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Evaluation of Groundwater Yield Capacity Using Dar-zarrouk Parameter of Central Kwara State, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration between all authors. Author MAB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors AOA and SOI managed the analyses of the study. Authors KOO and KNO managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The quest to meet the required groundwater need of citizens of Nigeria, especially Central Kwara State for both domestic and industrial application in the face of scarce water resources, occasioned by incessant borehole failure/low yield, has prompted researches for viable source of water. The central Kwara state falls within the basement complex region of Nigeria known as the hard rock terrain, where availability of groundwater is dependent mainly on structural features and their dispositions to yield groundwater. The second order parameters were determined from the interpretation of vertical electrical sounding results. These Dar-zarrouk parameters was used to determined the groundwater yield index value by multiplying the coefficient of anisotropy (λ) and total transverse resistance (T) and was used to model the groundwater yield capacity map. The north-eastern and the central region of the area has the highest prospect for groundwater yield while

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part of the north western, north central and the south eastern part has medium prospect for groundwater yield and the rest of the area has prospect for low yield except for the south western end. Part of the south western and the middle part of the north eastern part has lean or least prospect for groundwater yield. The boreholes data and hand pump well across the entire study area were used to validate the accuracy of the groundwater yield capacity map.

Keywords: Coefficient of anisotropy; transverse resistance; longitudinal conductance, groundwater yield capacity.

1. INTRODUCTION

Groundwater is one of the most valuable natural resources on the earth surface and serves as one of the main sources of drinking water. Basement complex have problem of potable groundwater supply due to the crystalline nature of the underlying rock which lack primary porosity [1] citied in [2]. Groundwater storage capacity in those areas is dependent on depth of weathering and intensity of fracturing of the underlying rock. For basement complex rock to become good aquifers, they must be highly fractured and highly weathered. Thickness of the weathered overburden and fractured zone determined the nature and intensity of hydrodynamic activities within the usually discrete bodies of aquifer in the terrain [3,4] citied in [2]. Groundwater in crystalline rocks that have no intergranular porosity moves in a connected fracture network; but far from all fractures are permeable, and fracture permeability varies considerably [5] citied in [2]. It is generally recognized that, in the prospect area of faults and fracture, the fault core and central zone have low permeability while the outer damage zone has enhanced permeability compared with the surroundings [6,7,8] citied in [2]. In typical basement complex areas such as the study area, the occurrence of groundwater in recoverable quantity as well as its circulation is controlled by geological factors *i.e.* faults, joints and fracture zones [9,4]. Therefore to target potential basement aquifers that can give copious supply of groundwater in these areas, the aforementioned geologic features must be intercepted by boreholes [2]. Thus, groundwater potential of a basement complex area is determined by a complex interrelationship between the geology, post-emplacement, tectonic history, weathering processes and depth, composition of the weathered layer, aquifer types and combination, groundwater flow pattern, climate, recharge and discharge processes [10] citied in [2]. Consequently, the geoelectric parameters that would be of hydrologic significance to evaluate the groundwater yield of a given area will be largely determined by the prevailing factors that influence the occurrence of the resources in the area. In other words, prediction of groundwater yield capacity is a spatial decision problem that typically involves a large set of feasible alternatives.

Therefore, in this research work Electrical resistivity methods were used in Central Kwara comprising four Local Government i.e. part of ASA, MORO Kwara East, Kwara West Local Government of the state, which are underlain by rocks of the Precambrian Basement Complex of Nigeria with the aim of evaluating the groundwater yield capacity

1.1 Site Description and Geology of the Study Area

The area is geographically enclosed within latitude 8^0 31' 0''N to 8^0 43' 0''N and longitude $4^0$28'00''N to 4^0 34' 0''E, It is sandwich between four local government areas, within the Central of Kwara State in present Nigeria. Moro Local Government to the North and North Eastern part of the study area, Asa Local Government to the West, and Kwara West and Kwara East Local Government to the South of the study area. The area is made up of about forty (40) Towns and Villages accessibility is through major and minor road networks. The topography is generally undulating (Fig. 1) with some areas characterized by hilly ridges and gentle steeps. The area enjoys a tropical climate with two distinct seasons, comprising of rainy season (April to October) and dry season (November to March) with the temperature ranging between 23^0C to 32^0C and dry season. The study area is located within north Central Basement Complex region of Nigeria. It belongs to the Precambrian Basement Complex (Fig. 2). It is made up of mainly older granite towards the North Western part of the study area, while the rest is of the undifferentiated basement complex rock. The hydrogeology of the study area consists of streams, rivers, drainage and geological structures (like faults, fractures, crack, joints and weathered materials).

