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RESEARCH ARTICLE

GEOELECTRIC STUDY OF GROUNDWATER REPOSITORY IN PARTS OF AKWA IBOM STATE, SOUTHERN NIGERIA

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ABSTRACT

Geoelectric survey employing Vertical Electrical Sounding (VES) was carried out in order to assess the groundwater repositories. A total of seven soundings were obtained with their layer resistivity, thickness and depth within the maximum electrode separation. The geoelectric parameters obtained were used to estimate the Dar-Zarrouk parameters (longitudinal conductance and transverse resistance), hydraulic conductivity and transmissivity. The result shows the aquifer resistivity ranging from 77.14 to 784.76 Ωm, with thickness ranging from 28.78 to 80.04 m. The longitudinal conductance have values ranging from 0.071 to 0.825 Ω^{-1} while the values of hydraulic conductivity and transmissivity range from 1.087 to 5.881 m/day and 60.180 to 374.031 m^2/day respectively. The contour maps generated show the variation of these parameters across the subsurface, and areas with poor protective capacity were delineated. The results also delineate the groundwater potential of the study area as moderate, while the corrosivity rating indicates non-corrosive and slightly corrosive.

KEYWORDS

Aquifer, resistivity, longitudinal conductance, transmissivity.

1. INTRODUCTION

Electrical resistivity technique has been successfully employed in groundwater exploration due to the fact that it is non-invasive and relatively cheap geophysical technique. Electrical resistivity method involving VES has proved to be useful in groundwater study (George et al., 2014; Ibuot et al., 2013; Niwas and Singhal, 1981; Singh, 2005; Soupious et al., 2007). This method has been widely used in groundwater exploration to determine depth to water table, aquifer geometry and groundwater quality by analyzing measured apparent resistivity field data. The evaluation of groundwater repositories has become necessary for proper groundwater resource management particularly in time like this when groundwater is facing great challenges due to poor waste management practices peculiar to most developing countries of the world. Many geologic related factors affects groundwater repositories in terms of transmissibility, flow and storage (Ibanga and George, 2016; George et al., 2017; Ibuot et al., 2019).

The variation of factors such as dissolved ions, soil composition, thickness, grain sizes and pore spaces affects the groundwater potential of an area. A lot of pressure is put on subsurface aquifer (groundwater) by the increase in population and urbanization. In a settlement, potable water plays a major role in determining the growth and development of that settlement. The study area has witnessed an increased in population which has signal an increase in local economy, the inhabitants being farmers, civil servants, students etc. They rely mostly on boreholes as a major renewable fresh water source thus increasing the demand for potable water supply. Groundwater exists below the earth surface within saturated layers of sand, gravel and pore spaces in sedimentary as well as crystalline rocks. In order to pursue large scale development of groundwater, it is essential to have reliable information that will aid in determining groundwater potential.

Environment can be evaluated without interfering with the hydrogeologic system through the use of geophysical studies (Niwas and Singhal, 1981; Lashkaripour and Nakhaei, 2005; Yahaya et al., 2009; George et al., 2015; Obiora and Ibuot, 2020; Uwa et al., 2018). To avoid drilling abortive wells, geophysical investigation is imperative because it helps to delineate potential water bearing units (aquifer units) while on the other hand, assessment of Water yielding capacity of aquifer are traditionally determined from parameters obtained from well pump tests and well log data, which is time consuming and expensive (Singh, 2005). The geophysical studies will help in solving the problems of fail boreholes, since it will give a wider knowledge of the subsurface. It will also delineate the subsurface lithology and prolific aquifer zones. The nature of the subsurface materials is a great factor in designing of appropriate groundwater management strategies in any geologic environment, whose properties (physical and chemical) and spatial distribution constitutes the goal of all hydrogeologic and hydrogeophysical investigations (George et al., 2014; Obiora et al., 2015). This study focused on evaluating the groundwater potential, corrosivity and the distribution of the aquifer parameters in the study area, this will give useful information that will guide against drilling of unproductive boreholes.

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2. LOCATION AND THE GEOLOGY OF THE STUDY AREA

The study area covers part of Itu L. G. A, of Akwa Ibom state (Figure 1), the study area, which is located in an equatorial climatic region is characterized by two major seasons. They are the rainy (March–October) and dry (November-February) seasons (Akpan et al., 2013; Ibuot et al., 2013; George et al., 2010). The study area occupies the valleys associated with the Niger delta Basin (Figure 1), and is subjected to constant inundation by the water of coastal flank. The study area is geologically characterized by the Miocene Akata Formation (shales, intercalated sands and silestones), Miocene-Pliocene Agbada Formation (sands and sandstones, intercalated with shales) and the Pliocene Benin Formation (coarse - grained sand, gravelly sands with minor intercalation of clays and shales) from top to bottom respectively. The middle and the upper sand units of the Benin Formation constitute the major hydrogeologic units in the area (Esu and Amah 1999; Akpan et al., 2013). The water table in the area varies from 1.3m to 52m according to (Evans et al., 2010). Generally, the sands in the study area are mature, coarse and moderately sorted.

