International Research Journal of Geology and Mining (IRJGM) (2276-6618) Vol. 5(2) pp. 12-19, March, 2015
DOI: http://dx.doi.org/10.14303/irjgm.2015.107
Available online http://www.interesjournals.org/irjgm

Full Length Research Paper

Determination of Dar-zarrouk parameters for prediction of Aquifer protective capacity: A case of Agbani Sandstone Aquifer, Enugu State, Southeastern Nigeria.

Austin C. Okonkwo*[1] and Gabriel Z. Ugwu[2]

[1]Department of Geology and Mining, Enugu State University of Science and Technology, Enugu, Nigeria
[2]Department of Industrial Physics, Enugu State University of Science and Technology, Enugu, Nigeria

***Corresponding author e-mail**: austinoxdiol@yahoo.com

ABSTRACT

The prediction of the protective capacity of Agbani Sandstone Aquifer, within the Enugu state university of science and technology, Agbani campus was investigated using the Dar - Zarrouk parameters. The study area is underlain by Agbani Sandstone and Awgu Shales. A total of 13 (thirteen) vertical electrical sounding (VES) was carried out within the study area. Longitudinal conductance, longitudinal resistivity, transverse resistance and apparent resistivity data was computed from the interpreted VES data. The longitudinal conductance data was used to predict the protective capacity of the Agbani Sandstone Aquifer. Three protective capacity zones were delineated; the good, moderate and poor/weak protective zones. Areas around the Auditorium, V.C's lodge and the existing borehole are within zone of good protective capacity, while health centre and hostel's 1 and 2 are within zone of poor/weak protective capacity. The Agbani Sandstone is however more than 80% protected from surface and underground fluid contamination within the study area. The information provided from this study should therefore guide future groundwater development in the study area.

Keywords: Longitudinal conductance, Transverse resistance, apparent resistivity, Agbani Sandstone, Aquifer protective capacity, Groundwater development.

INTRODUCTION

The concept of Dar Zarrouk parameters was first proposed by Maillet (1947). This postulation holds from the fact that, when the thickness and resistivity of a lithologic subsurface layer is known, its transverse resistance (R) and longitudinal conductance (S) can be calculated easily. Hence their correlative resistivities determined. Dar – Zarrouk parameters have since been used in the estimation/study of the hydraulic properties of aquifers. Onuoha and Mbazi (1988) used the concept of Dar – zarrouk parameters to estimate the transmissivity of Ajali Sandstone aquifers in southeastern Nigeria. Ezeh (2011) applied the concept of Dar – Zarrouk parameters for estimating aquifer hydraulic properties in Enugu State. Okonkwo and Ezeh (2013) applied the concept in estimating aquifer hydraulics and delineation of groundwater quality zones. Ekwe, *et al* (2010) also applied the same concept in a low permeability formation for aquifer hydraulic characteristics. Okonkwo, *et al* (2014) used the concept to infer the subsurface lithological extent.

In this present study, the concept has been used to predict the aquifer protective capacity of Agbani Sandstone aquifer at Enugu State University of Science and Technology, Agbani campus, Enugu State.

LOCATION AND PHYSIOGRAPHY

The case study area is the Enugu state university Agbani campus, located in Nkanu west local government, Enugu state (Figure 1). Agbani is located roughly about 15.9km southeast of Enugu metropolis and about 6.85km northeast of Ozalla town. It is bordered at the west by the