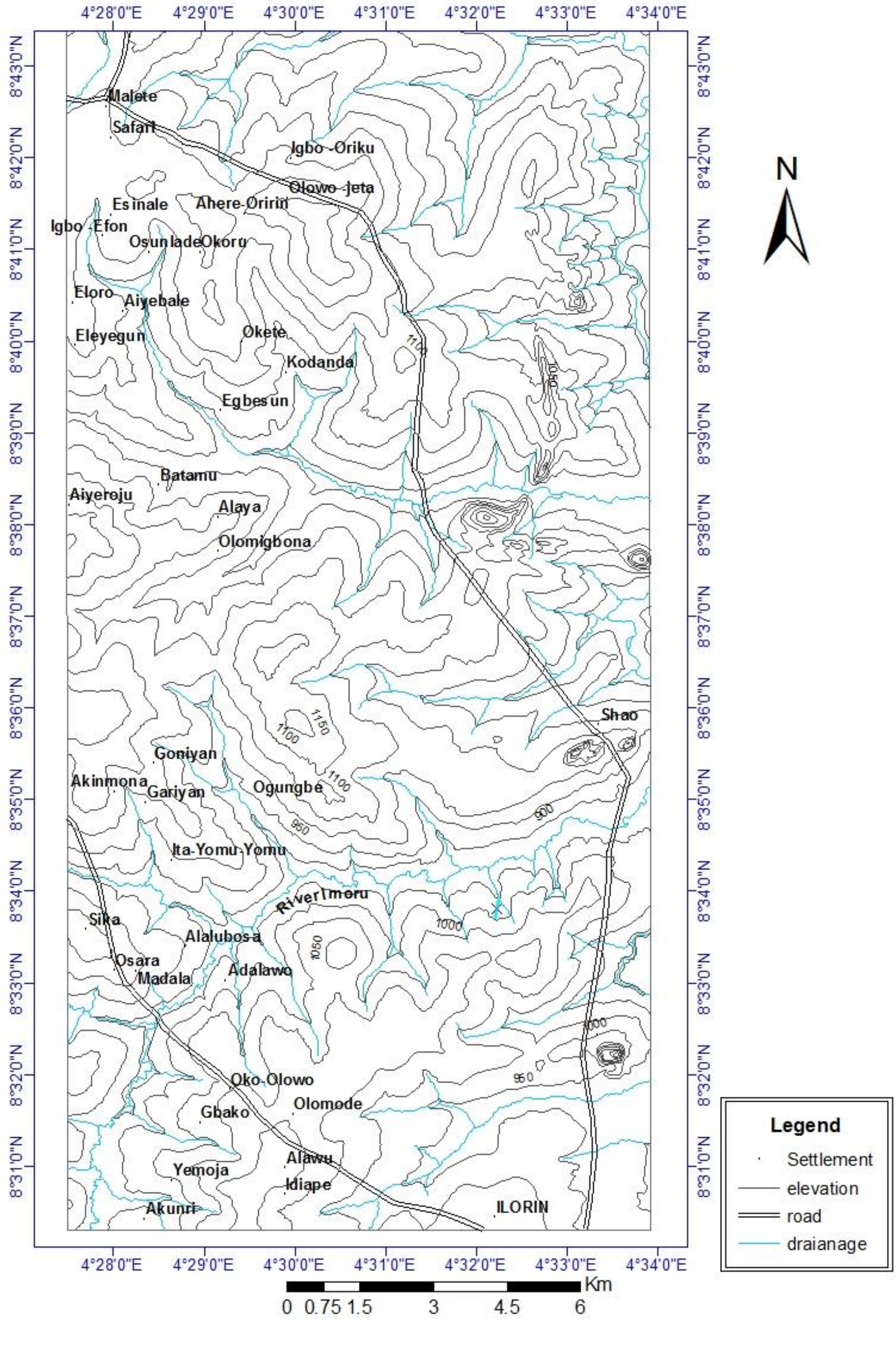

Fig. 1. Location map of the study area

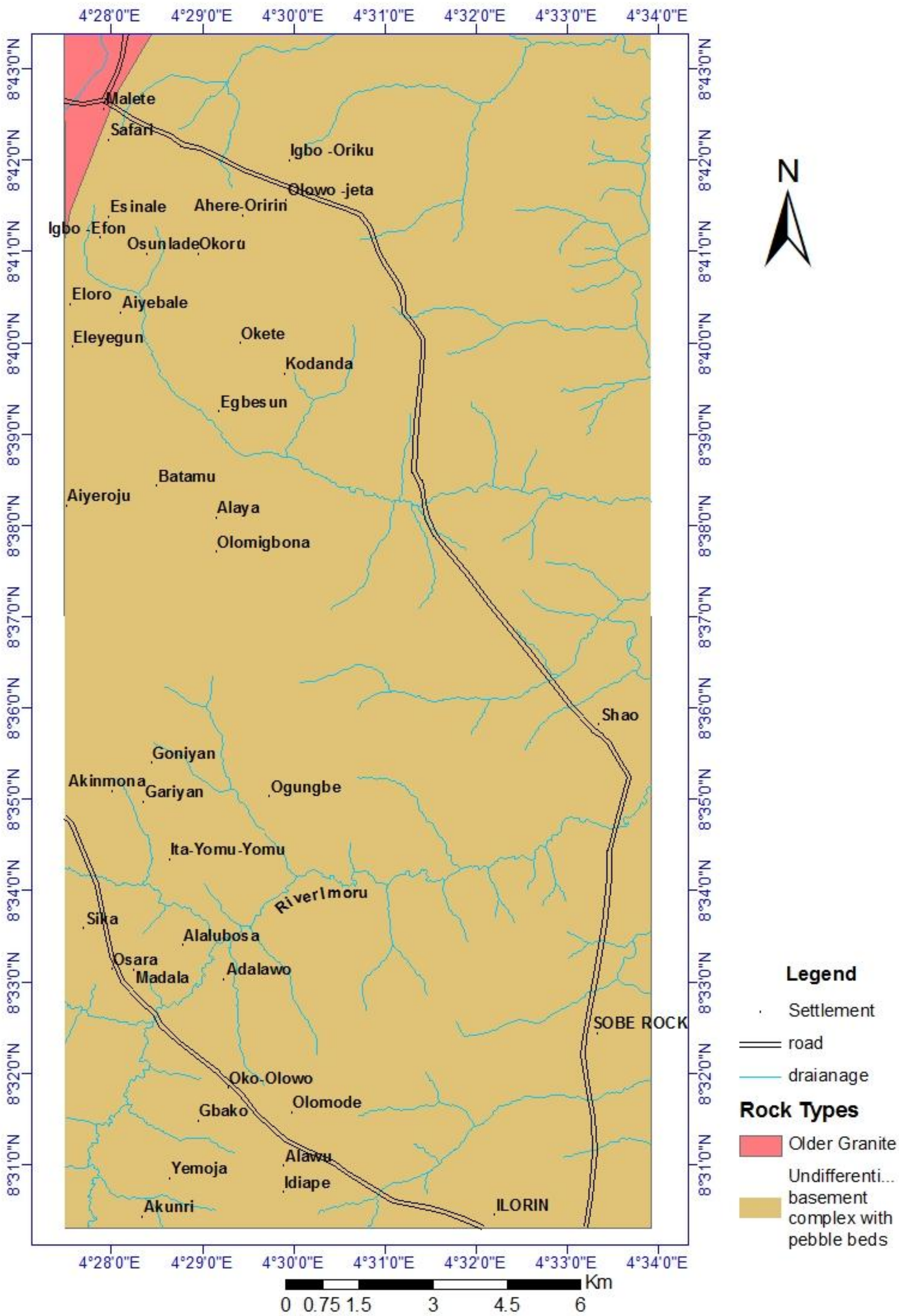

Fig. 2. Geological map of the study area

2. RESEARCH METHODOLOGY

The Schlumbeger depth sounding was used to investigate the change of resistivity with depth [11,12]. The measured unit is the apparent resistivity, ρa, which is the product of a geometrical factor, K, and the quotient of the measured potential, ΔU, and the source current,

I. The apparent resistivity is plotted versus AB/2 in meters on bilogarithmic paper resulting in a vertical electrical sounding (VES) curve. The vertical electrical sounding (VES) curve showed the change of resistivity with depth, since the effective penetration increases with increasing electrode spacing. The interpretation of the VES curve is both qualitative and quantitative. The qualitative interpretation involved visual inspection of the sounding curves while the quantitative interpretation utilized partial curve matching technique using 2-layer master curve which was later refined by a computer iteration technique Resist version [13] that is based upon an algorithm of [14]. The quantitatively interpreted sounding curves gave interpreted results as geoelectric parameters (that is, layer resistivity and layer thickness). Subsequently, VES interpretation was used to determine the second order parameters (Dar-Zarrouk). The Dar-zarrouk parameters are exclusively relevant in the lithological differentiation and delineation of aquifer geometry. In these applications, full advantage is taken of the combinations of thickness and resistivities into one single variable that is the coefficient of anisotropy which is used as bases for the evaluation of properties. However, in this present study, these parameters have been developed further through the application of the product of the coefficient of anisotropy (λ) and the total transverse resistance (T) i.e. (λ*T) to determine the groundwater yield index value which was found to be very relevant and useful in determination and evaluation of groundwater yield capacity. The groundwater yield capacity index value was used to model the groundwater yield capacity map.

3. RESULTS AND DISCUSSION

3.1 Characterization of Dar – Zarrouk Parameters in Groundwater

The coefficient of anisotropy is estimated along with the secondary geoelectric parameters. The estimation shows that the total longitudinal conductance varies from 0.07 to 0.66 Ω^{-1} in the study area (Fig. 3). The qualitative use of this parameter is to demarcate changes in total thickness of low resistivity materials. The total transverse resistance ranges from 89.22 to 11,287.52 Ωm Fig. 4, which gives information about the thickness and resistivity of the area. The average longitudinal resistivity calculated from sounding curves ranges from 11.5 to 137.35 Ωm in the area (Fig. 5), which helps in calculating the total depth