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Full Length Research Paper

Geoelectrical sounding for estimating groundwater potential in Nsukka L.G.A. Enugu State, Nigeria

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Sixty six vertical electrical soundings (VES) have been used to evaluate the ground water potential in Nsukka Local Government Area of Enugu State, Nigeria. The project domain lies within longitudes 7°13′00″ - 7°35′30″ and latitudes 6°43′30″ - 7°00′30″ and covers an area of about 480 km² over three main geological formations. The resistivity and thickness of the aquiferous layer at various observation points were determined by the electrical survey. Also zones of high yield potentials were inferred from the resistivity information. Transmissivity values were inferred using the calculated Dar Zarrouk parameters. Results show highly variable thickness of the aquiferous layer in the study area. Aggregate transverse resistance indicates greater depth of the substratum in the southeastern part of the study area, underlain mostly by the Ajali Formation. High values of transmissivity also predominate, thus suggesting thick and prolific aquiferous zone.

Key words: Resistivity, transverse resistance, transmissivity.

INTRODUCTION

Nsukka Local Government Area lies between longitudes 7°13′00″ - 7°35′30″ and latitudes 6°43′30″ - 7°00′30″ in Enugu State, Southeastern Nigeria. It spreads over an area of about 480 km^2 (Figure 1). As a result of increasing need for water in the area, in addition to lack of surface water sources, lately there has been a greater interest in the use of groundwater. However, various problems exist emanating from the insufficient knowledge of the subsurface geophysical conditions in many parts of the area. The exploitation of groundwater involves the sinking of boreholes at sites, which sometimes are chosen arbitrarily. In several cases this resulted in abortive boreholes, extremely low yield and total failure of some supply wells in the area. Thus proper precautions must be taken to reduce the risk of spending large sums of money in sinking abortive boreholes. In the present study, an attempt has been made to establish a geophysical database for the area from the interpretation of 66 vertical electrical sounding conducted in 22 locations within the area. It is hoped that such a database would enhance the success rate of future groundwater exploration and exploitation in the area.

Physiography

The study area shows two major types of landforms which consist of a high relief zone with undulating residual hills, valleys and the lowland areas (Figure 2). The residual hills are the remnants of the Nsukka formation which constitute the surface layers. These layers are highly weathered and eroded and overly the Ajali Sandstone. The lowlands are most profound in the northwestern part of the study area and serve as the collecting centre of the run offs during the rainy season.

Geology

The study area consists of three major geologic formations; the Mamu, Ajali and Nsukka formations, respectively (Figure 3).

The Mamu formation, previously known as lower coal measures (Reyment, 1965), consists of fine-medium grained, white to grey sandstones, shaly sandstones, sandy shales, grey mudstones, shales and coal seams. The thickness is about 450m and it conformably underlies the Ajali formation. The Ajali formation, also known as false bedded sandstone, consist of thick friable, poorly sorted sandstones, typically white in colour but sometimes iron-stained. The thickness averages 300 m and is often overlain by considerable thickness of red earth, which consists of red, earthy sands, formed by the weathering and ferruginisation of the formation. The

