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Evaluation of Aquifer Characteristics and Ground Water Potentials in Awka, South East Nigeria, Using Vertical Electrical Sounding

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Abstract: Geoelectrical sounding method was adopted in the evaluation of the aquifer characteristics and ground water potentials in Enugu-Agidi to the SE of Awka. A total of 30 vertical electrical sounding stations were occupied along five traverse lines within a (1×1) km² area using the Schlumberger electrode configuration. The results show a 5-6 interpretable geoelectric layers with a lithologic sequence consisting of thick shale beds alternating with thin beds of sandstone. The lithology varies dominantly from shale towards the Offia river valley to the NW and grades into sandstone to the SE in all the traverses. The study delineated two confined aquifers along traverse one (1) at VES 2 and 3 locations and shallow unconfined aquifers in the entire traverse. The confined aquifers have resistivities varying from 252 to 277 Ωm , at the depth range of 130 to 205 m and thicknesses varying from 18 to 26 m, respectively. Estimated aquifer resistivities, depths, thicknesses and transmissivities for the unconfined aquifers varies from 292 to 6,500 Ωm , 25 to 87 m, 5.7 to 38.2 m and 1,027.50 to 105,000 Ωm^2 , respectively. The aquifer depth and aquifer transmissivity maps generated from geoelectric parameters show that large aquifer depths corresponds to low transmissivity values and vice versa, which are attributed to the increase in shale content with depth. The viability of deep boreholes under unconfined aquifer condition is poor in the study site based on the depth of investigation, such that the prospects for shallow boreholes with high transmissivities is high towards the central and SE of the site from the river valley. This has serious consequences on the quality of the water and the sustainability of the boreholes. The general ground water potential in the site is poor due to its geological characteristics. Excellent and sustainable yields are obtained from confined aquifers in the area when intercepted at depth, which is highly localized.

Key words: Resistivities, confined aquifer, unconfined aquifer, aquifer depth, aquifer transmissivity

INTRODUCTION

The growing demand for potable water supply has been the major problem of most urban centres in Nigeria. Potable drinking water is the basic need for any society to lead a healthy and productive life and for industries and agriculture to flourish. It is estimated that approximately 100l/day of safe drinking water is the minimum amount of water required per

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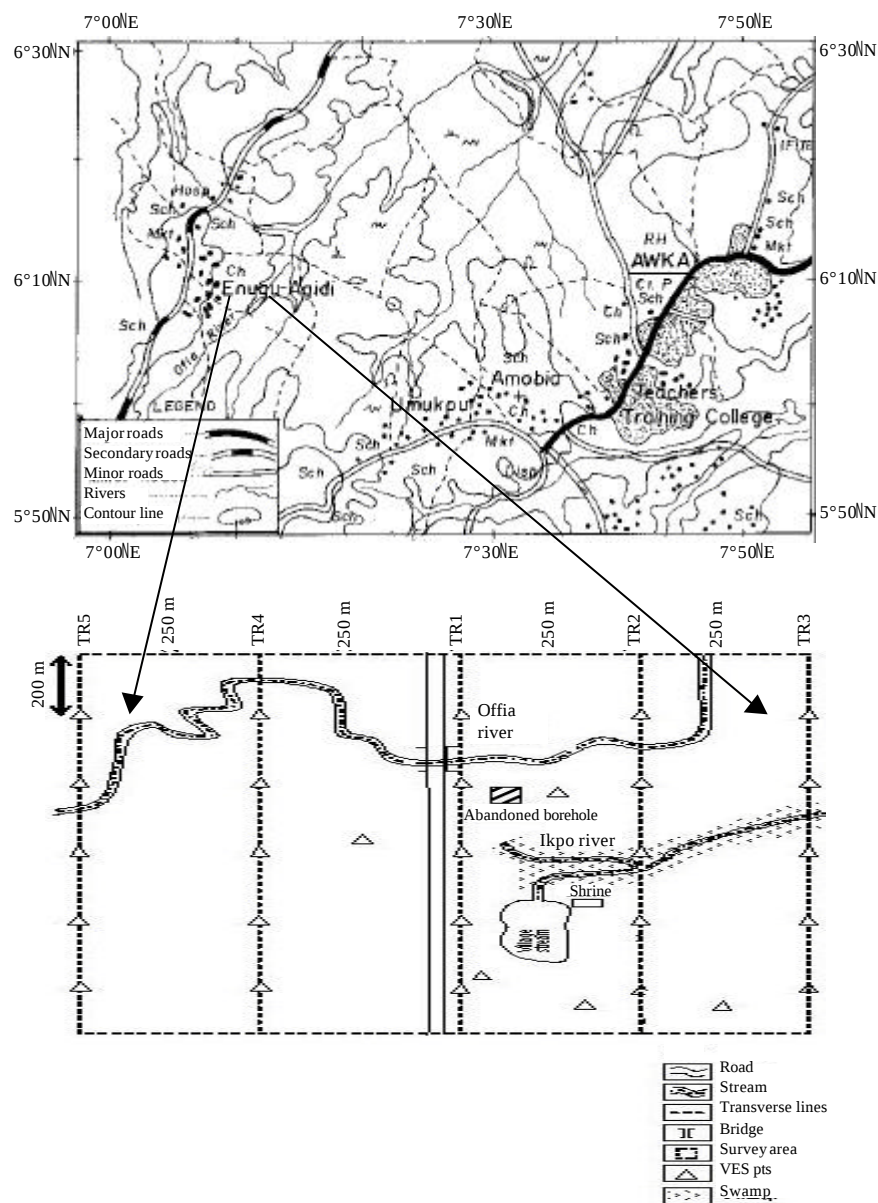