H to the high resistivity bedrock and the average transverse resistivity varies from 43.47 to 892.03 Ωm, which clearly illustrates that it is more than the average longitudinal resistivity (Fig. 6). This indicates that the true resistivity normal to the plane of structural features is greater than the true resistivity parallel to the plane of structural features. Based on these estimates it was found that the coefficient of anisotropy ranges from 0.06 to 1.96, which depicts the true variation of the anisotropy character of rock formation. The area with high values of coefficient of anisotropy suggests that the fracture system must have extended in all the directions with different degrees of fracturing, which had greater water – holding capacity from different directions of the fracture(s) within the rock resulting in higher porosity. At the same time, unidirectional fracture may not produce good yield of water and such areas show low values of coefficient of anisotropy [15]. Consequently, it indicates the presence of macro-anisotropy in the present geoelectric structures in the area.

The coefficient of anisotropy is very high at North western, western and small pocket at south western part of the study area and reaches a maximum values 1.96, as shown in anisotropy map (Fig. 7). It indicates that this physical property is not uniform in all directions and anisotropy plays a major role in fracturing. Here, it indicates more fracturing toward north western direction and thus suggests comparatively more groundwater potential zone and hence better prospect for groundwater availability.

3.2 Modeling of Groundwater Yield Capacity

The Dar-zarrouk parameters are exclusively relevant in the lithological differentiation and delineation of aquifer geometry. In these applications, full advantage is taken with combinations of thickness and resistivities into one single variable which is the coefficient of anisotropy used as bases for the evaluation of properties. However, in this present study, these parameters have been developed further through the application of the product of the coefficient of anisotropy (λ) and the total transverse resistance (T) i.e. (λ*T) to determine the groundwater yield index value which was found to be very relevant and useful in determination and evaluation of groundwater yield capacity.

The groundwater yield capacity index value was used to model the groundwater yield capacity map which has a values ranging between 32 groundwater yield capacity index to 5945.59 groundwater yield capacity index, with the least rating being from 32.88 to 350 G.W.Y.I. which implies dry /no yield, while between 350 to 450 G.W.Y.I., implies extremely low yield and 450 to 850 G.W.Y.I., implies very low yield, while between 850 to 1750 G.W.Y.I., presenting low yield and 1750 to 3000 G.W.Y.I., implying moderate yield, while 3000 G.W.Y.I. and above stands for high yield (Fig. 8).

