1. Introduction

This paper describes a geoelectric exploration for groundwater undertaken at Mbaitoli L.G.A. of Imo State, Southeastern Nigeria. The objectives are to study the occurrence of ground water in the Mbaitoli area of Imo State, determine the depth to water table and obtain the thickness of aquiferous zones.

Groundwater is the water found underground on the cracks and spaces of soil, sand, and rocks where it is stored and moves slowly through geologic formations (called aquifers). Groundwater is globally important and a valuable renewable resource for human life and economic development. An estimated 2 billion people worldwide rely on ground water for their drinking water supply Morris et al (2003).

In general, geoelectric measurements enable the electric resistivity of the subsurface to be determined. The interpretation of data from such measurements yields useful information on the...
structure and composition of these subsurface layers. Resistivity techniques are well established and widely used to solve a variety of geotechnical and geological problems (Ward; 1990). The primary purpose of the resistivity method is to measure the potential differences on the surface due to the current flow within the ground. Many research works have been done using electrical resistivity method. These include; Uma (1989) who carried out a study on the groundwater resources of Imo river basin using hydrological data from existing boreholes and concluded that three aquifer systems (confined, unconfined and semi-confined aquifers) exist in the area. Mbonu, et al (1990) carried out seventeen Schlumberger vertical electrical soundings (VES) in parts of Umuahia area for the generation of aquifer parameters. Agbodike I.I.C. et al (2013) used electrical resistivity method to determine the depth and thickness of the aquiferous zones in the Oru area of Imo-State. Among the various geophysical methods of groundwater investigation, the electrical resistivity method has the widest adoption in groundwater exploration (Olorunfemi, 1999; Ariyo, 2007; Afolayan et al; 2004). This is due to the fact that the field operation is easy; the equipment is portable and has greater depth of penetration.

2. Location and Geomorphology of the Study Area

The survey area lies within latitudes 5° 31′ N and 5° 4′ N and longitude 6° 56′ E to 7° 08′ E (Ofodile, 2001). The designated area covers about 204km². It has a population of 237,555 with 31 autonomous communities. The town comprises such communities as Umunoha, Afara, Ifakala, Orodo, Ubomiri, Egbeada, Idem Ogwa, Awo Mbieri, Alaenyi Ogwa, Abazu Ogwa and Ochi Ogwa among others Emmanuel et al (2014). The map of this study area is shown in figure 1. It lies within the tropical rain forest belt of Nigeria with luxuriant growth of trees, it has humid tropical climate with high temperature and seasonal rainfall. Two main climate seasons characterized the study area namely: dry and rainy seasons. The rainy season starts from April to October with a mean annual rainfall of about 1,500mm to 2000mm. The dry season extends from November to March, in between this period harmattan occurs. The area has an average annual temperature above 20°C which creates an annual relative humidity of 75%. The study area is drained by both surface water and groundwater. One of the surface water is Okitankwo River which flows westwards and represents a recharge zone with high infiltration capacity. Majority of the roads are accessible. The good network of tarred and track roads made the field data acquisition possible.

3. Geology of the study area

The study area lies within Anambra Imo drainage basin of southeastern Nigeria. Benin formation is the major lithologic unit that predominate the study area. The Benin formation is underlain by Ogwashi-Asaba formation and is the youngest in Imo-sedimentary basin (Offodile, 2001; Reyment, 1965). It has Benin formation which was formerly known as coastal plain sands Reyment (1965). The sands and sandstones are coarse to fine grained and commonly of granular texture. The formation consists of friable sand with intercalations of shale and clay lenses occurring occasionally at some depths (Short and Stauble; 1967). The formation is partly estuarine, partly lagoon, partly deltaic and fluvial, lacustrine in origin Reyment (1965). The sands and sandstones in this formation are coarse grained, very granular, pebbly to very fine grained. They are either white in colour or yellowish brown. Hematite grains, feldspars are also obtained. The shale are grayish brown, sandy to silty and contains some plant remains and dispersed lignites (Short and Stauble; 1967). The Benin formation is known to have reliable groundwater that could sustain borehole production.
The high permeability of the coastal plain sands, the overlying lateritic earth and the weathered top of this formation provide the hydrologic conditions favouring aquifer formation in the study area. There is also copious rainfall in the area which makes the aquifer prolific and provides for steady groundwater recharge.

4. Theory and methods

This study adopted vertical electrical sounding (VES) using the Schlumberger array. For a Schlumberger spread, the two current electrodes and the two potential electrodes are still placed in line with one another centered on some location, but the potential and current electrodes are not placed equidistant from one another.

