Available online at www.scholarsresearchlibrary.com

Scholars Research Library

Archives of Physics Research, 2010, 1 (2):37-45
(http://scholarsresearchlibrary.com/archive.html)

Archives of Physics Research
Scholars Research Library
ISSN 0976-0970

2-D Resistivity Imaging Applied In Groundwater Exploration in Awka, Se Nigeria

Ehirim, C. N. and Ebeniro, J. O.

Geophysics Research Group, Physics Department, University of Port Harcourt, P. O. Box 122, Uniport Choba, Port Harcourt

---

Abstract

The groundwater resource of Enugu-Agidi to the SE of Awka was investigated using 2-D resistivity imaging. The survey was conducted along four profile lines each of length 1000m; with inter-traverse spacing of 250.0m within a (1x1) km^2 area. Data acquisition was performed using Wenner-alpha array with a 10m electrode spacing to a maximum of 60m, and the Abem Terameter (SAS) 1000C. The data was processed by using RES2DINV software, and results were presented as inverse resistivity sections with RMS errors of between 2.2% to 6.6%. The resistivity of these inverse models varies from 15.25Ωm to 99927.0Ωm. Three promising confined aquifers were delineated to the NW and SE of profiles 1 and 2, respectively, at depths of between 62.0m to 90.0m. These were overlain by low resistivity hemispherical structures of confining clay / shale bed of resistivity < 205Ωm. This revelation was confirmed by the abandoned artesian well situated 20m to the east of traverse one. Unconfined aquifers were delineated at shallow portions of the sections along the traverses at an average depth of about 37.0m. The resistivity of the confined and unconfined aquifer materials varies from 243Ωm to 19037Ωm. The subsurface topography generally dips to the NW and SE of the river valleys in all the traverses, with major bedrock upwarp along P2-Profile in agreement with surface topographical expressions.

Keywords: 2D Resistivity Imaging, Confined Aquifer, Unconfined Aquifer, and Groundwater.

INTRODUCTION

The search for groundwater as the only uncontaminated source of potable water supply, especially in areas having complex geological and topographic features has increased remarkably in the recent, due to advances in geophysical instrumentation, field techniques and interpretation

(3). Recent developments in resistivity methods have led to the acquisition of data in 2-D space, and interpretation in the form of electrical resistivity imaging (Tomography).

The conventional resistivity method of sounding and profiling gives an I-D model of the subsurface, which is not adequate in mapping areas of complex subsurface geology. Also the basic sounding interpretation assumption of horizontally stratified earth model which do not match the local geological model and failure of the profiling method to map changes in resistivity with depth are the major limitations of these methods (4, 5).

Resistivity imaging surveys provides a more realistic 2-D resistivity model of the sub surface, where resistivity changes in the vertical as well as in the horizontal direction along the survey line are mapped continuously even in the presence of geological and topographical complexities. 2-D surveys are the most practical economic compromise between obtaining very accurate results and keeping the survey costs down. A proper electrical image of the subsurface can be used to easily identify and map structural features related to fluid content, aquifer configuration, and qualitatively, the ground water flow direction. This method has variously been applied in groundwater studies and exploration (1, 2, 5), for mapping aquifer configuration (Confined and unconfined), aquitards, soil-bedrock interface topography, fracture zones, faults, and voids on the basis of their resistivities.