Fig. 1: Location map of the study area showing sounding points

person for good health (Falkenmark *et al.*, 1989). This is however, in variance to what obtains in most of our urban towns, where people are constrained to manage water because of inadequate supply.

The study area is located in Enugu-Agidi within the Offia river valley to the SE of Awka. It is delineated by longitude 5°50' N to 6°30' N and latitude 7°00' E to 7°50' E (Fig. 1). Awka and its environs has witnessed rapid growth in economic activities and increased urbanization in the recent past. This has made it difficult for the government to meet with the

water needs of the town. There are no sustainable surface water sources which can be impounded into dams to serve the water needs of its increasing population and thus, the town is heavily dependent on ground water for domestic, industrial and agricultural uses.

Ground water is expected to form a significant part of the water resources of Awka and its environs, considering the enormous tropical rainfall experienced each year. Unfortunately, Awka lacks enough ground water resources because of its distinct location and geological complexities. Efforts by the government and individuals to sink boreholes have not been very successful. When boreholes are drilled, the cost is prohibitive, aquifer depths are large if any and the yields in most cases are not encouraging.

The water table in the area, from available geological data and borehole data is estimated to lie within the depth range of 180-540 m. This implies that only wealthy individuals and the government can really sink boreholes because of the attendant cost. The sketchy nature of the aquifers and the lack of detailed hydrogeophysical data bank of the town are the major factors militating against the search for portable ground water. This study however is intended to form a base line study of the hydrogeophysical characterization of the town using geoelectrical method.

Among the geoelectrical methods, vertical electrical sounding technique has been frequently used in hydrogeophysical studies for ground water in both porous and fissured media (Onuoha and Mbazi, 1988; Mbonu *et al.*, 1991; Franjo *et al.*, 2003). This method is based on the response of the earth to the flow of regulated input current source. It is an efficient and cost effective geoelectrical method and provides a 1-D electrical impedance of the ground based on surface measurements, from which water saturation and lithological information are obtained.

This study attempts to investigate the subsurface hydrogeological conditions and to assess the ground water potentials of the town. The main objective is to delineate probable confined and unconfined aquifers that could be developed into productive boreholes. This will entail the estimation of geoelectric parameters (layer thicknesses and resistivities), from field geoelectrical measurements which are used in the determination of the Dar-zarouk parameters of transverse resistance (R) and longitudinal conductance (S) and hence the hydraulic conductivities (K) and transmissivities (T).

A contour map of the depth to the aquifers and transmissivities will be attempted, which will permit the assessment of the aquifer characteristics and ground water potentials and probable locations where sustainable water boreholes could be developed in the area.