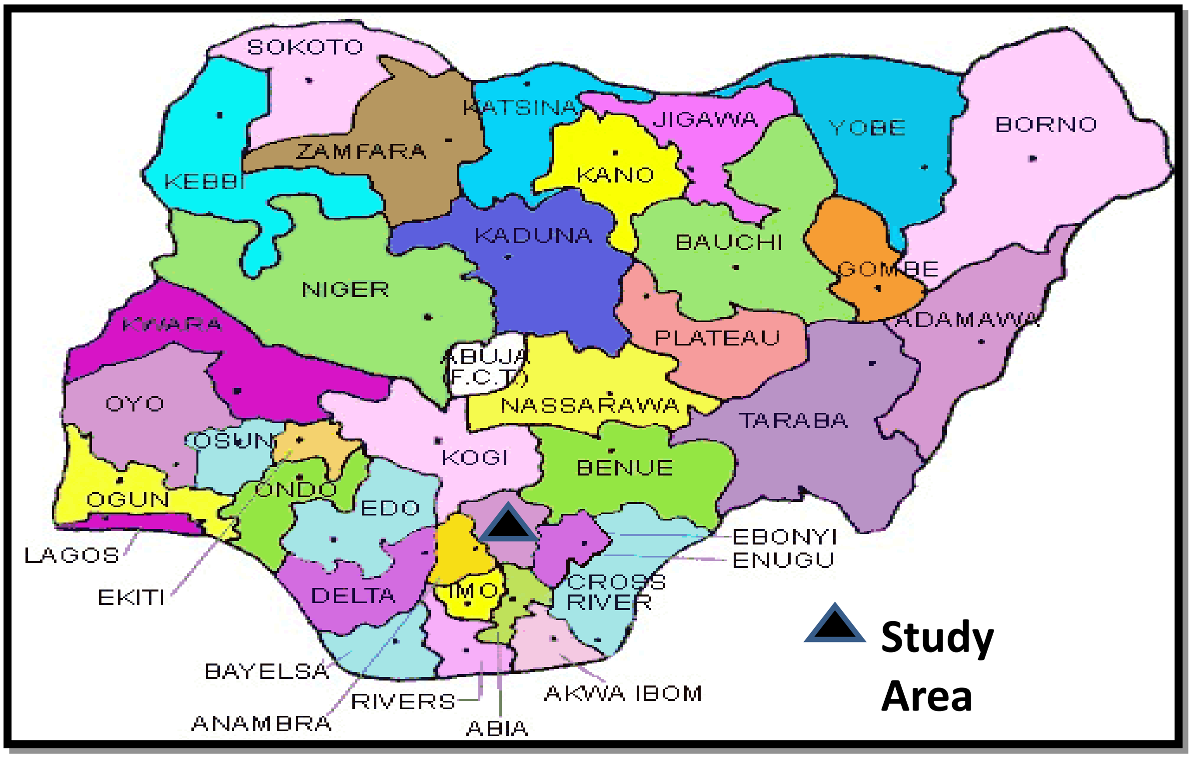

Figure1. Map of Nigeria showing the study area (World Gazette, 2011).

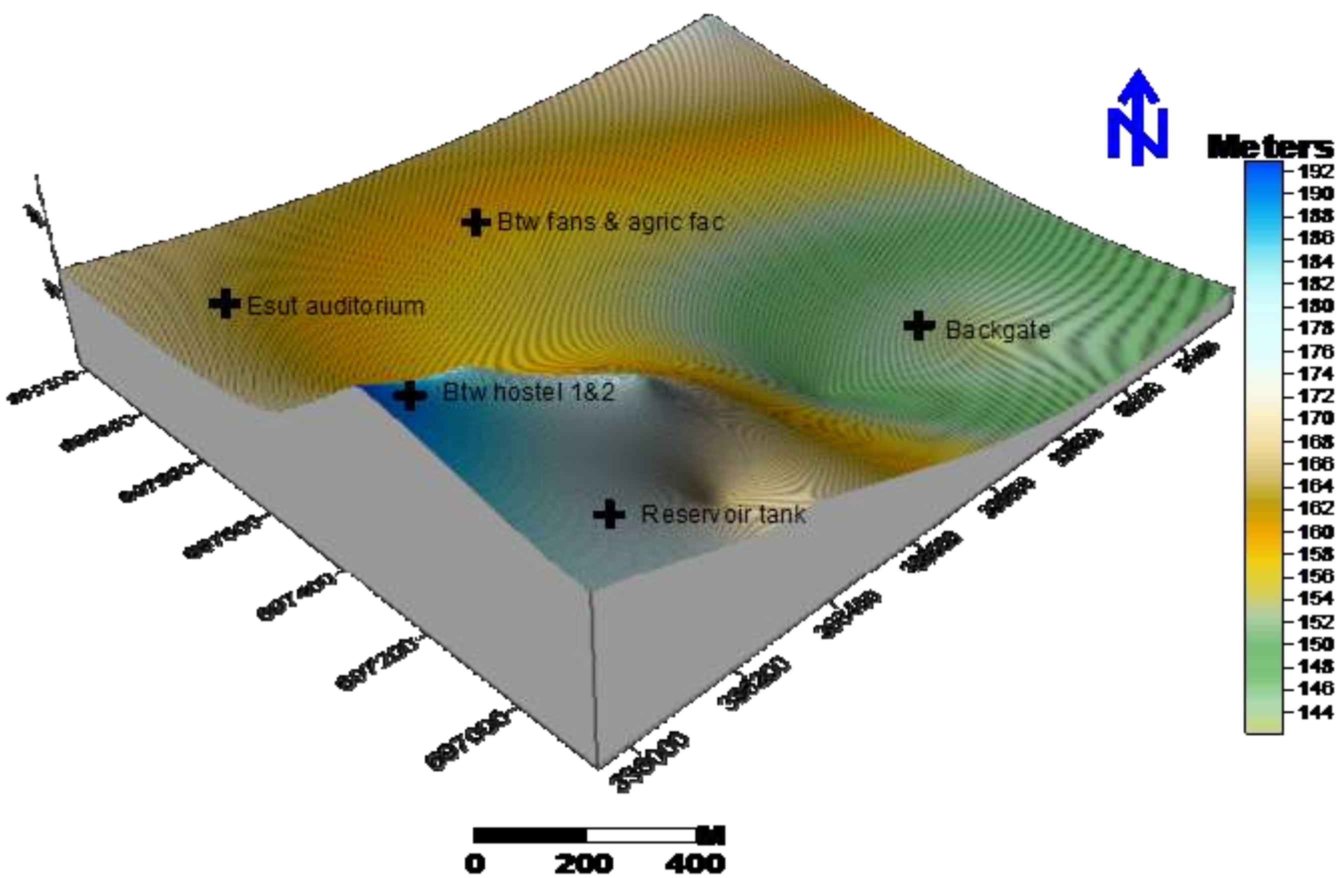

Figure2. Surface map of the study area.