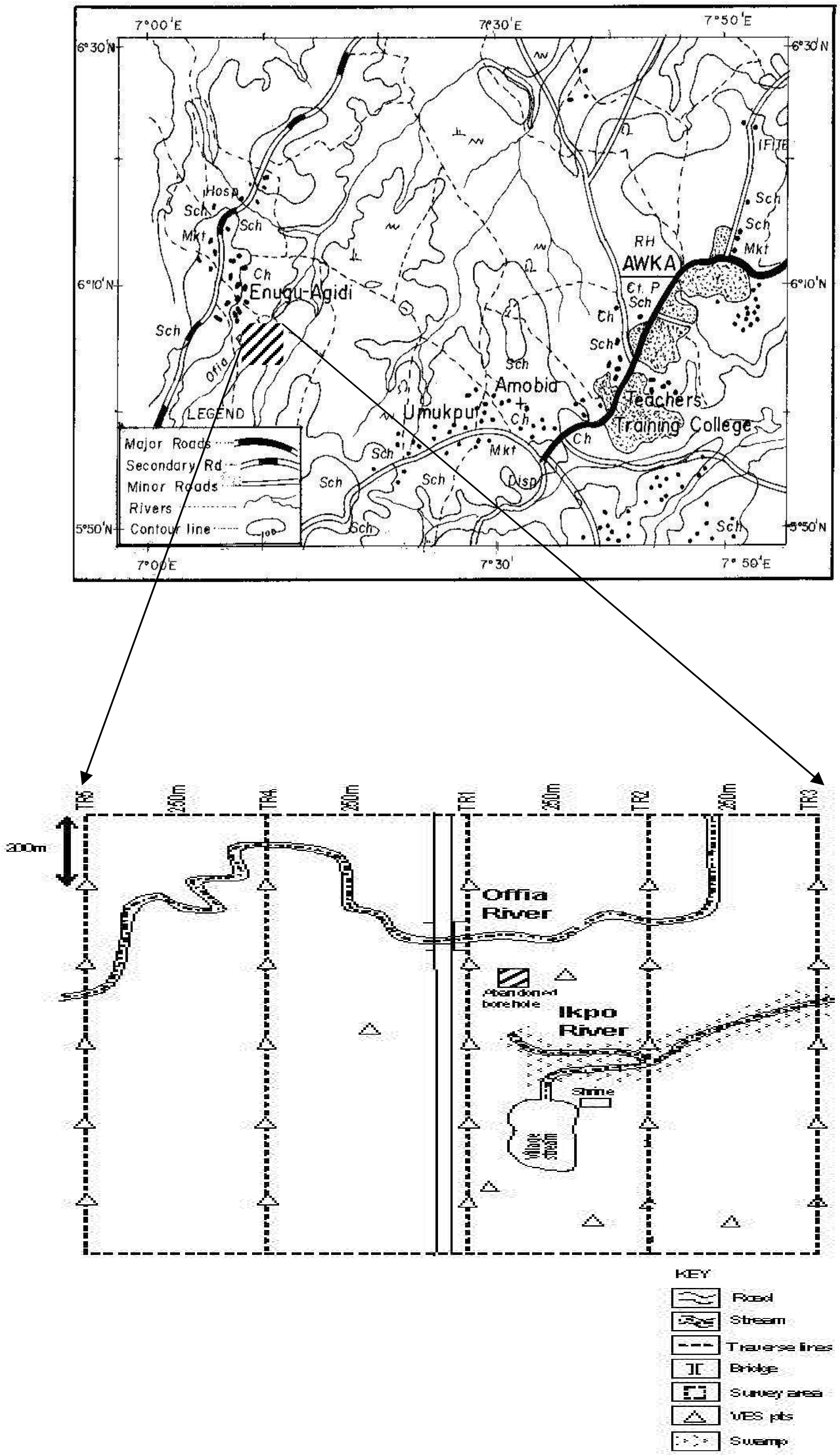
The study area lies in Offia river valley to the NW and Ikpo river valley to the east within Enugu-Agidi to the SE of Awka. It is delineated by Longitude $5^{0}50^{1}$N to $6^{0}30^{1}$N and Latitude $7^{0}00$E to $7^{0}50^{1}$E (Fig 1.0). The area is faced with the scarcity of potable drinking water due to its complex geology arising from thick deposits of poorly sorted sediments, irregular shape of its aquifers, and undulating topographies. Because 1-D vertical electrical sounding cannot map accurately this complex subsurface geology due to its limitations, the 2-D resistivity imaging was adopted for this investigation.

The site has an existing abandoned artesian well situated 160m to the SE from the Offia river. The well has a maximum yield of about 5.7 L/S, cloudy with a characteristic taste. The existence of this well aided the interpretation of 2-D data. This study is aimed at investigating the nature and distribution of subsurface rocks; delineate confined and unconfined aquifers, and locate probable spots for well development in the area. It is intended to demonstrate the robustness of 2-D electrical imaging in mapping the distribution of aquifers and subsurface topography in a geologically complex environment.