GEOLOGY OF THE STUDY AREA

Enugu-Agidi lies within the Anambra basin in the lower Benue trough tectonic unit. The geology and regional stratigraphy of the trough has been studied and described in details by many researchers, including Wright (1968). The Benue trough evolved during a tensional regime in the Cretaceous until Santonian-Campaman times when there was a wide spread regional tectonics in the trough initiating the formation of the present day Anambra basin (Reyment, 1965).

Sediments in the basin were laid during the Cretaceous with a NE-SW strike. These sediments have layers gently dipping in the direction of the North. Awka town and its environs are mainly underlain by the Imo shale formation. This consists of thick clayey shale, fine-textured, dark-grey to bluish-grey with occasional admixture of clay ironstones and thin sandstone bands (Fig. 2). The formation becomes sandier towards the top where it may consist of alternating bands of sandstone and shale (Wilson, 1925).

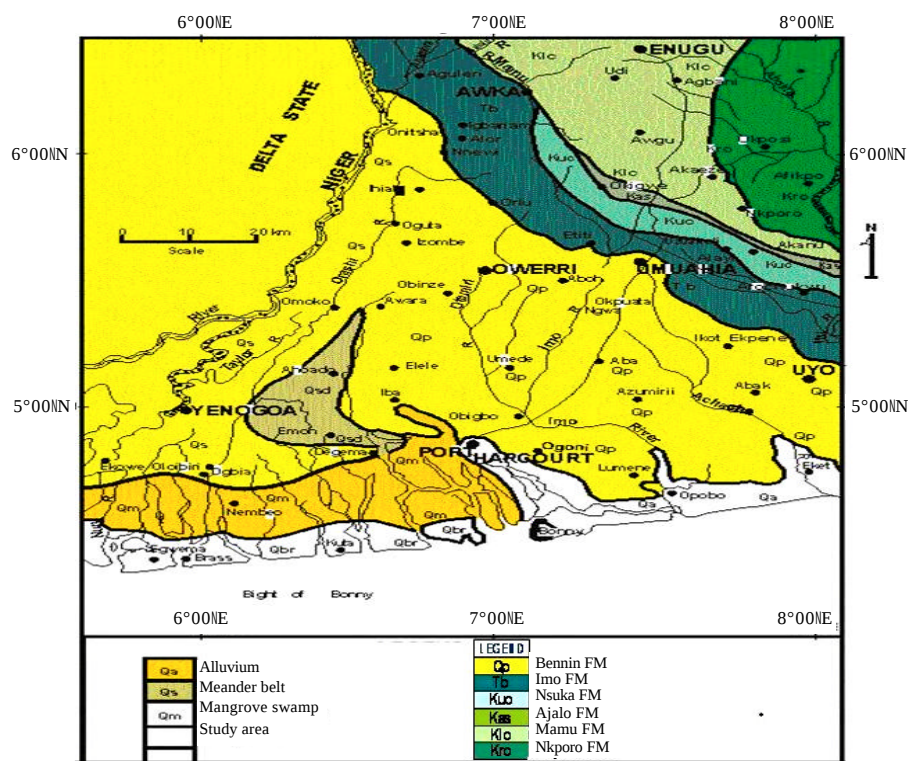


Fig. 2: Geologic map of the study area

The Imo shale formation is an aquiclude, but contains some thin lenses of sand bodies which when saturated and probably encountered, could yield productive boreholes under confined and unconfined conditions. The shales are hydrogeologically important since they form the confining impermeable layers. Impermeability is their major hydrogeological characteristics.

MATERIALS AND METHODS

The study area spanning a total $(1 \times 1) \text{ km}^2$ land area, was divided into 5 traverse lines, each of length 1000 m, with inter traverse spacing of 250 m. A total of 30 VES positions were occupied using the Schlumberger electrode array and Abem Terameter SAS 1000C, with a digital readout meter. Along each traverse, 5 VES positions with inter-VES spacing of 200 m were run to the NW-SE along the traverses within the project site (Fig. 1). The electrode spacing used has a maximum spread of $AB/2 = 600 \text{ m}$ and $MN/2 = 50 \text{ m}$, with regard to target depths of between 150-280 m.