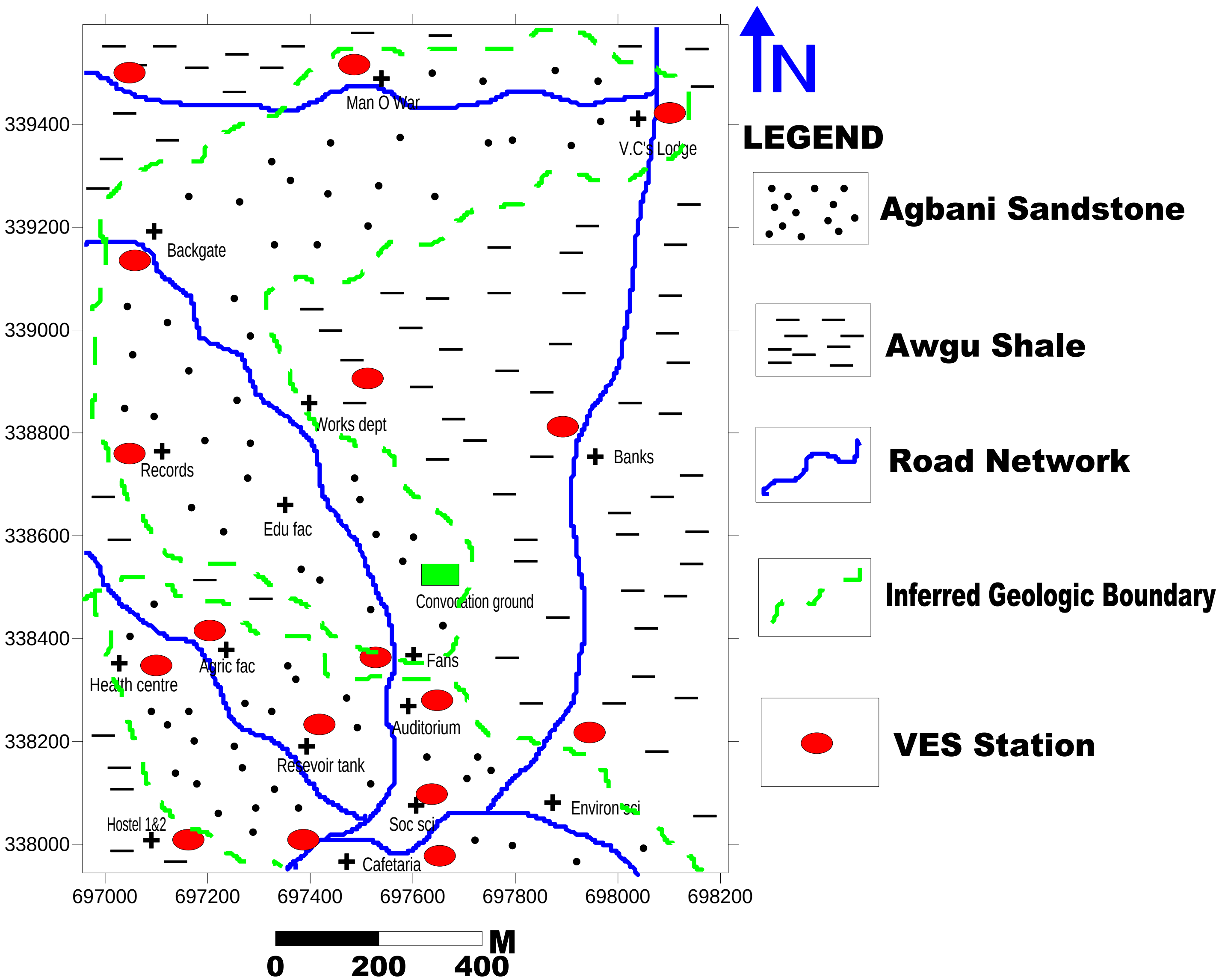

Figure3. Geologic map of the study area and VES stations.

Udi highlands, about 5000ft (1524m) above sea level (ASL) and practically situated in the lowland areas of Akpugo and Amurri about 250ft (76m) ASL. Locally, (Figure 2) the topography is typically undulating with a maximum elevation of 633ft (193m) ASL.

GEOLOGY

Agbani town, where the study area is located is practically underlain by Agbani Sandstone, (Figure 3) which is a lateral equivalent of Awgu Shale group. The Sandstone is quite laterally not extensive, as it outcrops only within the country around Agbani. It consist of medium to coarse grained, white to reddish brown, moderately consolidated at depth and highly consolidated at outcrop areas. Thickness variation is predominant in areas (towns) far from Agbani town centre. The Agbani sandstone is the reservoir aquifer at Agbani and environs. Hence, the need to investigate the subsurface extent within the Enugu state university campus, in order to determine suitable locations for groundwater development.

MATERIALS AND METHODS

Theoretical Basis

The apparent resistivity (ρ_a) function of current passed into the ground, measured by potential electrodes as potential difference (Voltage) is given as

$$\rho_a = \pi \frac{(AB/2)^2 - (MN/2)^2 \times R}{MN} \qquad (1)$$

Where R is the resistance, AB and MN are current and potential electrodes respectively. A multilayer resistivity

Table1. Computed Geoelectric parameters for VES stations of the study area

S/NO	Location	ρ_a (Ωm)	Thickness (m)	S (Ω^{-1})	T (Ωm^2)	ρ_L (Ωm)	ρ_T (Ωm)
1	Behind exams and records	2014	57.0	0.0283	114798	2014.13	2014
2	Behind health centre	5547	41.0	0.0073	227427	5616.43	5547
3	Opp; Agric faculty	875	53.0	0.0605	46375	876.03	875
4	B/w Hostel 1&2	3304	48.0	0.0145	158592	3310.34	3304
5	Behind social sciences	1302	46.0	0.0353	59892	1303.11	1302
6	Existing Borehole	965	75.0	0.0777	72375	965.25	965
7	Auditorium	13	38.0	2.9230	494	13.00	13
8	V.C's Lodge 1	45	135.0	3.0000	6075	45	45
9	V.C's Lodge 2	20	55.0	2.75	1100	20	20
10	B/w FANS & Agric faculty	90	85.0	0.9444	7650	90.00	90
11	Reservoir tank	100	55.0	0.5500	5500	100	100
12	Cafeteria	60	80.0	1.3333	4800	60.00	60
13	Opp; Man O war	14	44.0	3.142	616	14.00	14