Geology of the Study Area

Enugu-Agidi is underlain by the Tertiary Imo Formation of the Anambra basin. The formation was laid in the basin in a NE-SW strike, with layers gently dipping in the direction of North. The sediments consist of thick clayey shales, fine textured, dark grey to bluish grey with occasional admixture of clay Ironstones and thin sandstone bands (Fig 2.0). The formation becomes sandier towards the top where it may consist of alternating bands of sandstone and shale (7).

Fig. 1.0: Location Map of the Study Area showing sounding points



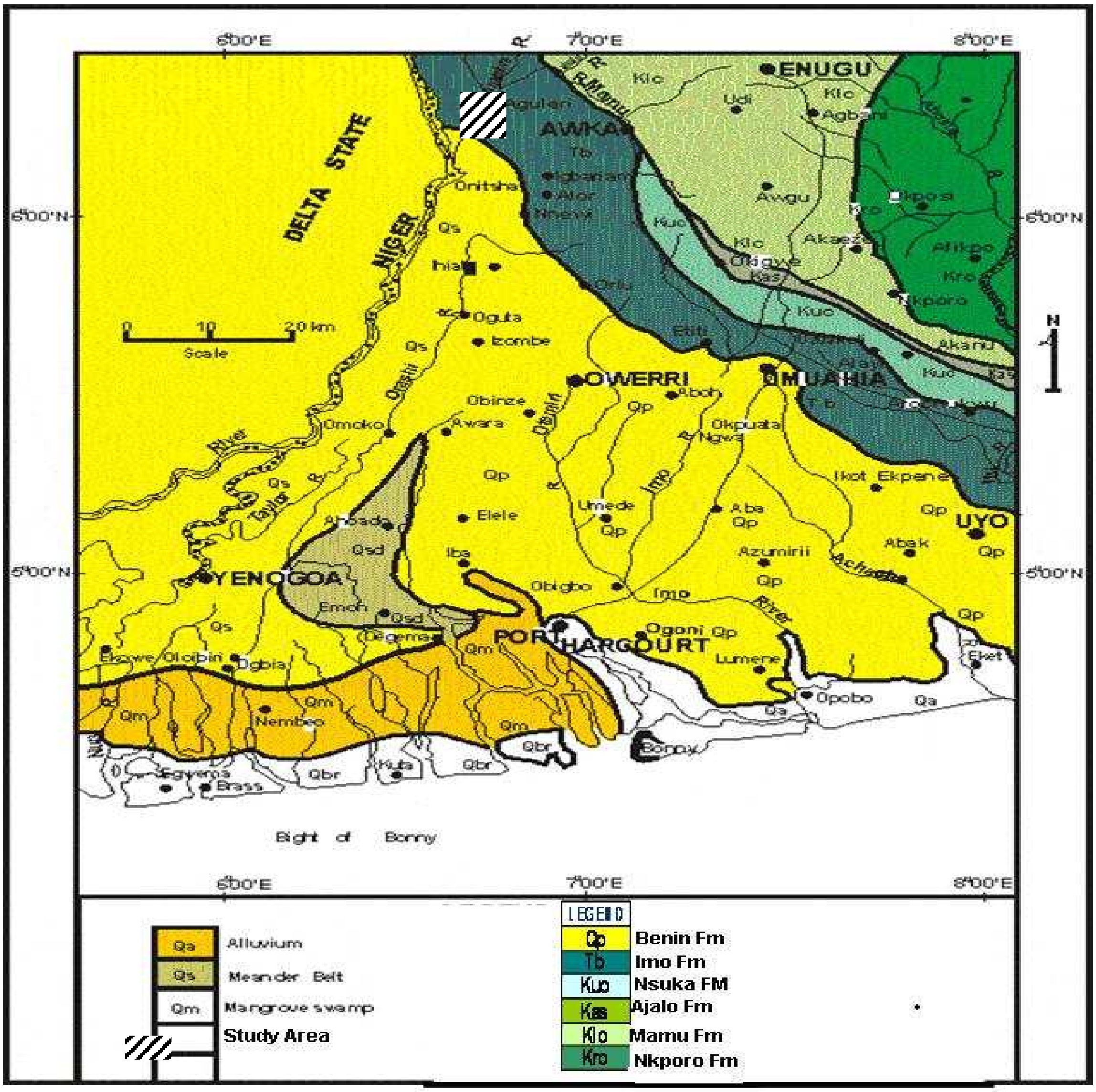


Fig. 2.0: Geologic Map of the Study Area

Hydrogeologically, the Imo Formation is an aquiclude characterized by thick deposits of poorly sorted sediments, irregularly shaped aquifers systems and deep water table. However, it does contain some thin lenses of sand bodies in alternation with the shales, which when encountered and saturated could yield productive boreholes under confined and unconfined conditions.

METHODOLOGY

2-D resistivity imaging surveys were performed along four profile lines each of length 1000m; with inter traverse spacing of 250m within a (1x1) km^2 area. Data acquisition was performed by Wenner – alpha array with a 10m electrode to a maximum of 60m spacing using the Abem

Terameter SAS 1000C. The electrodes were moved in a lip frog manner along the profile lines for each value of the electrode spacing “a” (m) to ensure continuous subsurface coverage (Fig. 3.0).

The data acquired was processed by using RES2DINV Software. The software employs a finite-element approach to the forward model and a least squares optimization technique to generate the true resistivity distribution in the subsurface (6). The algorithm is based on the minimization of the misfit between observed and calculated values in an iterative manner until a certain error level is reached, and the solution obtained. The results in the present study are presented as inverted models of the true resistivity distribution with depth along the profiles.

RESULTS

The results of the inverse models are displayed as cross sections of the true resistivity distribution of the subsurface with depth along each profile (Fig. 4.0). Varying anomalous features along each profile were delineated from the distribution of areas of low and high resistivities. The models exhibit gradational change in resistivity with depth, with varying subsurface topographies. The RMS errors vary from 2.2% to 6.6%, a reflection of the degree of fit between the calculated and field pseudosections.