Location for depth probes (VES point) were chosen after a detailed hydrogeological study of the area. Survey lines were in some places shifted to avoid obstacles and repeat readings were taken at the end of line to ensure continuity of the electrical response of the subsurface. Measurements of the resistance $R (\Omega)$ values at each VES point was recorded for subsequent analysis.

RESULTS AND DISCUSSION

The apparent resistivity data $\rho_a(\Omega m)$ from field measurements were used as inputs to a computer aided processing using Schlumberger analysis software to generate model curves. These model curves were adjusted through a minimization procedure in an iterative manner to ensure a match with the field curves from which appropriate models were obtained. The results of the VES's are presented as geoelectric sections of the true resistivity distribution of the earth with depth, having 5-6 interpretable geoelectric layers along each traverse.

A typical stratigraphic section which fits the VES model curves along traverse 1 is shown in Fig. 3a-e. It depicts a geoelectric section consisting principally of alternating sequence of shales and sandstones of varying resistivities and thicknesses in the entire

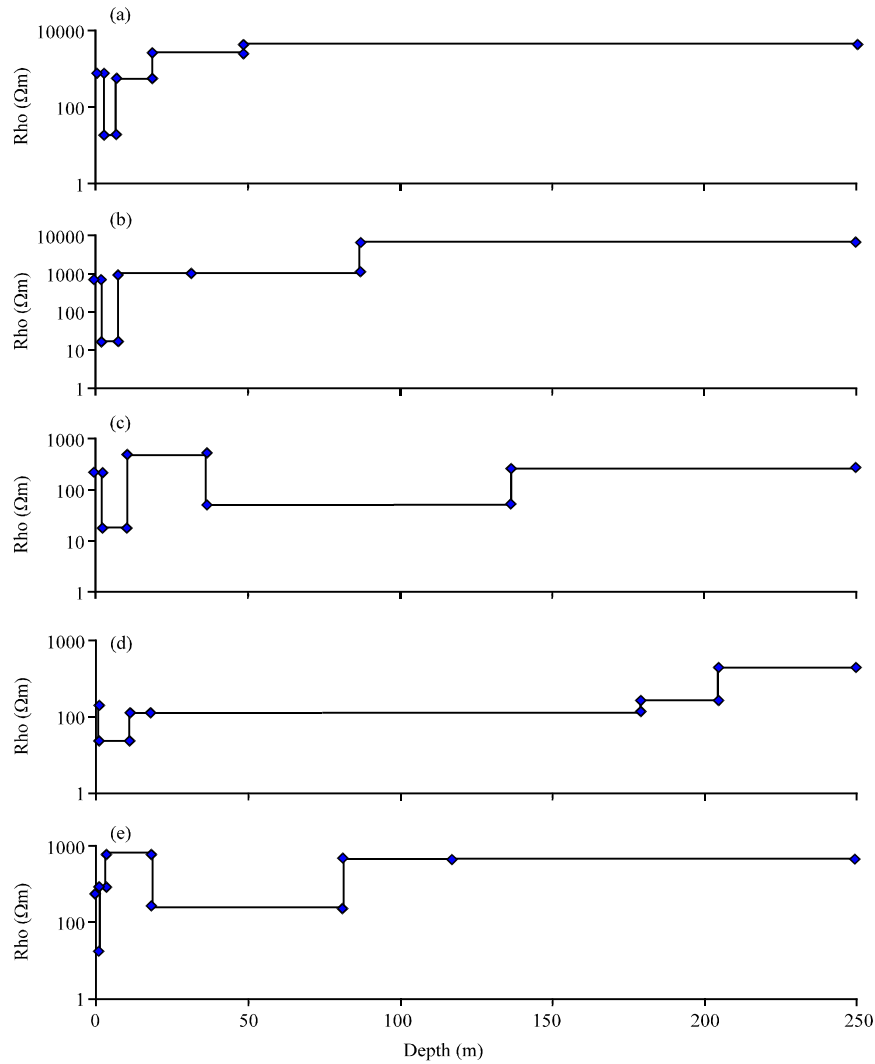


Fig. 3: A typical stratigraphic section which fits the VES model curves along transverse 1, (a) VES 1 (Tr1), (b) VES 2 (Tr1), (c) VES 3 (Tr1), (d) VES 4 (Tr1) and (e) VES 5 (Tr1)

traverse. The resistivity distribution of the rock materials with depth along the traverses, revealed confined aquifers along traverse 1 and unconfined aquifers in all the traverses.