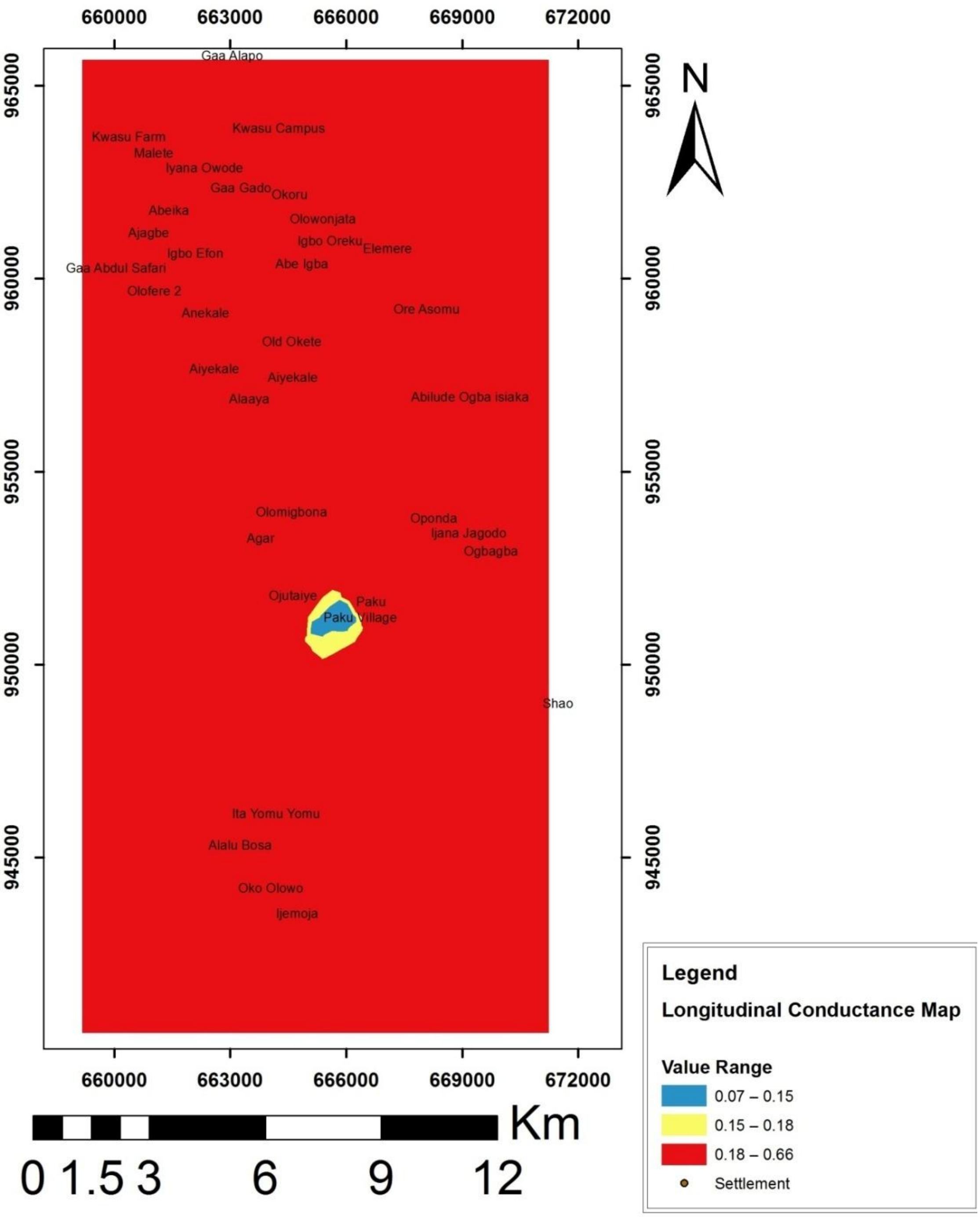

Fig. 3. Total longitudinal conductance map of the study area

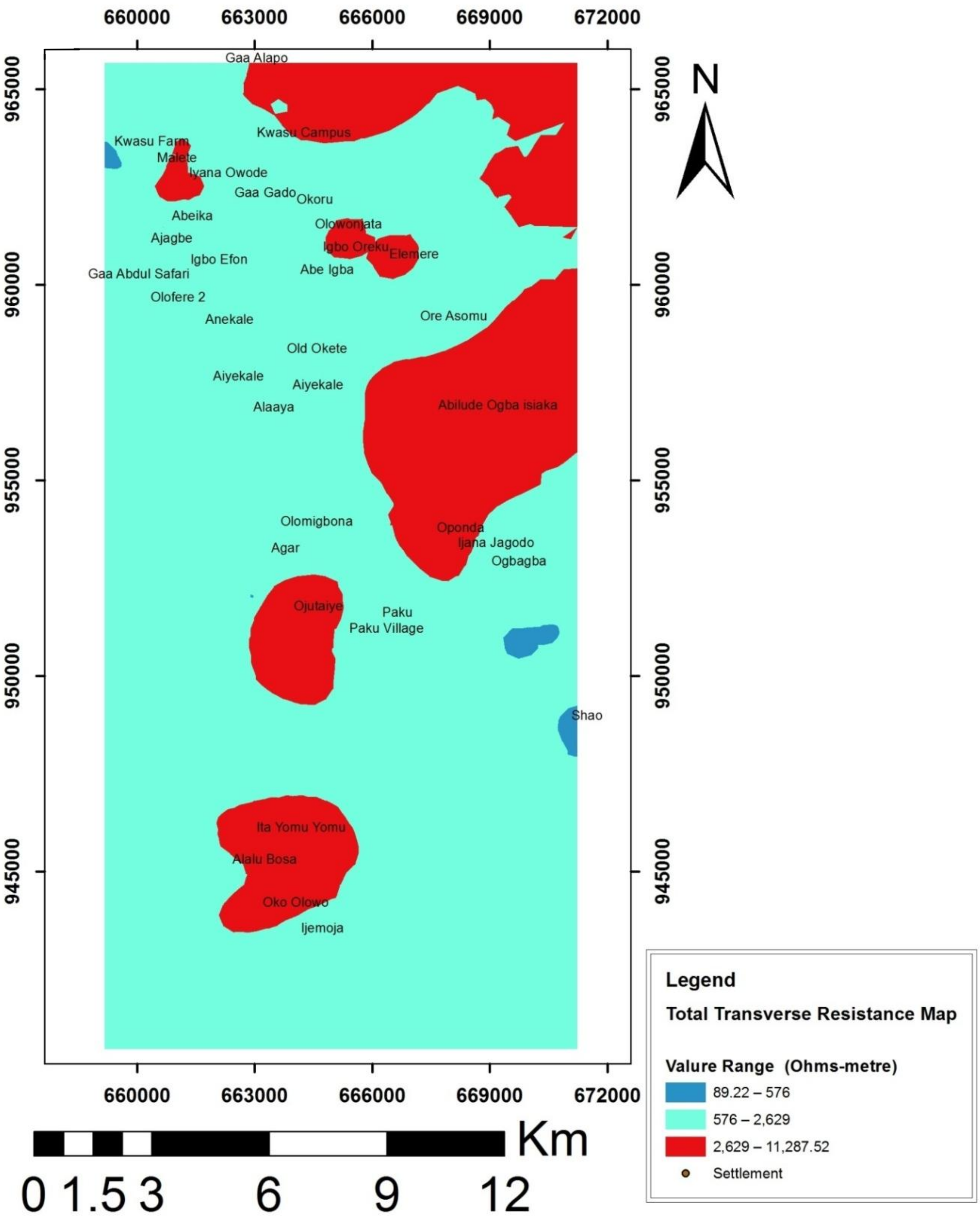

Fig. 4. Total transverse resistance map of the study area

Therefore, base on this, the entire study area was classified into high yield, moderate yield, low yield, Very low yield, extremely low yield and dry or no yield. The boreholes data and hand pump well across the entire study area, were used to validate the accuracy of the groundwater yield capacity map and hence of the proposed methodology. The locations and names descriptions of these boreholes and hand pump well were displayed on the groundwater yield capacity map shown in Table 1 and Fig. 8. The validation was carried out by superimposing the boreholes and hand pump well data on the groundwater yield capacity map.