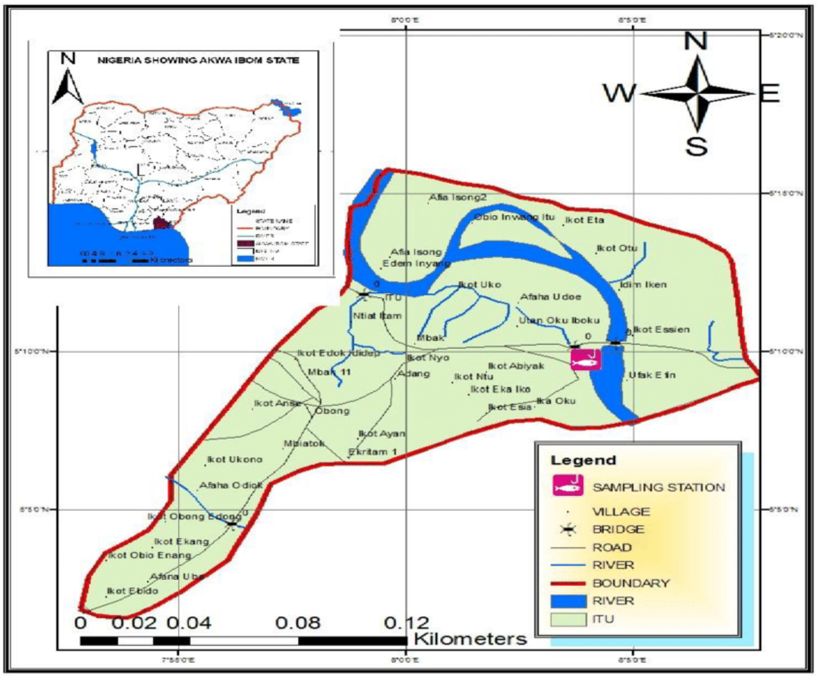

Figure 1: Location map of Itu L. G. A.

3. MATERIALS AND METHOD

Data from seven Vertical Electrical Soundings (VES) were acquired from the study area using the ABEM Terrameter, the study employs Schlumberger array with electrode spread varying between 1m - 600 m. Using equation 1, the apparent resistivity (ρ_a) was measured.

$$\rho_a = \pi.\left[\frac{\left(\frac{AB}{2}\right)^2-\left(\frac{MN}{2}\right)^2}{MN}\right].R_a \quad (1)$$

Where AB is the distance between the two current electrodes, MN is the distance between the potential electrodes, and R_a is the apparent electrical resistance measured from the equipment. The equation can be simplified as shown in equation 2;

$$\rho_a = K.R_a \quad (2)$$

Where K is the geometric factor : $\pi.\left[\frac{\left(\frac{AB}{2}\right)^2-\left(\frac{MN}{2}\right)^2}{MN}\right]$

The Global positioning system (GPS) was used in measuring the coordinates of the sounding points. The apparent resistivity obtained was plotted using bi-logarithm graph and the curves were smoothened and quantitatively interpreted in terms of true resistivity and thickness by a conventional manual curves and auxiliary charts (Orellana and Moony, 1996). The manually interpreted data was improved upon using the WinRsist software and geological curves were obtained for each VES point. The interpretation of the resistivity curves was based on a number of layers depicted on the observed curves and models that are geologically reasonable and produce acceptable fit. The geoelectric parameters of different layers are obtained after a number of iterations with minimal RMS error. The longitudinal conductance (S) and transverse resistance (T) were determined using equation 3 and 4:

$$S = \frac{h}{\rho} \quad (3)$$

$$T = \rho h \quad (4)$$

Where h is aquifer thickness and ρ is the aquifer resistivity.

According to Niwas and Singhal (1981), the analytical relationship between aquifer transmissivity (Tr), hydraulic conductivity (K) and aquifer thickness (h) is given by equation 5:

$$Tr = K\,h \quad (5)$$

And in accordance with Ekanem et al., (2019) who worked in a location with similar geological characteristics, we can estimate K from equation 6;

$$K = 139.12\rho_b{}^{-0.728} \quad (6)$$

Where ρ_b is the aquifer resistivity?

The relation (Equation 6) was used to estimate hydraulic conductivity (K) because the water bearing unit of the study area is a Coastal Plain Sands of the Niger Delta region of Nigeria. The hydraulic conductivities were multiplied with the aquifer thickness of interpreted VES stations to determine aquifer transmissivity (equation 5).