Traverse one at VES location 2 and 3 show remarkable geologic features based on the resistivity distribution of the rock layers with depth. They consist of an overlying massive shale bed of resistivities 121 and 52 Ωm , at depth of 179 and 137 m and thicknesses 178.7 and 100 m, respectively. This in turn overlies a sand layer with resistivity 277 and 252 Ωm , at depth of 205 m for VES2 and depth exceeding 130 m for VES3, with thicknesses 26 and 18 m, respectively. This is presumably, underlain by massive shale beds at depth based on the geology of the study area. The presence of this type of lithological sequence based on the VES results of the electrical survey satisfies the condition for the probable existence of a confined aquifer structure in the locations.

The resistivity distribution of the rock materials with depth also indicates that numerous sand beds of varying thickness abounds in the site, more particularly further away from traverse 1 to the other traverses. These sand beds which constitute the unconfined aquifers have resistivities varying from 292 to 6,500 Ωm , depths varying from 25 to 87 m and thicknesses varying from 5.7 to 38.2 m. The resistivity of the aquifers increases towards the SE and to the NW beyond the river valley due to decreasing clay/shale content.

The combination of the thicknesses and resistivities of the geoelectric layers into single variables, the Dar-Zarouk parameters of transverse resistance (R) and longitudinal conductance (S), were used to estimate hydraulic conductivities (K) and hence, the aquifer transmissivities (T) (Maillet, 1947; Kelly, 1977; Ekwe *et al.*, 2006). Using these values, contour maps of the aquifer transmissivities and depths were generated. These enable insights into the aquifer characteristics and ground water potentials in the site.

Both maps show the variability of aquifer transmissivities and depths spatially in the site. High aquifer depths were delineated at the mid-central portions of the map to the East and centrally to the West and South East, having values greater than 40 m to a maximum of 87 m (Fig. 4). Low values of less than 10 m are delineated mostly towards the river valley in the NW. The aquifer transmissivity map (Fig. 5) show that high aquifer transmissivities are delineated at the central portions of the map away from the river valley to the SE, having values of about 105,000 Ωm^2 and values of less than 20,000 Ωm^2 towards the river valley to the NW and East, respectively.

A comparative study of the two maps shows that areas of large aquifer depths have low aquifer transmissivities and vice versa. This however, has its implications on the viability of deep boreholes in the study area based on the depth of investigation.

The results of the geoelectric sounding are quite remarkable, as to the lithological variations, aquifer depths and transmissivities. These properties have bearings to the aquifer characteristics and ground water potentials in the site. The geoelectric sections show a 5-6 interpretable layers with a lithologic sequence which has thick shale beds alternating with thin beds of sandstone. The lithology varies dominantly from shale towards the river valley to the NW, which grades into sandstone to the SE of the river valley and beyond the river to the NW in all the traverses.

The study delineated two confined aquifers and shallow unconfined aquifers in the entire traverses. The confined aquifers were mapped along traverse 1 at VES 2 and 3 locations, with resistivities 277 and 252 Ωm , at depths of 205 m for VES 2 location and depth exceeding 130 m for VES 3 location, with thicknesses of 26 and 18 m, respectively. This was confirmed by the abandoned artesian well located 20 m to the east of VES 2 and 160 m to the SE from the Offia river valley. The well has a maximum yield of about 5.7l/s, cloudy with a characteristics taste, which probably might be the reason for its abandonment. They were no