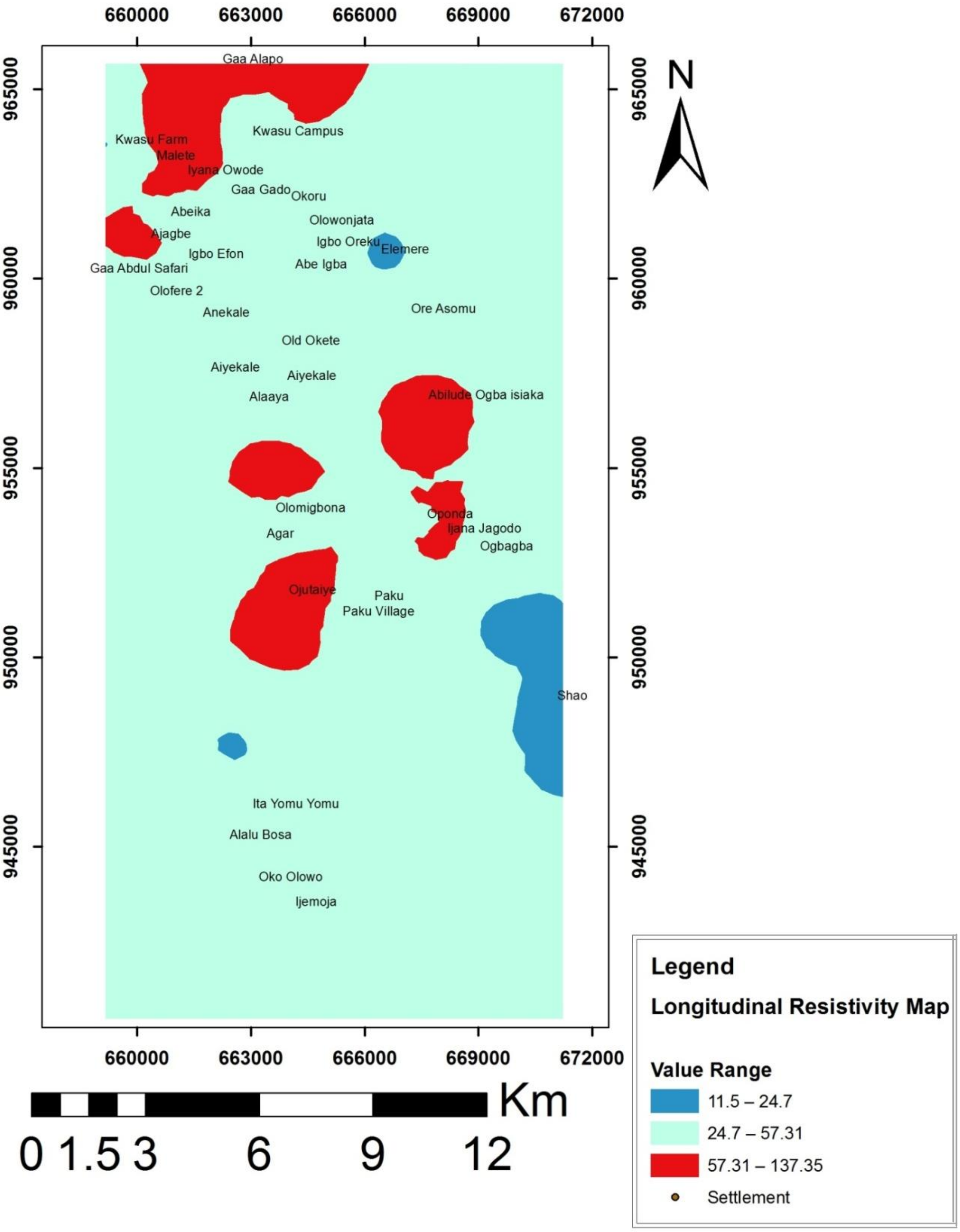

Fig. 5. Longitudinal resistivity map of the study area

Fig. 9 displays the Pie chart of the classified categories obtained from groundwater yield capacity model. About 6% of the investigated area has high groundwater yield capacity and is mainly concentrated in some part of northern end and part of the centre. Area with moderate groundwater yield capacity dominated 17% of the study area and was observed at the part of the northern, north western, Middle Eastern, part of the centre and part of the south western central. Area with low groundwater yield capacity dominated 17% and was observed at the south eastern central, north central, part of the central and south western end. Also, very low groundwater yield capacity dominated 27% of the investigated area and was observed at the part of the south eastern and south of the study area. While extremely low groundwater yield capacity dominated 1% of the investigated area and dry/no yield dominated the largest part of the area with 32% which indicates that the entire area is of low yield