interpreted model consists of layer apparent resistivities, thickness and depth. Further derivatives are convolved to generate the geoelectric parameters. These show electric boundaries separating layers of different resistivities (Zohdy, *et al*, 1990). A geoelectric layer is described by two fundamental parameters: its layer apparent resistivity (ρ_a) and its thickness (h). The geoelectric parameters derived based apparent resistivity and thickness,
Longitudinal conductance (S)

$$S = h/\rho_a \qquad \textbf{(2)}$$

Where S is the longitudinal conductance, h is thickness and ρa is apparent resistivity of the aquiferous layer.
Transverse resistance (T)

$$T = h.\rho_a \qquad \textbf{(3)}$$

Where T is the transverse resistance, h is thickness and ρa is apparent resistivity of the aquiferous layer.
The parameters T and S were named the “Dar – Zarrouk parameters “by Maillet (1947).

Longitudinal Conductance

The longitudinal conductance (S) is the geoelectric parameter used to define target areas of groundwater potential. High S values usually indicate relatively thick succession and should be accorded the highest priority in terms of groundwater potential.

Transverse Resistance

The transverse resistance (T) is one of the parameters used to define target areas of good groundwater potential. It has a direct relation with transmissivity and the highest T values reflect most likely the highest transmissivity values of the aquifers or aquiferous zones.

Data Acquisition and Interpretation

A total of 13 (thirteen) vertical electrical sounding (VES) were carried out within the case study area (Figure 3) The schlumberger electrode spreading was used with maximum current electrode separation (AB) of 400m. The initial interpretation of the VES data was accomplished using the conventional partial curve matching technique, with multilayer master curves in conjunction with auxillary point diagrams (Orellana and Mooney, 1966; koefoed, 1979; Keller and Frischknecht, 1966). From this, estimates of layer resistivities and thicknesses were obtained which served as starting points for computer assisted interpretation. The computer program RESOUND, was used to interpret all data sets obtained. From the interpretation of the resistivity data it was possible to compute, for every VES station the geoelectric parameters (Table 1).

AQUIFER PROTECTIVE CAPACITY EVALUATION

The Dar-zarrouk parameters, Transverse resistance (T) and Longitudinal conductance(S), obtained from the geoelectric layer parameters (Table 1), were used to determine the overburden protective capacity of the Agbani Sandstone aquifer in the study area. The longitudinal conductance map (Figure 7) computed from equation 4 for all the VES locations was utilized in the evaluating the overburden protective capacity in the study area. This is because the earth subsurface acts as a natural filter to percolating fluid. Hence, its ability to retard and filter percolating ground surface polluting fluid is a measure of its protective capacity (Olorunfemi et al., 1999). The highly impervious clayey overburden, which is characterized by relatively high longitudinal conductance, offers protection to the underling aquifer (Abiola,et al., 2009).
The values of longitudinal conductance(S) obtained from the study area, range 0.0073 to 3.142 Ω^{-1} (Table 1). The data were used to generate the longitudinal conductance map (Figure 7) using SURFER 9 Contouring Toolkits. Aquifer overburden protective capacity could be zoned

Table2. Longitudinal Conductance/Protective capacity rating (Oladapo and Akintorinwa, 2007)

Longitudinal Conductance (Ω^{-1})	Protective Capacity Rating
>10	Excellent
5 – 10	Very good
0.7 – 4.9	Good
0.2 – 0.69	Moderate
0.1 – 0.19	Weak
<0.1	Poor

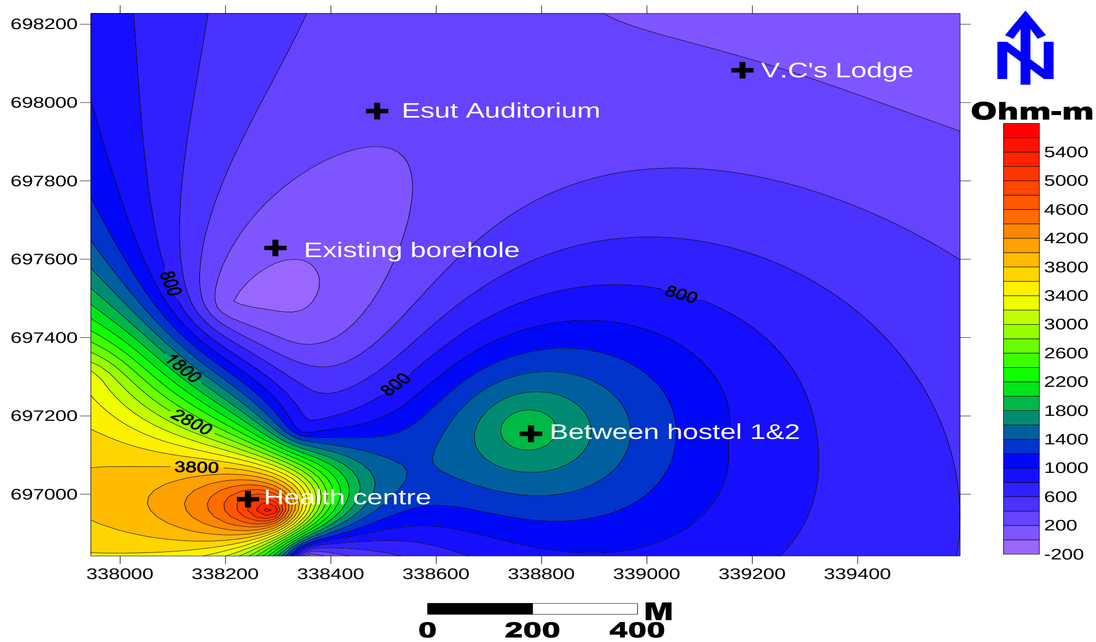

Figure4.: Longitudinal resistivity map of the study area.