4. RESULTS AND DISCUSSION

The values aquifer geoelectric parameters (resistivity and thickness) are presented in Table 1. The study area is characterised by heterogenous lithology with aquifer resistivity values ranging from 77.14 Ωm to 356.31 Ωm. The low to moderate resistivity values across the aquifer geoelectric layers can be attributed to conductive argillaceous geomaterials. The aquifer thickness ranged from 28.78m to 80.04m, the relatively high aquifer thicknesses indicate the presence of prolific aquifers. These parameters (resistivity and thickness) were used in estimating the Dar-zarrouk parameters (longitudinal conductance and transverse resistance), hydraulic conductivity and transmissivity. The contour map (Figure 2) shows the variation of aquifer resistivity across the study area as it increases from northeast to southwest, with the highest values observed in the southwestern part of the study area. The variation of aquifer thickness (Figure 3), shows highest aquifer thickness in the southern part while the lowest is observed in the central part of the study area.

Table 1: Aquifer Electric and Geohydraulic parameters

VES stations	Longitude (ºE)	Latitude (ºN)	Aquifer resistivity(Ωm)	Aquifer thickness(m)	Longitudinal conductance(Ω^{-1})	Transverse resistance (Ωm^2)	Hydraulic conductivity (m/day)	Transmissivity (m^2/day)	Corrosivity rating
1	7.6824	5.1942	243.57	57.42	0.236	13985.790	2.546	146.215	Non-corrosive (NC)
2	7.6881	5.1776	784.76	55.39	0.071	43467.860	1.087	60.180	Non-corrosive (NC)
3	7.7058	5.1795	267.36	54.71	0.205	14627.270	2.379	130.176	Non-corrosive (NC)
4	7.6940	5.1860	166.26	28.78	0.173	4784.963	3.363	96.771	Slightly corrosive (SC)
5	7.7092	5.1807	107.72	64.40	0.598	6937.168	4.612	297.005	Slightly corrosive (SC)
6	7.6868	5.1968	77.14	63.60	0.825	4906.104	5.881	374.031	Slightly corrosive (SC)
7	7.6953	5.1824	356.31	80.04	0.225	28519.05	1.931	154.513	Non-corrosive (NC)

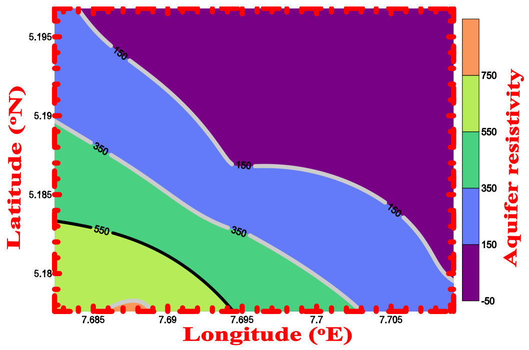

Figure 2: Contour map showing the variation of aquifer resistivity

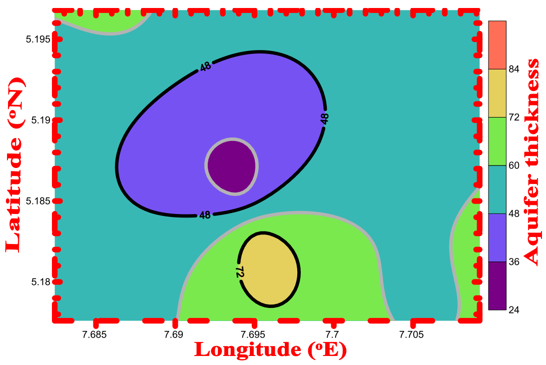

Figure 3: Contour map showing the variation of aquifer thickness

The values of longitudinal conductance range from 0.071 Ω^{-1} to 0.825 Ω^{-1} indicating poor, weak, moderate and good protective capacity across the study area according to the rating of (Henriet, 1976). Generally, it can be inferred that the underlying aquiferous layer is moderately protected from the surface contamination flow due to the fact that the protective capacity of most part of the study area is moderate. Figure 4 shows increase in longitudinal conductance from southwest towards to northern part an indication that the northern part is more protected from surface contaminants than the southern other parts. It could be inferred that the southern part is more vulnerable to surface contaminants. The transverse resistance has values ranging from 4906.104 Ωm^2 to 43467.860 Ωm^2 and varies in opposite direction to the longitudinal conductance but in the same trend with resistivity (Figure 5).

