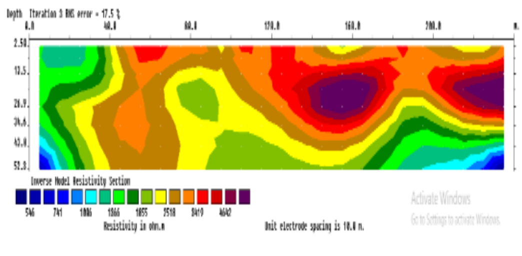

Figure 4: 2 D resistivity image for location 2

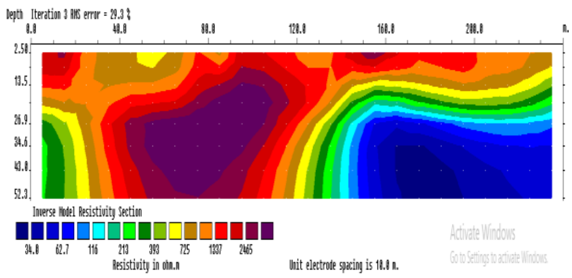

Figure 5: 2 D resistivity image for location 4

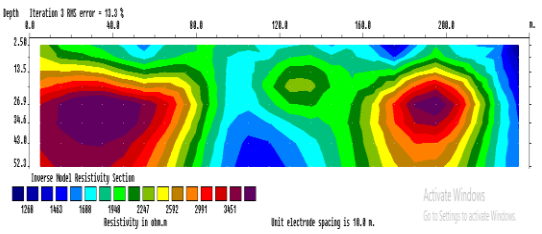

Figure 6: 2 D resistivity image for location 5

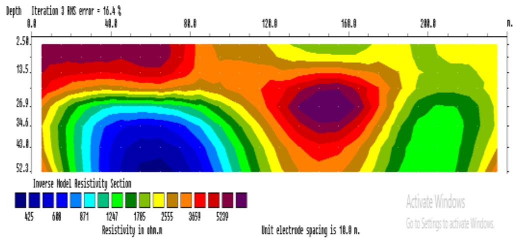

Figure 7: 2 D resistivity image for location 6

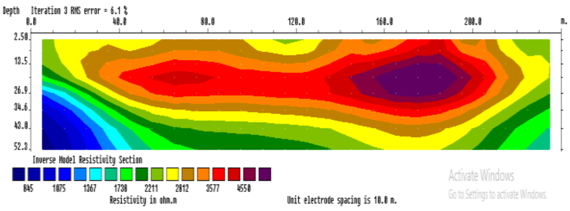

Figure 8: 2 D resistivity image for location 7

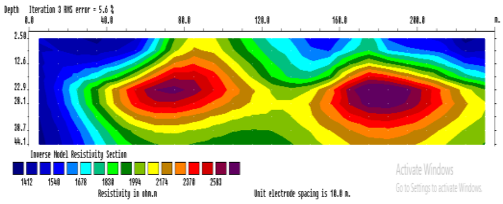

Figure 9: 2 D resistivity image for location 8

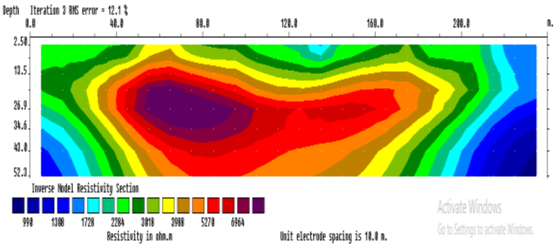

Figure 10: 2 D resistivity image for location 9

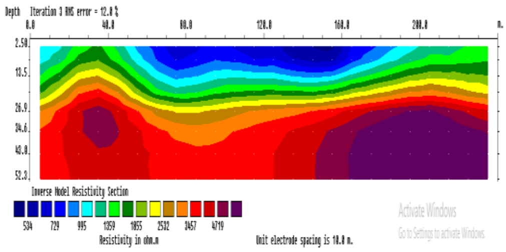

Figure 11: 2 D resistivity image for location 10

CONCLUSION

A 2D resistivity tomography had effectively revealed the lateral and vertical subsurface information of the area. Three geologic layers were delineated: topsoil, laterite fine sand and coarse-grained sand which was suspected to host the aquifer. The geologic layer of this area is characterized by pore spaces that enhance groundwater permeability and storage. The research has been able to determine the sub-surface lithology of the study area thus revealing its distribution.

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