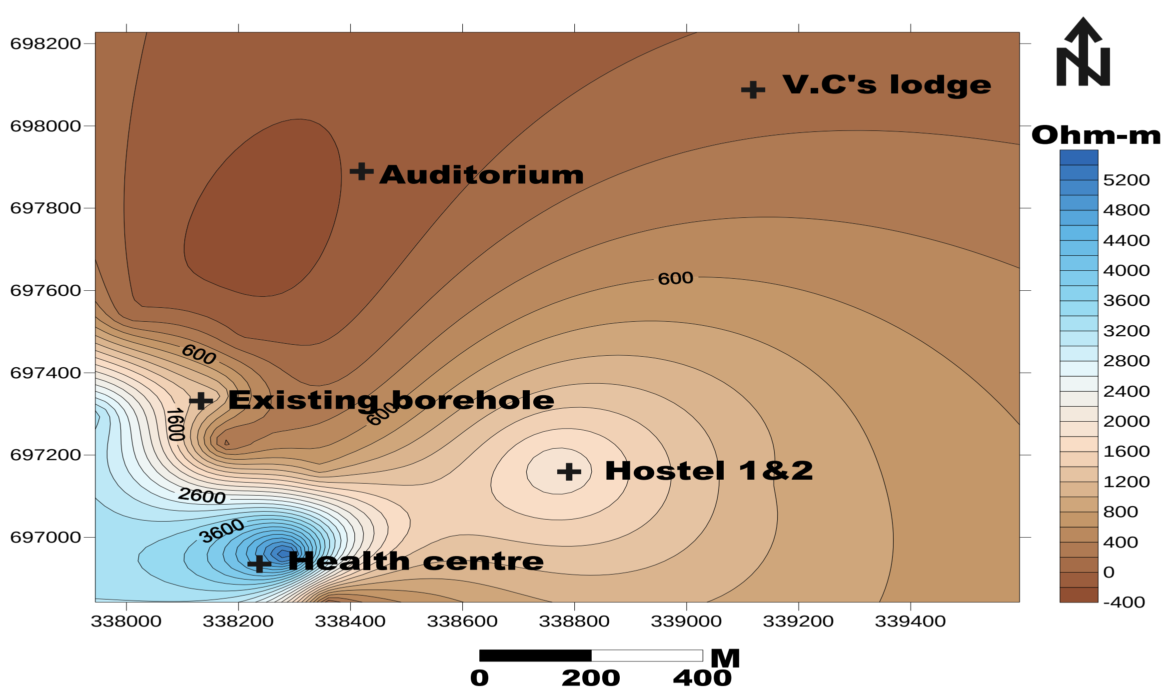

Figure5. Apparent resistivity map of the study area.

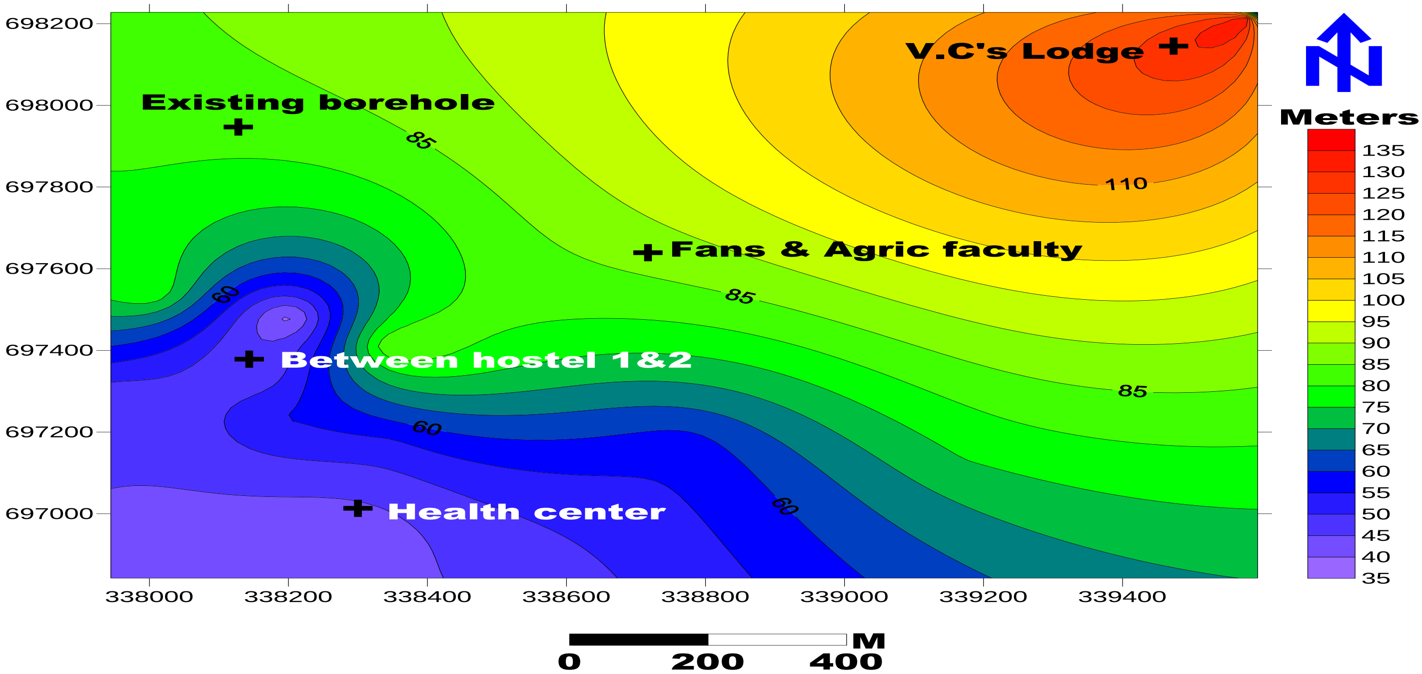

Figure 6. Isopach map of the study area.