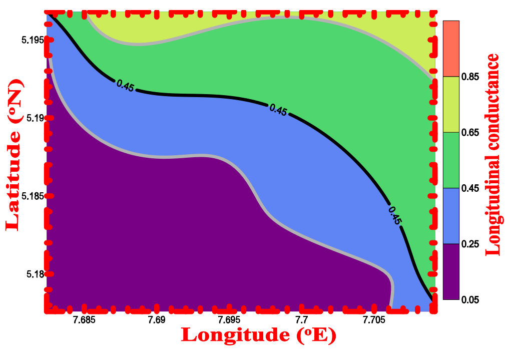

Figure 4: Contour map showing the variation of longitudinal conductance.

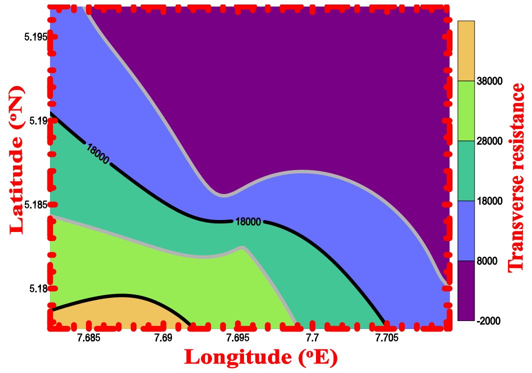

Figure 5: Contour map showing the variation of transverse resistance

The hydraulic conductivity (K) ranges from 1.087 m/day to 5.881 m/day, the distribution of K shows high values in the northern part of the study area (Figure 6). The values of hydraulic conductivity and thickness help in estimating transmissivity with values ranging from 60.180 to 374.031m^2/day. The contour (Figure 7) shows high aquifer transmissivity in the northern parts of the study area. The contour maps (Figures 6 and 7) reveal that increase in hydraulic conductivity lead to a corresponding increase in transmissivity. it can be inferred that the sensitivity of K to facies change affects the variation of aquifer transmissivity. The high transmissivity observed in the northern part is an indication of high groundwater reserve in that zone, while the southwestern part can be delineated as zone with low groundwater potential. According to the ratings of Baeckmann and Schwenk the results reveal the study area to be non-corrosive and slightly corrosive (Table 1), this indicates the presence of some corrosive elements in regions that are slightly corrosive (Baeckmann and Schwenk, 1975).

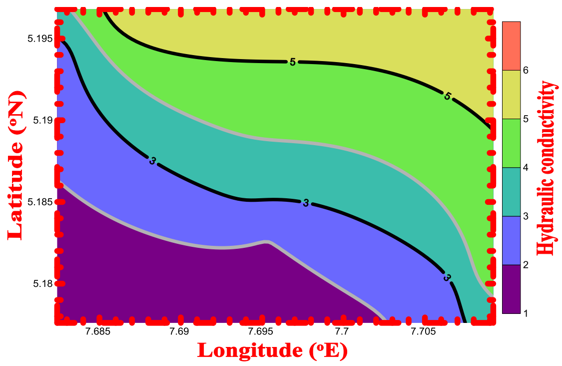

Figure 6: Contour map showing the variation of hydraulic conductivity

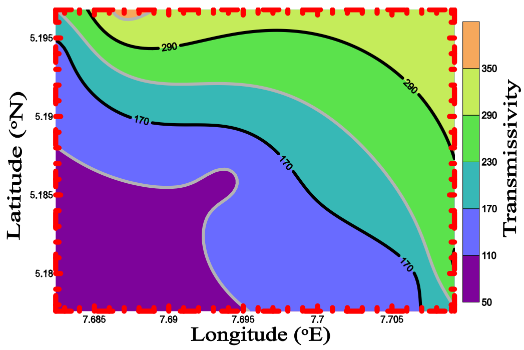

Figure 7: Contour showing aquifer transmissivity

5. Conclusions

The study revealed the subsurface lithology of the study area. The values of aquifer resistivity and thickness were obtained from the computer modelling. The varying lithology shows the heterogeneous nature of the subsurface. The aquifer geoelectric parameters were used in estimating the Dar-zarrouk parameters, hydraulic conductivity and transmissivity. The variability of these parameters is shown in the contour maps generated from the surfer software. Groundwater potential of the area was delineated as high and moderate, the longitudinal conductance and transverse resistance (hydraulic parameters) were estimated from the geoelectric parameters. The changes in the contour maps may be attributed to the influence of the electric-hydraulic anisotropies, also variations in lithology, grain size, pore shape and pore channels. The protective capacity of the study area from values of longitudinal conductance was also delineated while the values of the aquifer transmissivity reveal the study area as having good groundwater potential. This study emphasizes the contribution of geophysical methods in the determination and distribution of aquifer parameters. Therefore, there is need for more study to be carried out in the study area to assess the groundwater quality integrating geophysical and physicochemical approach.

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