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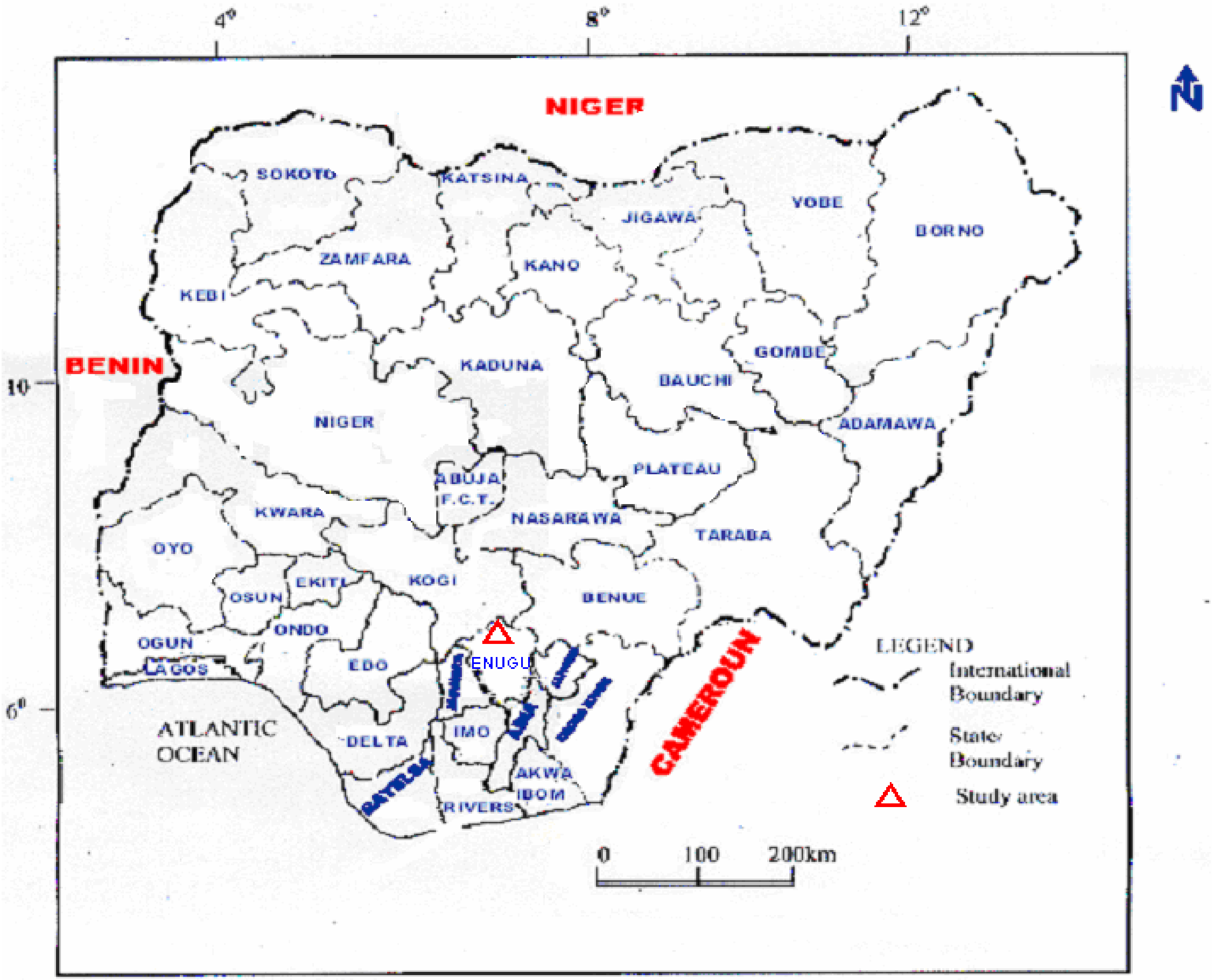

Figure 1. Map of Nigeria showing the location of the study area.

Nsukka formation, previously known as the upper coal measures (Reyment, 1965), lies conformably on the Ajali sandstone. The lithology is very similar to that of Manu formation and consists of an alternating succession of sandstone, dark shale and sandy shale, with thin coal seams at various horizons. Eroded remnants of this formation constitute outliers and its thickness averages 250 m.

Hydrogeology

The hydrologic units within the study area include confined, semi-confined, water table and perched aquifers. Confined conditions exist over the Ajali sandstones in areas overlain by the Nsukka formation and also in the Manu formation where overlying Ajali sandstone and Nsukka formation are considerably reduced in thickness or eroded. Semi-confined situation exist in places and usually comprise interbedded thick sequence of sand (aquifer) and sandy clay or clayey-sand aquicludes. Various aquifers in this group occur in the upper to middle horizons of Ajali sandstone and in the upper section of the Manu formation and constitute the partial recharging zones for the deeper-seated confined aquifers (Egboka and Onyebueke,1990; Akudinobi and Egboka, 1996).

Unconfined aquifer units in the study area occur mostly in the Ajali sandstone and represent sections of the formation where the semi-permeable or impermeable cap beds have either been eroded or they are absent. The thickness of these aquifer units vary from shallow to deep in places. Perched aquifer conditions occur mostly in the lateritic or red earth cover over the Nsukka formation and in the upper sandy units of the formation. The perched aquifer is generally thin and measurements in dug holes gave thickness values ranging from 3 - 8 m with an average of about 4.6 m (Uma, 2003).