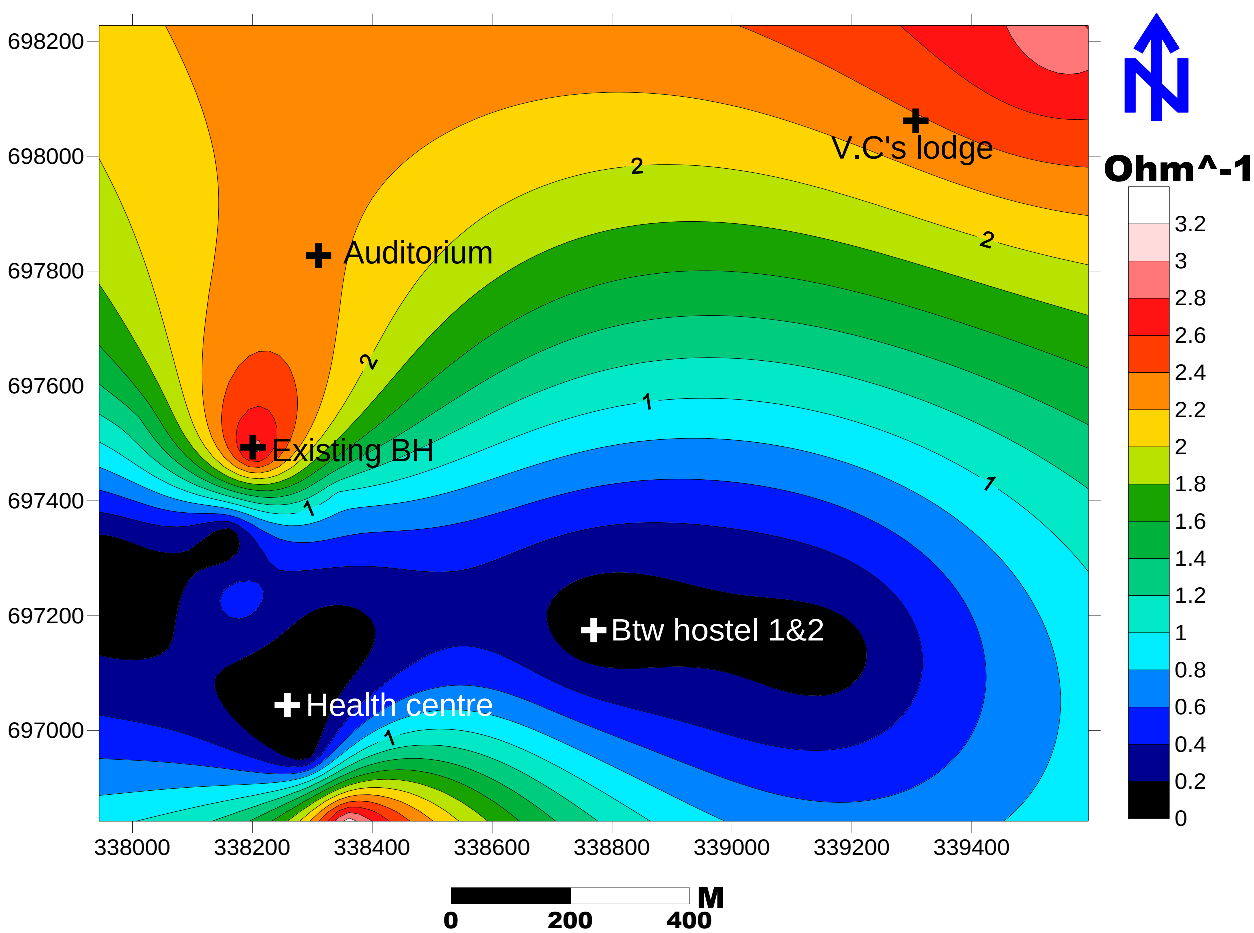

Figure7. Longitudinal conductance map of the study area.