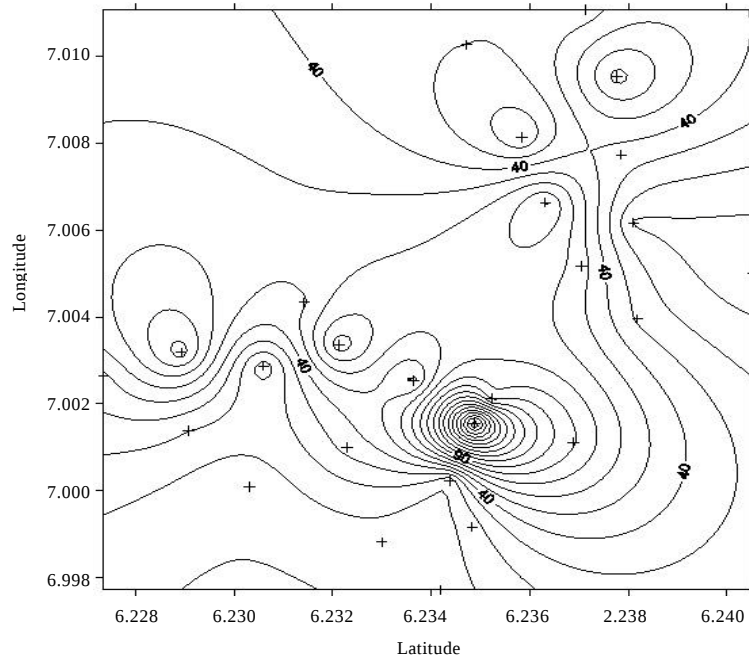


Fig. 4: Aquifer depth map of the study area

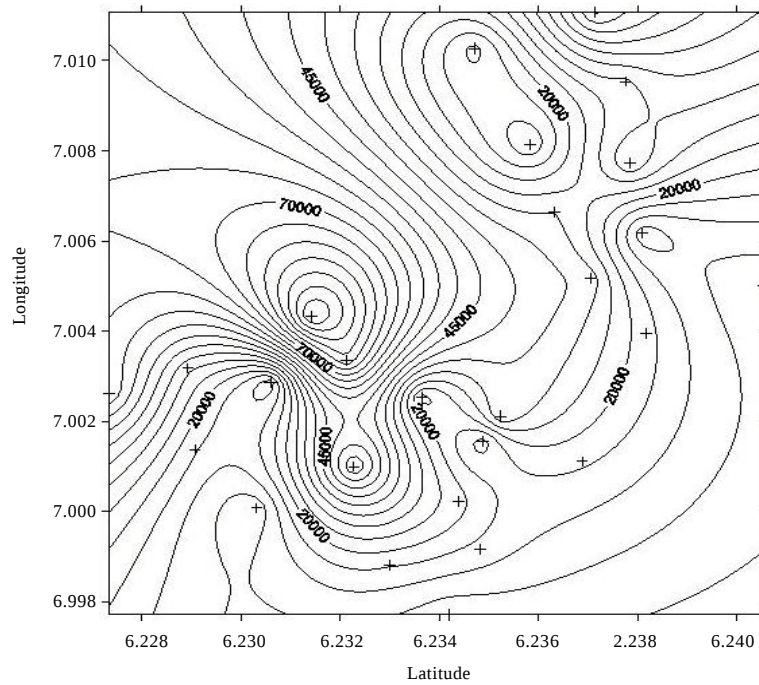


Fig. 5: Aquifer transmissivity map of the study area

borehole data for the artesian well to calibrate the VES data; their existence aided the interpretation of the VES results. It is however, suggested that artesian conditions could exist within 300 m circumference of the respective VES points and could be exploited.

Unconfined aquifers of varying thicknesses were mapped at depth, particularly further away from the river valley to the NW and SE. These aquifers have resistivities varying from 292 to 6,500 Ωm , depths varying from 25 to 87 m and thicknesses varying from 5.7 to 38.2 m. The resistivity of these aquifers increases towards the SE and also towards the NW beyond the river, which is an indication of decreasing clay/shale content and increasing sandstone formation.

The aquifer depths and transmissivity maps estimated from the geoelectric sections revealed the variability of these parameters spatially within the study area. The aquifer depth map show that aquifer depths increases further away from the river valley to the SE and NW of the river. Aquifer depths for sustainable boreholes exist at depths exceeding 40 m at the mid central to the extreme portions of the site to the SE.

The aquifer transmissivity map also show that high aquifer transmissivities are delineated at the mid-central to central portions of the site. High aquifer transmissivities implies zones of high porosities and permeabilities. This has values varying from 20,000 to 105,000 Ωm^2 towards the central portion of the map to the East. The knowledge of the aquifer transmissivity distribution provides a fundamental source of information on the quality of the aquifers and hence, zones where sustainable boreholes could be installed.