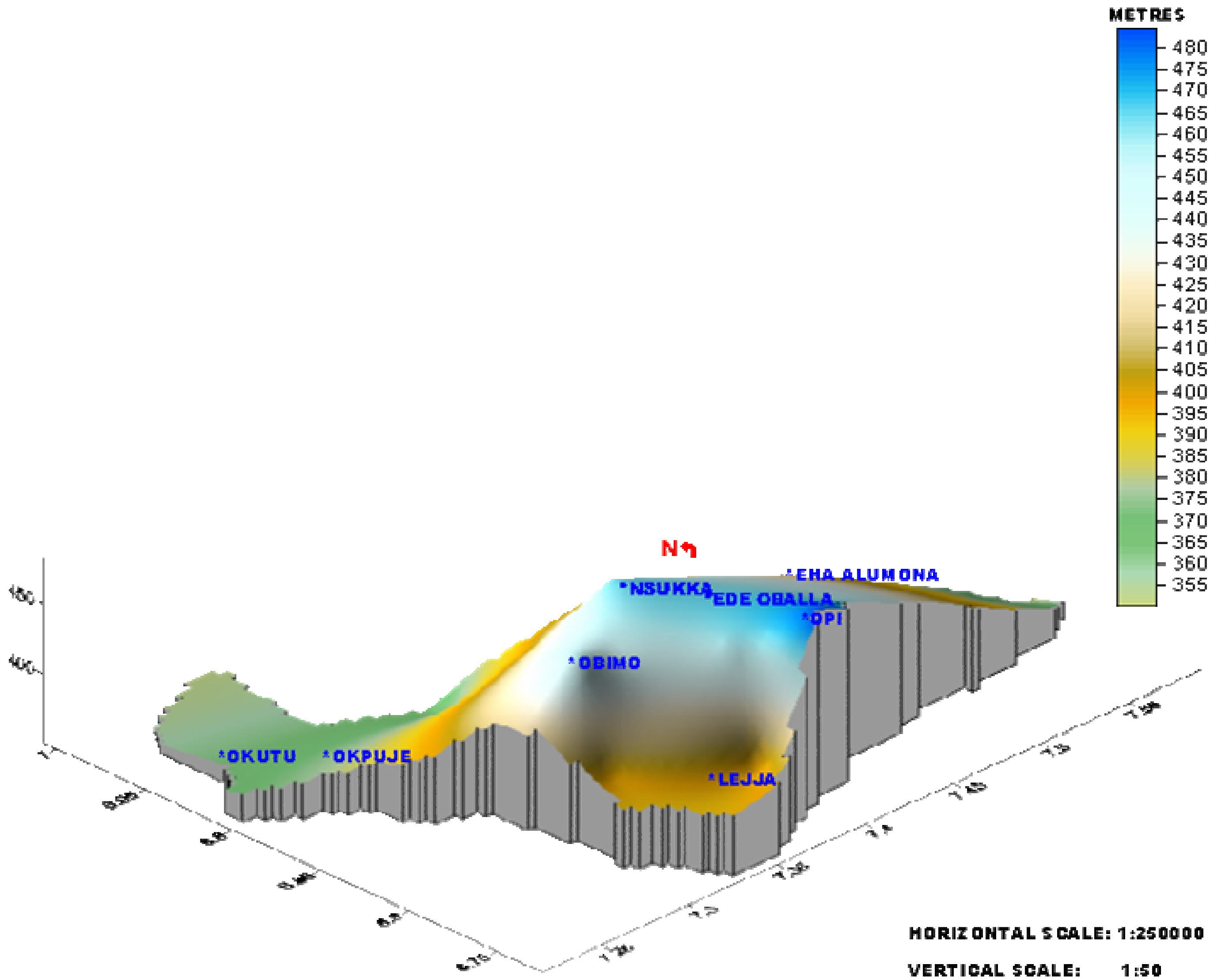

Figure 2. Surface map of the study area.

DATA ACQUISITION AND INTERPRETATION

Sixty six vertical electrical soundings (VES) were carried out in twenty two locations within the study area (Figure 3). The Schlumberger electrode configuration was used with maximum current electrode separation ranging from 800 m to 1.2 km.