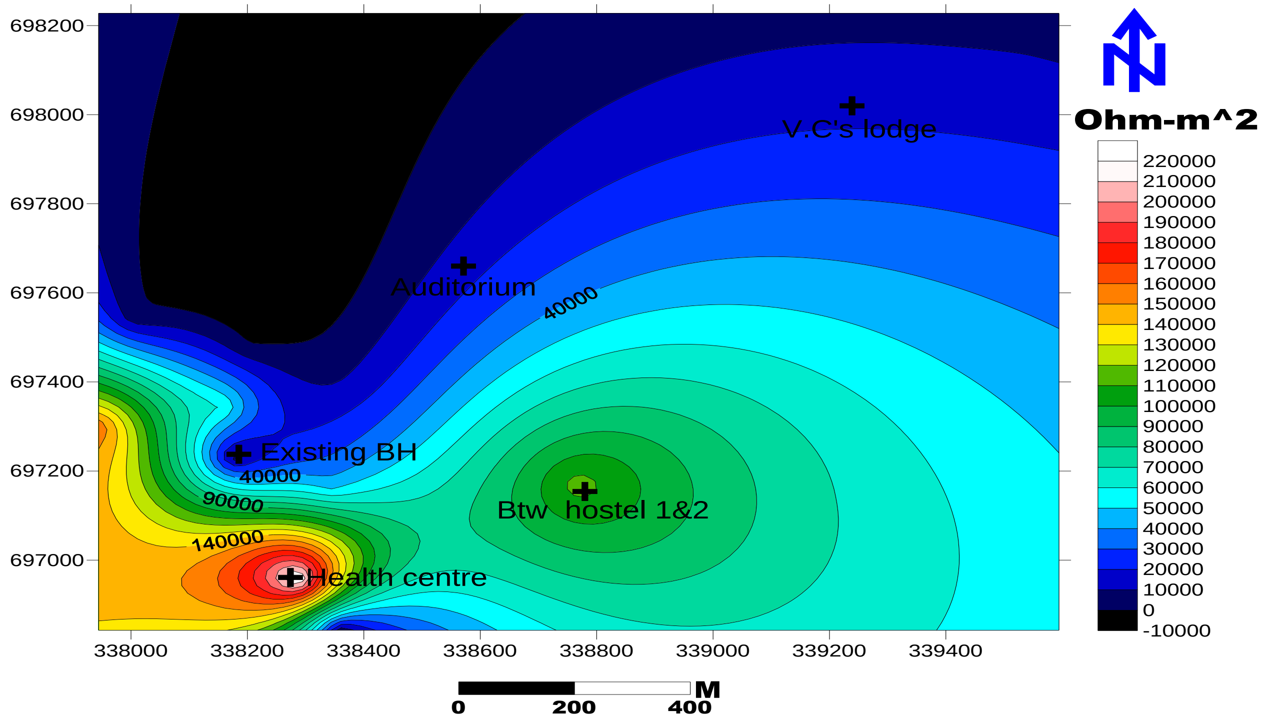

Figure 8: Transverse resistance map of the study area.

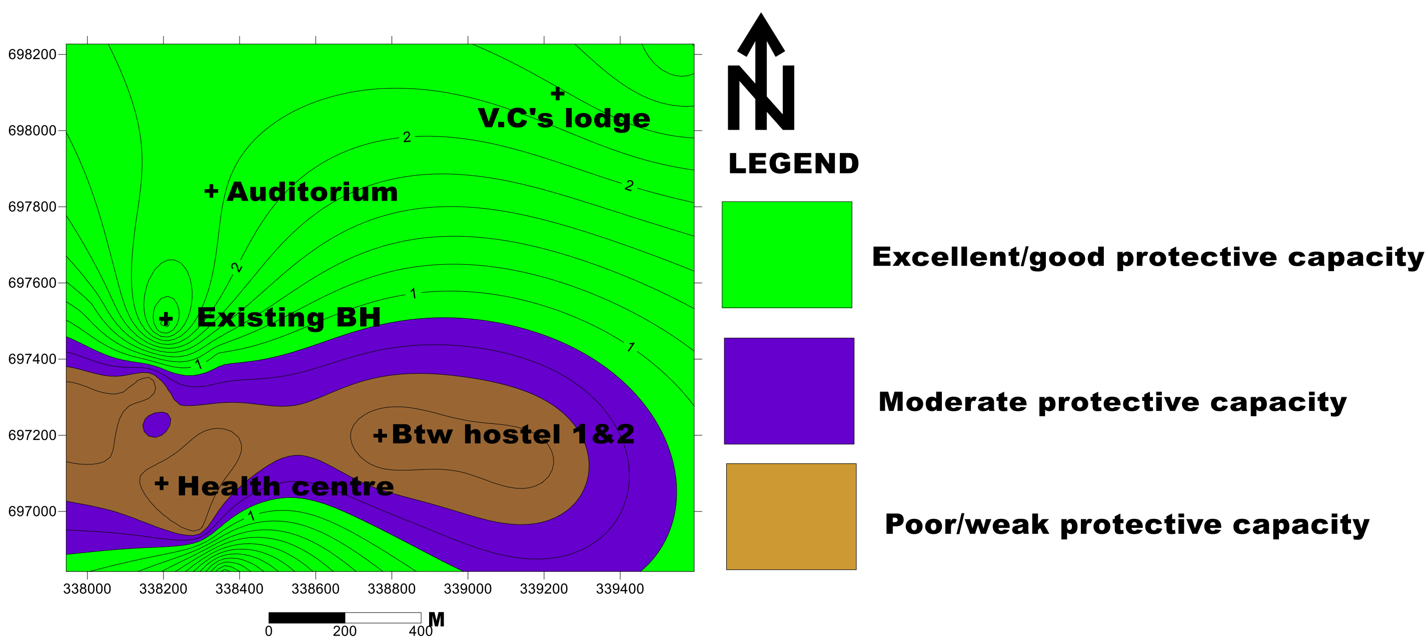

Figure 9: Overburden (Aquifer) protective capacity map of the study area.

(Table 2) into excellent, good, moderate, weak and poor protective capacity (Oladapo and Akintorinwa, 2007). Zones where the conductance is greater than 10Ω^{-1} are considered zones of excellent protective capacity. The portion having conductance values ranging from 0.7 to 9.9Ω^{-1} are considered zones of good protective capacity. Also, the portion ranging from 0.2 to 0.69Ω^{-1} was classified as zone of moderate protective capacity; that ranging from 0.1 to 0.19Ω^{-1} was classified as weak protective capacity and the zone where the conductance value is less than 0.1Ω^{-1} was considered poor protective capacity. However, in the study area, the protective capacity are zoned into poor/weak, moderate and good protective capacity rating (Figure 9). Areas around the V.C's lodge, Auditorium and existing borehole fall within the zone of good protective capacity, with a relative thickness of 75 to 135meters, while areas around hostel's 1 and 2 and health centre has a poor/weak protective capacity.