The viability of deep boreholes under unconfined aquifer condition is not good in the study site, based on the depth of investigation, since areas of large aquifer depths with appreciable thicknesses have low transmissivity values, which might be attributed to the increase in shale content with depth. The implication of this is that, the prospect for shallow boreholes with high transmissivities is high. This has serious consequences on the quality of the water because of the proximity of the aquifers to the surface and to the sustainability of the boreholes for potable water supply.

The general ground water potential in the area is poor because of its geological characteristics. Excellent yields are obtained from confined aquifers in the area when intercepted at depth, which is highly localized. The results of this study have been validated by drilled boreholes in the site, which authenticates the efficacy and robustness of the geoelectrical method in hydrogeological problems.

CONCLUSION

The geoelectrical investigation of the site revealed a lithologic sequence which consists of thick shale beds alternating with thin beds of sandstone. The lithology varies dominantly from shale towards the river valley to the NW, which grades into sandstone to the SE of the river valley and beyond the river to the NW in all the traverses. The study delineated two confined aquifers along transverse 1 at VES 2 and 3 locations and shallow unconfined aquifers in the entire traverses.

The aquifer depth map show that aquifer depths increase further away from the river valley to the SE and NW of the river, such that aquifer depths for sustainable boreholes exist at depths exceeding 40 m at the mid-central to the extreme portions of the site to the SE. The aquifer transmissivity map also shows that aquifer transmissivity increases further away from the river valley to the SE and NW of the river

Large aquifer depths corresponds to low transmissivity values, which are attributed to the increase in clay/shale content with depth, such that, the viability of deep boreholes under

unconfined aquifer condition is poor in the study site. The implication of this is that, the prospect for shallow boreholes with high transmissivities is high towards the SE and NW of the river, with serious consequences on the quality of the water and the sustainability of the boreholes. The general ground water potential in the site is poor because of its geologic characteristics. Excellent yields are obtained from confined aquifers in the area when intercepted at depth, which is highly localized.

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REFERENCES

- Ekwe, A.C., N.N. Onu and K.M. Onuoha, 2006. Estimation of aquifer hydrolic characteristics from electrical sounding data: The case of middle Imo River basin aquifers, South-Eastern Nigeria. *J. Spatial Hydrol.*, 6: 121-132.
- Falkenmark, M., J. Lindquist and C. Widstrand, 1989. Macro-scale water scarcity requires micro-scale approaches. *Nat. Resour. Forum*, 13: 258-267.
- Franjo, S., U. Kosta and D. Ivan, 2003. Hydrogeological mapping of miocene aquifer by 2-D electrical imaging. *Rudavsko-Geolosko-Naftm Zbornik*, 15: 19-29.
- Kelly, W.E., 1977. Geoelectric sounding for aquifer hydraulic conductivity. *Ground Water*, 15: 420-425.
- Maillet, R., 1947. The fundamental equations of electrical prospecting. *Geophysics*, 12: 529-556.
- Mbonu, P.D.C., J.O. Ebeniro, C.O. Ofoegbu and A.S. Ekine, 1991. Geoelectric sounding for the determination of aquifer characteristics in parts of the Umuahia area of Nigeria. *Geophysics*, 56: 284-291.
- Onuoha, K.M. and F.C.C. Mbazi, 1988. Aquifer Transmissivity from Electrical Sounding Data: The Case of Ajali Sandstone Aquifers South West of Enugu, Nigeria. In: *Ground Water and Mineral Resources of Nigeria*, Ofoeglu, C.O. (Ed.). Vieweg-Verlag, Nigeria, pp: 17-30.
- Reyment, R.A., 1965. *Aspects of the Geology of Nigeria*. Ibadan University Press, Ibadan, Nigeria.
- Wilson, R.C., 1925. The geology of the Eastern railways. *Bull. Geol. Survey Nig.*, 19: 95-102.
- Wright, J.B., 1968. South atlantic continental drift and the benue trough. *Tectonophysics*, 6: 301-310.