The initial interpretation of the VES data was accomplished using the conventional partial curve matching technique, with two-layer master curves in conjunction with auxiliary point diagrams (Orellana and Mooney, 1966; Koefoed, 1979; Kellar and Frischknecht, 1966). Based on this, estimates of layer resistivities and thickness were obtained, which served as a starting points for computer-assisted interpretation. The computer program OFFIX was used to interpret all the data sets obtained. From the interpretation of the resistivity data, it has been possible to compute, for every VES station, the longitudinal conductance.

$$S = hi / \ell i \quad (1)$$

and the transverse resistance

$$R = hi\ell i \quad (2)$$

Where hi and ℓi are thickness and resistivity respectively, of the aquiferous layer (Maillet, 1947).

Transmissivity values for the aquiferous layer have also been estimated from equation (2) above using the analytical relationship of Niwas and Singhal (1981). They showed that:

$$Tr = K\sigma R = kS/\sigma \quad (3)$$

where σ is the aquifer conductivity ($1/\ell$) and K is the hydraulic conductivity of the aquifer. In the present study, the quantity (Kσ)

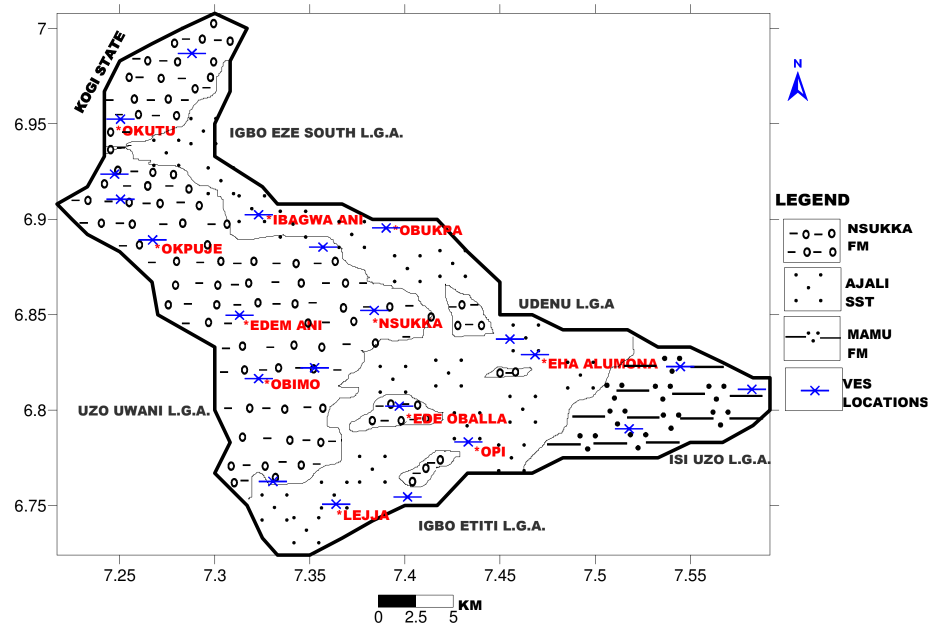

Figure 3. Geologic map of the study area.