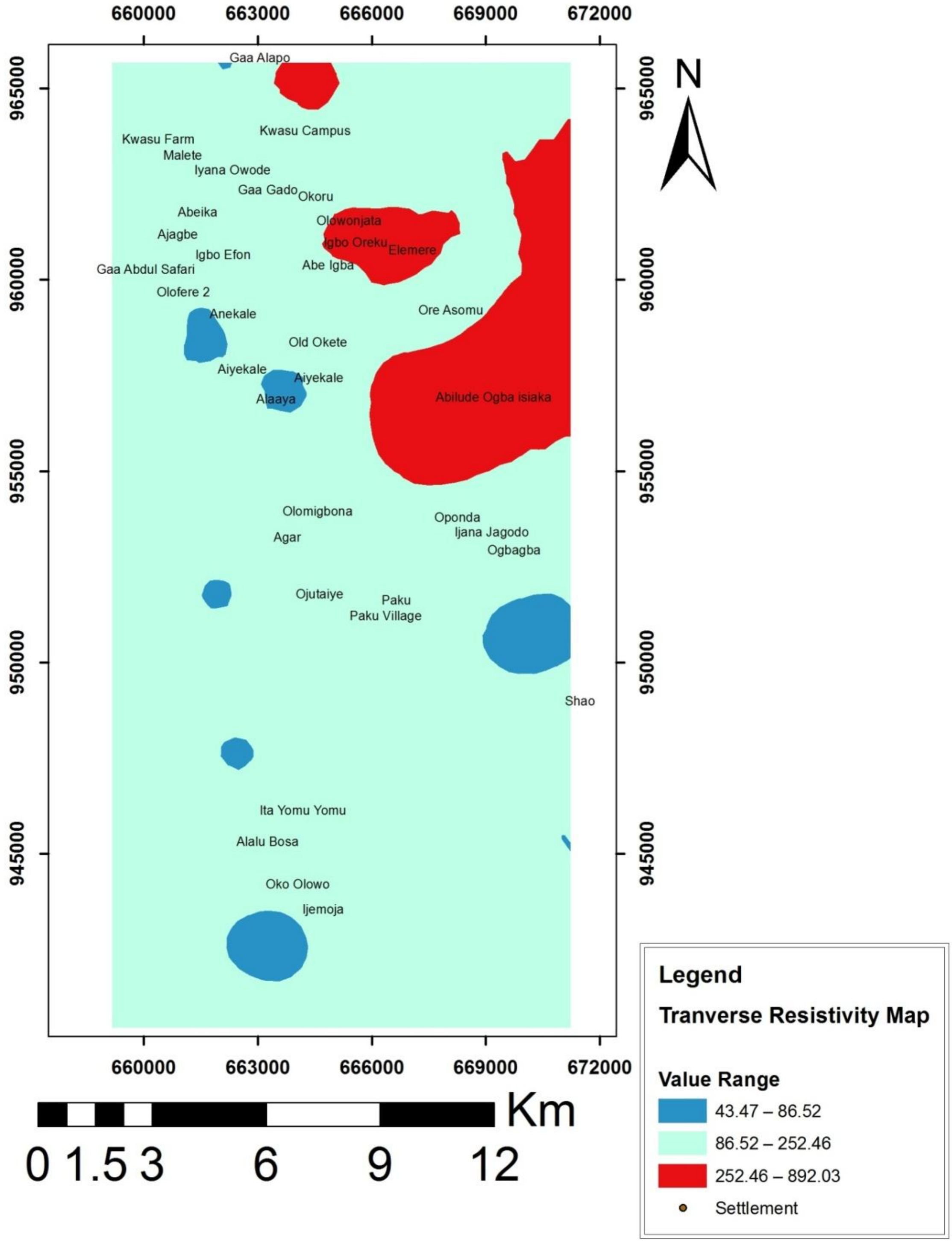

Fig. 6. Transverse resistivity map of the study area

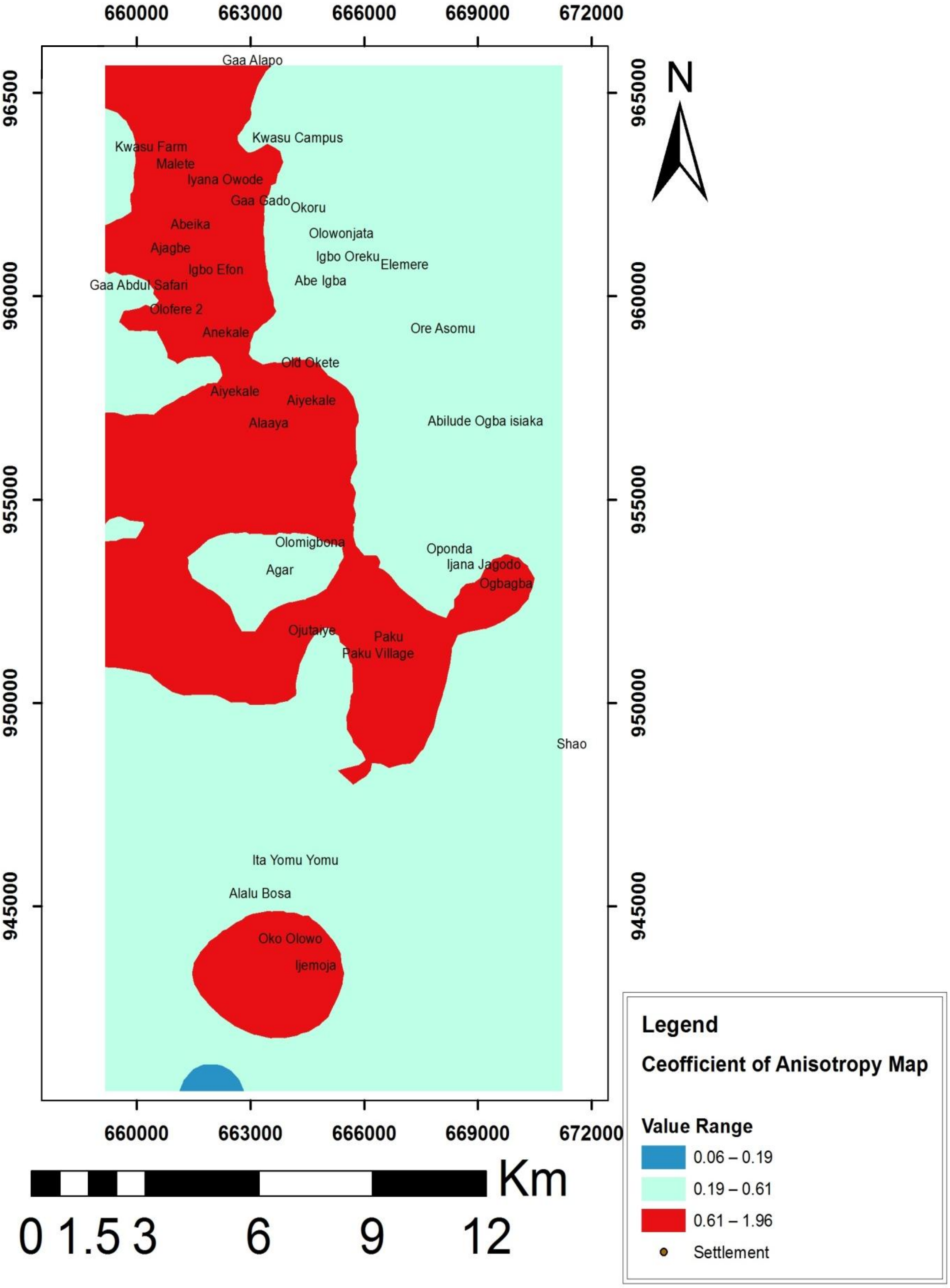

Fig. 7. Coefficient of anisotropy map of the study area

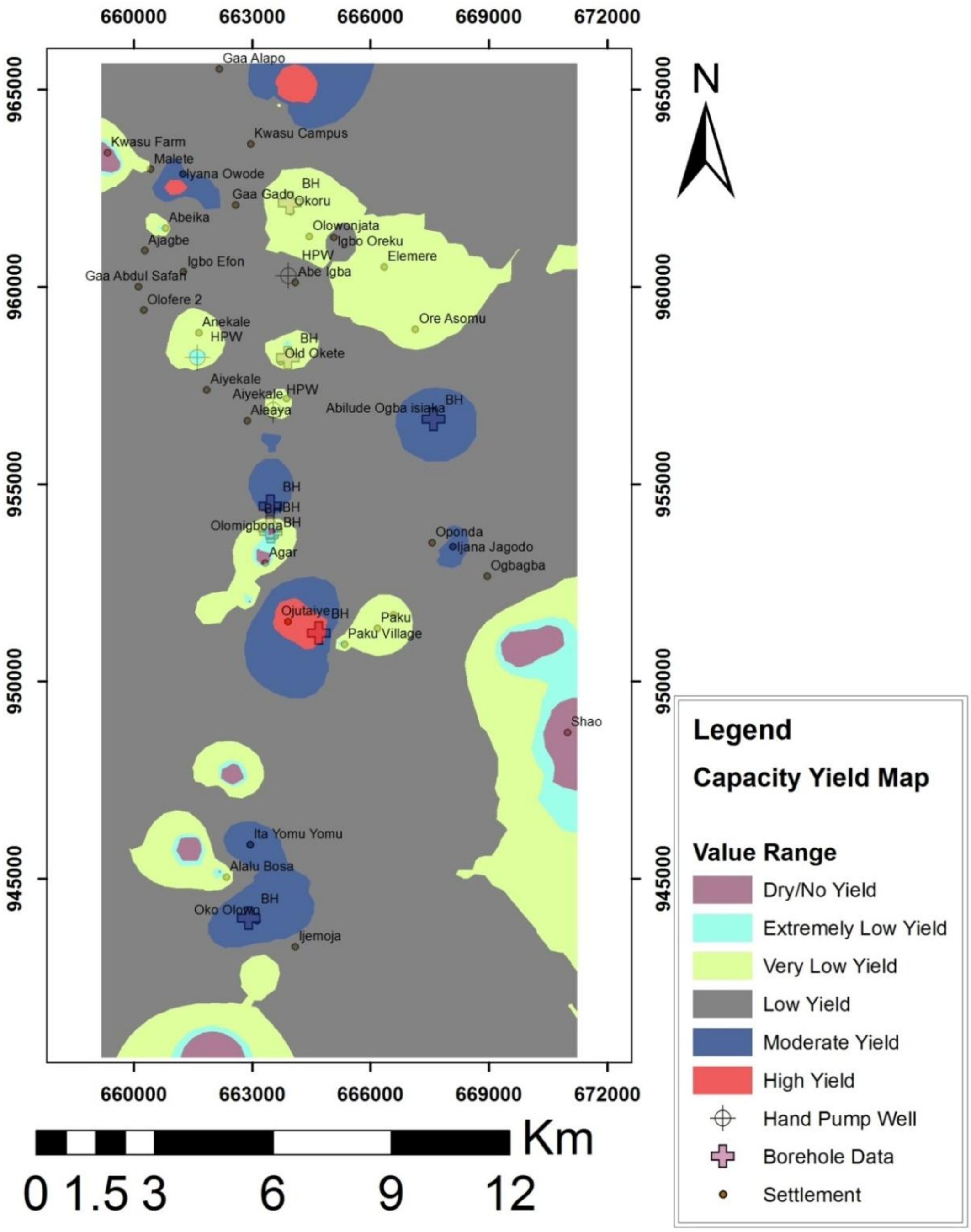

Fig. 8. Validation of groundwater yield capacity map of the study area

Table 1. Groundwater yield classifications

Groundwater yield capacity value	Classification
32 – 350	Dry/No yield
350 – 450	Extremely low yield