P1-profile delineated three hemispherical low resistivity anomalies to the NW, centre, and SE of the profile. The most prominent of these structures is isolated to the NW of the section towards the Offia river valley, at surface points 225m to 393.75m. This is followed by the second structure centered on the profile at surface points 450m to 581.25m, and finally the less pronounced structure to the SE of the section.

The two dominant low resistivity structures have resistivity <160Ωm, interpreted as clay/shale formations of thicknesses 60m and 52m, respectively, and depths in excess of 65.0m. This is underlain by sand materials of resistivities >243Ωm to 5473Ωm, with an average thickness of 43m and depth >101m. The bedrock is characterized by high resistivities >5473Ωm. The rock formations along this profile dip towards the river valley to the NW with increasing thicknesses and depths. This cross section has a lithology that varies dominantly from clay/shale to the NW and sandstone to the SE of the profile.

P2-profile lies to the east of P1-profile, and delineated two low resistivity anomalies to the NW and NE of the profile. The dominant anomaly is situated to the SE, towards the Ikpo river valley, at surface points 600m to 825m, and the less pronounced low resistivity anomaly to the NW towards the Offia river valley. This prominent low resistivity structure has resistivity <206Ωm, interpreted as shale beds which grades into shaley sands with varying moisture content, of thickness 82m and depth in excess of 85m. This is underlain by sand materials of resistivities >323 to 4222Ωm, with average thickness of 60m. The bedrock has resistivity >4222Ωm. The dipping of the rock formations towards the low resistivity structure to the SE is pronounced in the cross section, with an up warp of the bedrock at the centre.

P3-profile lies to the west of P1-profile, and isolated one low resistivity anomaly to the SE of the section. This low resistivity hemispherical anomaly is situated at surface points 600m to 750m, with resistivity <477Ωm, interpreted as saturated sands of thickness 80m, with an overlying top soil of shale. This is underlain by sand materials with resistivities >682Ωm to 5693Ωm in the entire section with average thickness of 62.0m. The bedrock resistivity is >5693Ωm. The rock formation dips generally towards this structure to the SE of the section.