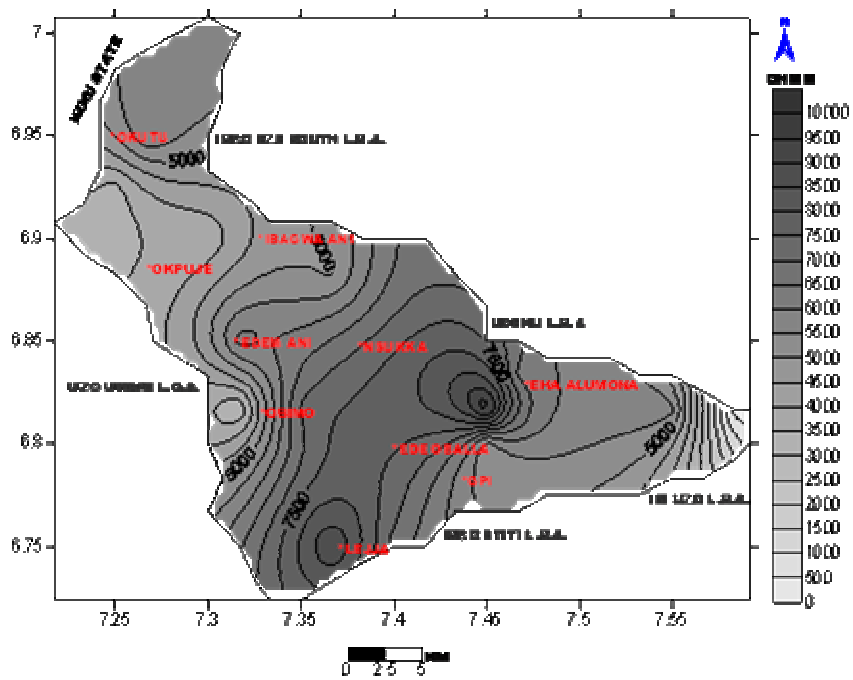

Figure 4. Apparent resistivity of the aquiferous layer.

was assumed to remain fairly constant in areas of similar geologic setting and water quality (Niwas and Singhal, 1981).

RESULTS AND DISCUSSION

Maps of the apparent resistivity, the thickness, the transverse resistance and the transmissivity of the aquiferous layer have been constructed using the results of the resistivity sounding interpretation. The resistivity variation is shown in Figure 4, while the isopach map of the aquiferous layer is shown in Figure 5. Aquifer thickness is variable, increasing from the east and northwest to the

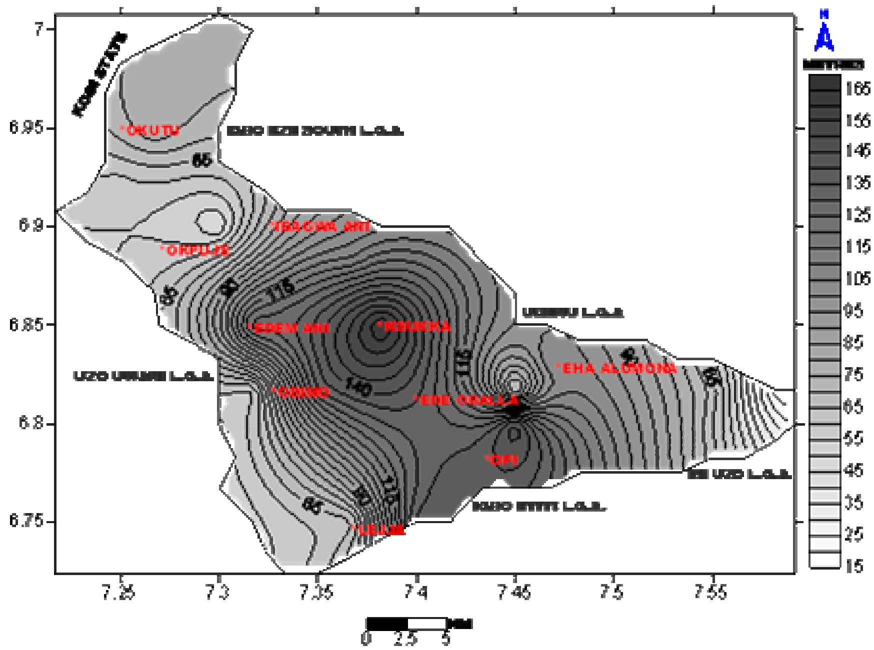

Figure 5. Isopach map of the aquiferous layer.