The apparent resistivity computed from the measurement of voltage, \( V \) and the current \( I \) is given by simple equation shown below

\[
\rho = \pi \left( \frac{a^2}{b} - \frac{b}{4} \right) \frac{\Delta V}{I}
\]  

In Schlumberger array, the current and potential pairs of electrode have a common midpoint but the distances between adjacent electrodes differ so that \( a \neq b \). Theoretically, the resistivity (\( \rho \)) of a material is directly proportional to the potential difference \( V \) and inversely proportional to the induced current \( I \)

\[
\rho \propto \frac{V}{I} 
\]  

\[
\rho = k \frac{V}{I} 
\]  

And we have that, \( R = \frac{V}{I} \)

Hence

\[
\rho = kR 
\]  

Where \( k \) is the geometric factor, \( R \) is the resistance.
The geometric factor $k$ depends on the electrode separation. $R$ is the resistance of the volume of ground between the potential electrodes. If $V$ and $I$ are measured in milli-volts and milli-amperes respectively and the distance of separations in meters, then the resistivity ($\rho$) is expressed in ohm-meter.

A total of ten vertical electrical soundings were acquired at different locations within the study area with maximum spread of 400m, using the ABEM Terameter SAS 4000. The data were acquired under favourable weather condition. Additional data in the form of vertical electrical sounding, electric log data (borehole log data), lithological data (strata-log or litho-log) were acquired from Anambra Imo River Basin. The observed field data was converted to apparent resistivity values by multiplying with the Schlumberger geometric factor. These apparent resistivity values were plotted against half electrode spacing on logarithmic coordinates to obtain the sounding curves from which resistivity and thickness of the layers were determined. Information from existing boreholes was also utilized in this study for the purpose of correlation with the vertical electrical sounding data. The hydro-geophysical survey shows that the study area is underlain by Benin formation. The lithology is dominantly sand, silty sand clay sandy-clay and sandstone (fig. 13). Six geoelectric curve types were encountered in the study with the Ak curve type dominating the area.

5. Results and Interpretation

The results obtained in this study are highlighted in tables 1 and 2 while figures 2 to 13 show the resistivity and aquifer distributions as part of the results. A combination of these results and history of drilling data obtained from previous drilling reveals and confirms that aquifer resistivity varied from 338ohm-m at Obokpo Ubomiri to 161000ohm-m with a mean value of 52904.8ohm-m, aquifer depth varied from 83.2m at Alaenyi Ogwa to 169m at Umuduru Ifeakala with a mean value of 138.22m, aquifer thickness ranges from 24.9m at Umuowa Obokpo to 73.9m at Odumara Obi Oordo with a mean value of 48.81m. In general, the aquifer system revealed a near - homogenous hydrological and hydraulic characteristics, indicating very prolific aquifer system.
Fig. 3 2D and 3D Iso - Resistivity values at AB/2 = 40m

Fig. 4 2D and 3D Iso - Resistivity values at 200m

Fig. 5 2D and 3D Iso - Resistivity values at AB/2 = 250m
Fig. 6 2D and 3D iso - Resistivity values at 400m

Fig. 7 Contour map of the spatial variation of aquifer depth in the study area
Fig. 8 3D plot of the spatial variation of aquifer depth in the study area.

Fig. 9 Contour map of the spatial variation of aquifer resistivity in the study area.

Fig. 10 3D plot of the spatial variation of aquifer resistivity in the study area.
Fig. 11 Contour map of the spatial variation of aquifer thickness in the study area.

Fig. 12 3D plot of the spatial variation of aquifer thickness in the study area.
Table 1  Summary of Aquifer layer parameters

<table>
<thead>
<tr>
<th>M. No</th>
<th>Location</th>
<th>Resistivity (ohm-m)</th>
<th>Thickness of layer (m)</th>
<th>Core type</th>
<th>Filter</th>
<th>No. of layer</th>
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<tbody>
<tr>
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<tr>
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<td>TK</td>
<td>5</td>
<td></td>
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<td>3</td>
<td>Akwa Ibom</td>
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<td>3.2</td>
<td>TK</td>
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<tr>
<td>5</td>
<td>Cross River</td>
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<tr>
<td>6</td>
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</tr>
<tr>
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</table>

Table 2  Iso - Resistivity Data of the Study Area

<table>
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<th>VES No</th>
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<th>Location</th>
</tr>
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</tr>
<tr>
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<td>Delta</td>
</tr>
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</tr>
</tbody>
</table>

6. CONCLUSION

This paper has provided relevant information on the aquifer resistivities, aquifer thickness and depth to layers of the study area. Hence an effective water supply scheme for mbaitoli and its environs can be developed using the results in this research work stated as follows; aquifer resistivity varied from 338ohm-m at Obokpo Ubomiri to 161000ohm-m with a mean value of 52904.8ohm-m, aquifer depth varied from 83.2m at Alaenyi Ogwa to 169m at Umuduru Ifeakala with a mean value of 138.22m, aquifer thickness ranges from 24.9m at Umuowa Obokpo to 73.9m at Odumara Obi Ordo with a mean value of 48.81m. In general, the aquifer system revealed a near - homogenous hydrological and hydraulic characteristic, indicating very prolific aquifer system.

7. REFERENCES