P4-profile also lies to the west of P_1-profile, and isolated two poorly defined low resistivity anomalies to the NW of the section. These structures have resistivities <691Ωm, interpreted as sand materials with thicknesses 68m and 30m, respectively, with a top soil of shale. From the SE to the NW below the low resistivity structures, the formation becomes dominantly sandy and dips towards the NW, with slight up warp of the bedrock at the centre of the section. Its resistivity varies from <1,137Ωm to 19,036Ωm. The bedrock has resistivity >19,036Ωm.

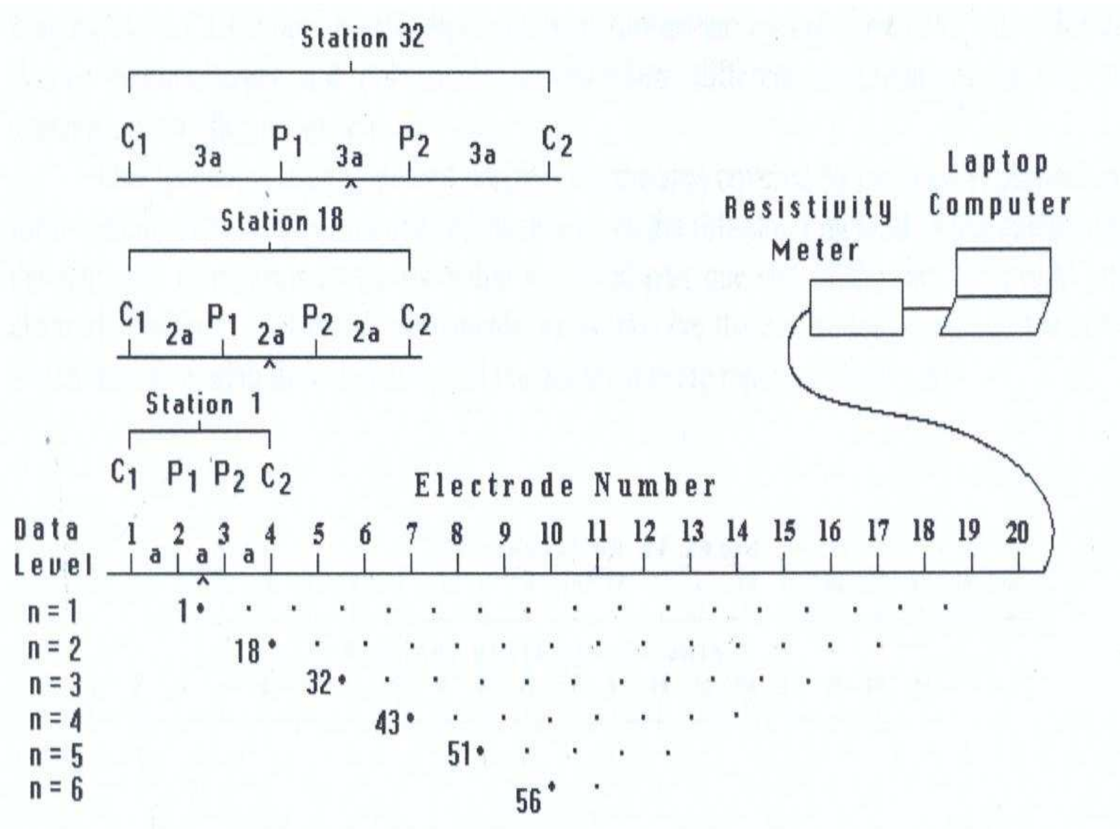
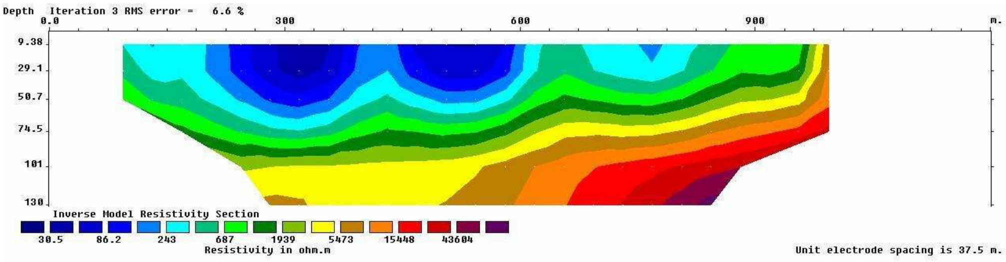
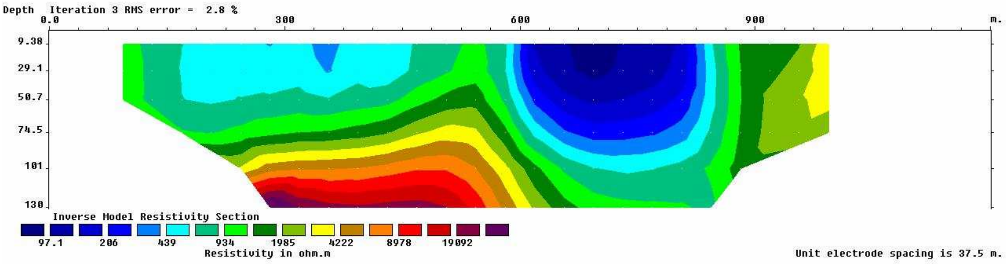