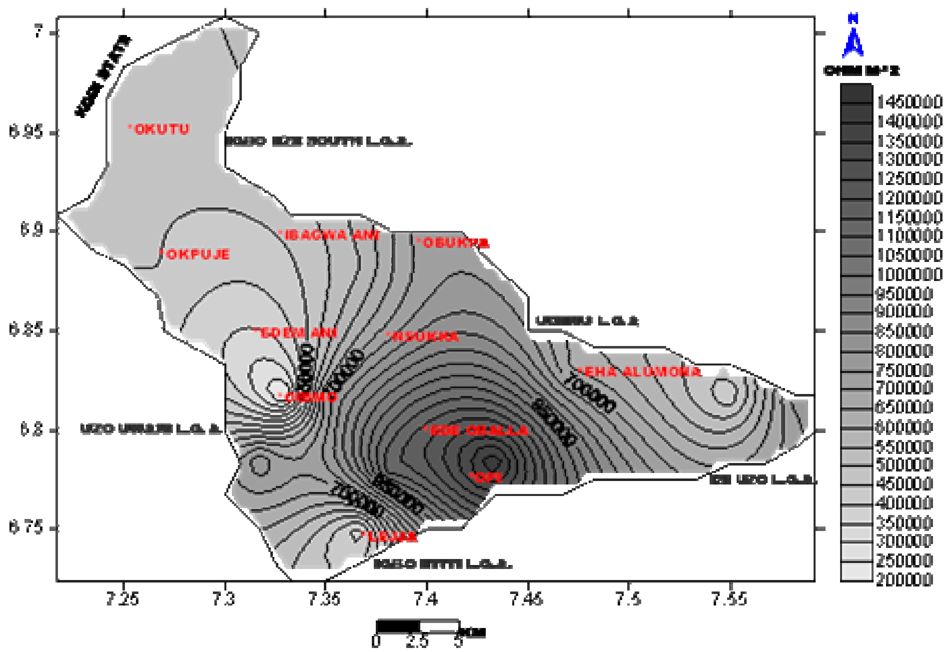

Figure 6. Transverse resistance map of the study area.

central part of the study area. Aquifer resistivity also shows similar trend. However, the resistivity of the layer depends more on the saturation of the layers and not necessarily on the thickness of the aquifer, hence higher resistivities may not correlate with areas of thicker aquifer. The distribution of the aquifer transverse resistance computed from the vertical electrical sounding interpretation is shown in Figure 6. Maximum values are observed around Ede-Oballa-Opi axis on the south-eastern part on the study area. Transmissivity distribution (Figure 7) also shows similar trend with the highest value of 2423 m²/day at Ede-Oballa-Opi, thus suggesting very

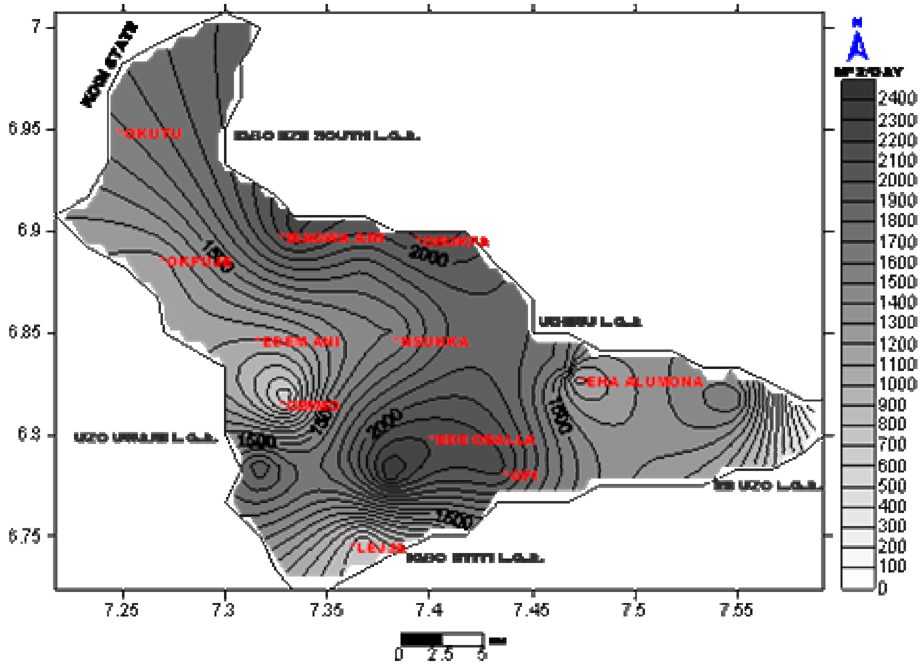

Figure 7. Transmissivity map of the study area.

high quality reservoir. This value is comparable to those of Onuoha and Mbazi (1988), Ezigbo and Ozoko (1989); Egboka and Onyebueke (1990), Uma (2003) and Ezeh (2008), for Ajali Sandstone. Relating the transmissivity distribution (Figure 7) and geology (Figure 3), it is evident that higher transmissivities are expected in areas underlain by the Ajali formation.

Conclusion

The application of VES technique has provided detailed information on the thickness and hydrogeoelectrical characteristics of the aquifer in the study area. The presence of thick and highly prolific aquiferous zone assures the area of adequate water resource.

The study will no doubt guide the borehole programmes and provide additional database for groundwater development and utilization in the area.

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