RESULTS AND DISCUSSION

Interpreted VES data were used to compute the longitudinal conductance, transverse resistance, longitudinal resistivity and the transverse resistivity (Table 1). Contour maps of apparent resistivity, isopach, longitudinal conductance, transverse resistance and the longitudinal resistivity were also constructed and compared. The apparent resistivity, transverse resistance and longitudinal resistivity proved diagnostic, as relatively high values usually indicated thick succession of arenaceous (sandy) subsurface rocks. Hence, areas of high longitudinal resistivity (Figure 4), high apparent resistivity (Figure 5) and high transverse resistance (Figure 8) possibly show the trend of the Agbani Sandstone in the study area. The longitudinal resistivity, transverse resistivity and the apparent resistivity show lateral trend section of the Agbani Sandstone in a NE – SW direction within the study area. Areas around the law faculty building through the health centre to the back gate, close to the existing borehole are underlain by a thick succession of Agbani Sandstone (Figure 4). The isopach map show high variable values in the study area (Figure 6). In the southwestern part, underlain by the Agbani Sandstone, the thickness range between 35 and 70m with an average of 52.5m. While in a NW – SE trend, the thickness range between 70 and 100m with an average thickness of 85m. The distribution of the longitudinal conductance computed from the resistivity sounding interpretation of the study area (Figure 7), were used to predict the Aquifer protective capacity (Figure 9). Areas around the V.C's lodge, Auditorium and existing borehole fall within zones of good protective capacity, while areas around hostel's 1 and 2 and health centre has a poor/weak protective capacity. The areas with good protective capacity are zones that indicate no possible surface or underground fluid contamination. This zone predominates in the study area.

CONCLUSION

The application of Dar – Zarrouk parameters has proved useful in the prediction of Aquifer protective capacity of Agbani Sandstone, within the Enugu state university of science and technology (ESUT) permanent site. The Aquifer protective capacity are zoned into poor/weak, moderate and good protective rating. However, groundwater development can be undertaken within areas around the Auditorium and V.C's lodge, as these areas have the highest thickness of the Agbani Sandstone and a good aquifer protective capacity. This study should therefore serve as useful guide for future groundwater development and citing of productive boreholes in the campus.

REFERENCES

Abiola O, Enikanselu PA, Oladapo MI (2009). Groundwater potential and Aquifer protective capacity of overburden units in Ado – Ekiti, Southwestern Nigeria. Int.J. Phy. Sci. 4(3): 120 – 132.

Ekwe AC, Nnodu IN, Ugwumbah KI, Onwuka OS (2010). Estimation of aquifer hydraulic Characteristics of low permeability formation from geosounding data: A case study of Oduma Town, Enugu state. J. Earth Sci. 4(1):19-26.

Ezeh CC (2011). Geoelectrical studies for estimating aquifer hydraulic properties in Enugu State, Nigeria. Int. J. Phy. Sci. 6(14):3319-3329.

Okonkwo AC, Ezeh CC (2013). Aquifer hydraulics and delineation of groundwater quality zones using Electrical resistivity method at Oduma and environs in Enugu state, Southeastern Nigeria. J. Geol. Min. 3(1):31-39.

Okonkwo AC, Ezeh CC, Opara AI, Nwatarali RAN, Dimanyi MS, Enang E (2014). Using the Dar-zarrouk concept to infer the subsurface lithological extent of Agbani Sandstone, Enugu state, Nigeria. Int. Res. J. Geol. Min. 4(1): 29 – 36.

Onuoha KM, Mbazi FCC (1988). Aquifer transmissivity from electrical sounding data: the case of Ajali Sandstone aquifers southwest of Enugu, Nigeria. In: Ofoegbu CO Ed. Groundwater and Mineral Resources of Nigeria. Vieweg – Verlag. Pp17-30.

Oladapo MI, Akintorinwa OJ (2007). Hydrogeophysical study of Ogbese Southwestern, Nigeria. Global J. Pure and App. Sci. 13(1): 55 – 61.

Olorufemi MO, Ojo JS, Akintunde OM (1999). Hydrogeophysical evaluation of the groundwater potential of Akure metropolis, Southwestern Nigeria. J. Min. Geol. 35(2): 207 - 228

Orellana E , Mooney HM (1966). Master tables and curves for vertical electrical sounding over Layered structures. Interscience, Madrid.

Keller GV, Frischknecht FC (1966). Electrical methods in geophysical prospecting. Pergamon Press.

Koefoed O (1979). Geosounding principles, 1 Elsevier, Amsterdam.

Maillet R (1947). The fundamental equations of electrical prospecting". Geophysics. 12:529-556.

World Gazette (2011). Colourful map of Nigeria with 36 states. www.world-gazette.com

Zohdy AAR, Eaton GP, Mabey DR (1990). Application of surface Geophysics to ground – water investigation".USGS publications. 4th Edition. Pp116.

How to cite this article: Austin and Gabriel (2015). Determination of Dar-zarrouk parameters for prediction of Aquifer protective capacity: A case of Agbani Sandstone Aquifer, Enugu State, Southeastern Nigeria. Int. Res. J. Geol. Min. 5(1):12-19