Fig. 3.0: The arrangement of electrodes for a 2-D electrical survey and the sequence of measurements used to build a pseudo section (Adapted from Loke, 1999).

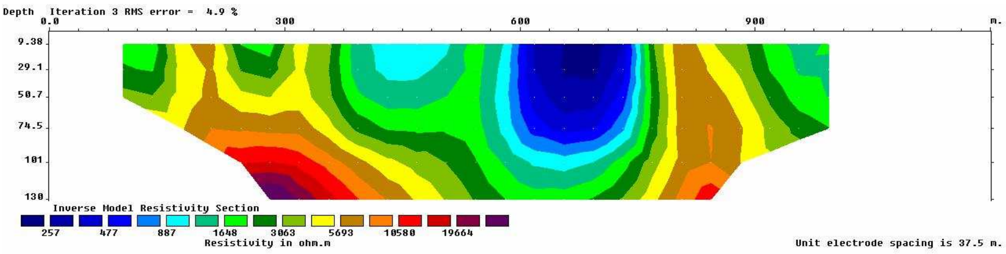
P_I Profile



P_2 Profile



P_3 Profile



P_4 Profile

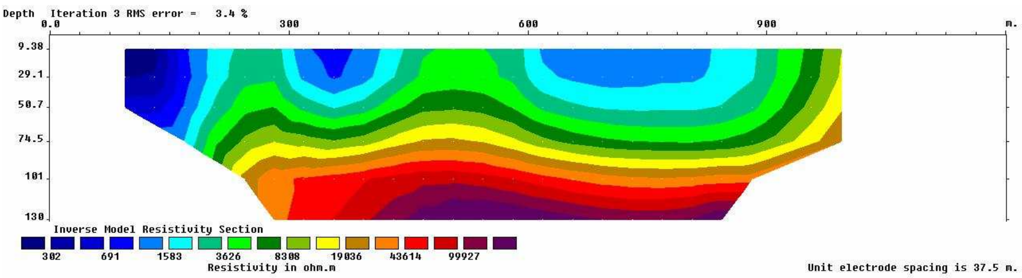


Fig. 4.0: Inverse model sections of the traverses

DISCUSSION

Results of field investigations along the four profiles, presented as inverse models of the true resistivity distribution of the subsurface, exhibits a smoothly varying resistivity distribution and varying topographies with depth. The inverse models have root mean square (RMS) errors of 2.2% to a maximum of 6.6%. This points to good agreement between the measured and calculated pseudosections, and implies that the geological structures in the area of study can be approximated with real 2-D structures.

The resistivities of the inverse models vary from 15.2 to 99,927Ωm in the profiles, with the lowest resistivity (15.25Ωm) along P_1-profile and highest bedrock resistivity (99,927Ωm) along P_4-profile. Two anomalous regions were isolated along the profiles. These are low resistivity hemispherically shaped zones, and a generally zone of smoothly varying resistivities with depth.

The low resistivity hemispherical anomalies were delineated to the NW and central portions of P_1-profile, with a resistivity range of 15.25 to <160Ωm. This was interpreted as impermeable rocks of clay/shale of thicknesses 60.0m and 52.0m, respectively. This has a lateral extent of 375m overlying high resistivity sandy formations. This presumably, is underlain by low resistivity impermeable shale layer at depth to create a confined aquifer condition.

This presumption was validated by the existing abandoned artesian well located 20m to the east of this profile. The artesian well falls almost to the centre of the low resistivity hemispherical structure to the NW of the profile, which suggests that these low resistive structures are probably confined aquifer zones in the area. However, there were no borehole data to calibrate the 2-D result in other to estimate the depth and lithology of this confined aquifer, the existing artesian well immensely aided the interpretation of the 2-D results.

Low resitivity hemispherical anomalous zones were also isolated along profiles 2, 3, and 4, with P_2-profile being more promising in terms of its resistivity. The structure is delineated to the SE of the profile towards the Ikpo river valley. The resistivity ranges from 48.55 to 206Ωm, and interpreted as impermeable shale beds which grades into shaley sands, with a thickness of 82m and lateral extent of 225m, which could be exploited for confined aquifer conditions. Confined aquifer structures appear to be well developed towards the river valleys to the NW and SE, and should be exploited with adequate geological and geoelectrical investigations.

The high resistivity zones are smoothly varying in all the profiles, likely pointing to changes in facies with depth. Fine sand to coarse sand stones dominates the shallow portions of the sections, while gravely sands dominate at depth. The resistivities of the fine sand – coarse sandstones varies from 243 (P_1) to 19,035Ωm (P_4) which constitute the unconfined aquifers in the area, while the resistivities of the gravely sands varies from 6,600 (P_2) to 99,927Ωm (P_4).

The subsurface topography generally dips to the NW and SE of the river valleys in the profiles, with major bedrock upwarp along P_2-profile. These revelations are in conformity with surface topographical expressions. These results have elucidated the robustness of 2-D electrical imaging in defining aquifer configuration, distribution of subsurface rocks, and subsurface topographies in the study area.

CONCLUSION

2-D resistivity imaging was adopted in the exploration of the groundwater resources in Enugu-Agidi, SE of Awka. The inverse resistivity models have RMS errors of between 2.2% to 6.6%, which implies that the geological structures can be approximated with real two-dimensional structures in the area.

The resistivity of these inverse sections varies from 15.25Ω along P_1-profile and the highest bedrock resistivity of 99,927Ωm along P_4-profile. Three promising confined aquifer structures were delineated along P_1- and P_2-profile lines towards the river valleys to the NW and SE, respectively. These structures were confirmed by the artesian well situated 20m east of P_1-profile which falls almost to the centre of the low resistivity structure to the NW towards the river valley of P_1 - profile.

Fine sands to coarse sandstone dominate the shallow portions of the profiles, which constitute the unconfined aquifers, and gravely sands dominate at depth. The subsurface topography generally dips to the NW and SE of the river valleys in the profiles, with major bedrock up warp along P_2-profile, in agreement with surface topographical expressions.

Acknowledgement
The author is grateful to the Anambra – Imo River Basin Authority for the opportunity to carry out this investigation. Special thanks go to the Consultancy, Research, and Development (CORDEC) of the University of Port Harcourt, for their support and guidance in acquiring the data used in this study.

REFERENCES

[1] K.A.Bakhtiar, *Journal of Zankoy sulaimani*, **2005** 8 (1) pp 5-14
[2] Carlyle, M., Partha, R., Troy, B., and Jim, M. (**2006**): *Geophysics* Vol. pp1177-1181
[3] G. Gokturkler, C. Balkaya, Z. Erthan, and A. Yurdakul, *Environmental Geology*, **2008** 54, pp 1283-1290
[4] D. H. Griffiths, and R. D. Barke, *Journal of Applied Geophysics*, **1993** 29, pp211-266.
[5] S. Franjo, U. Kosta, and D Ivan, *Rudarsko-geolosko-naftni Zbornic*, **2003** 15, pp 19-29.
[6] M. H. Loke, and R. D. Barke, *Geophysical prospecting*, **1998** 44, pp 131-152.
[7] R. C. Wilson, *Bulletin of Geological Survey of Nigeria*. **1925** 19, pp 95-102.