450 – 850	Very low yield
850 – 1750	Low yield
1750 – 3000	Moderate yield
3000 and above	High yield

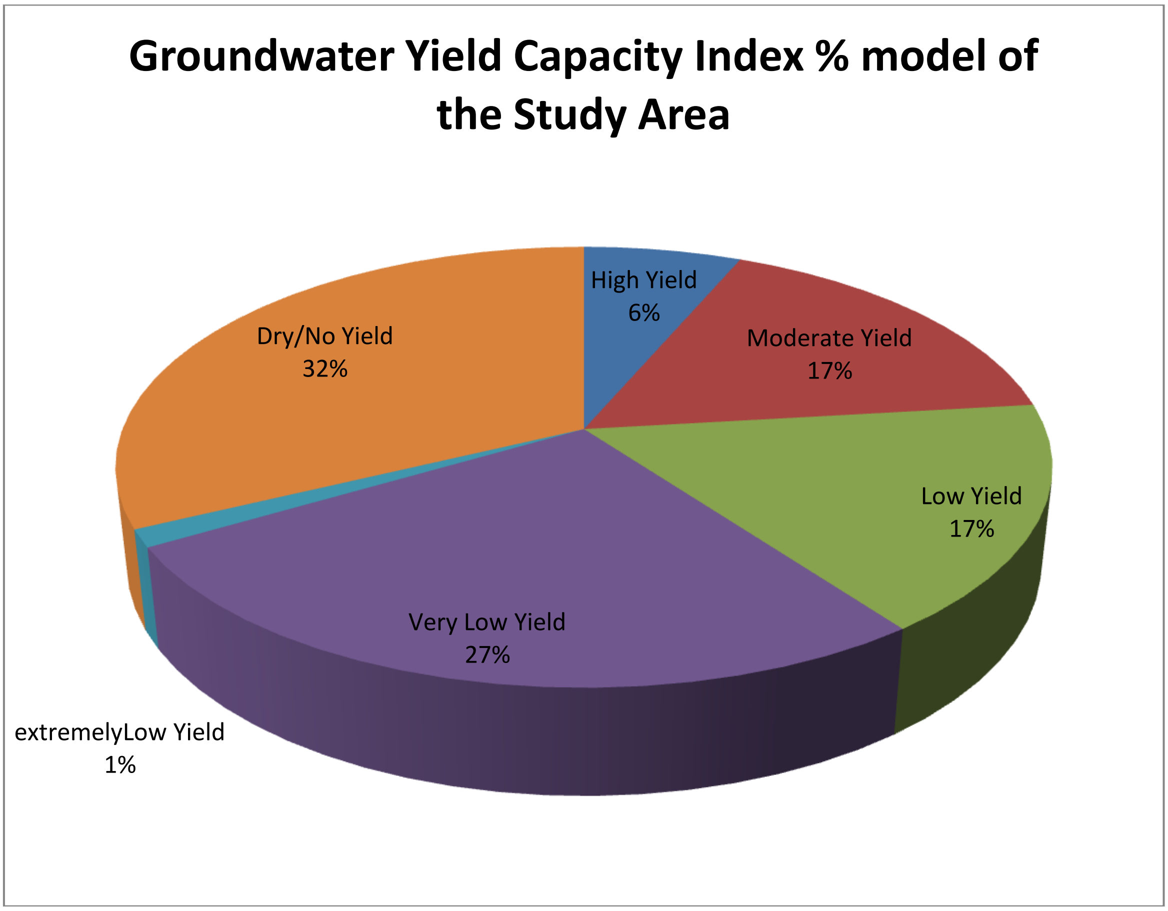

Fig. 9. Groundwater yield capacity index % model of the study area

4. CONCLUSION

The parameters was used to determine the groundwater yield index value (G.W.Y.I) by multiplying the coefficient of anisotropy (λ) and total transverse resistance (T) i.e. (λ*T). The groundwater yield capacity index value was used to model the groundwater yield capacity map which has a value ranging between 32 groundwater yield capacity index to 5945.59 groundwater yield capacity index, with the least rating being from 32.88 to 350 G.W.Y.I. which implies dry /no yield, while between 350 to 450 G.W.Y.I., implies extremely low yield and 450 to 850 G.W.Y.I., implies very low yield, while between 850 to 1750 G.W.Y.I., presenting low yield and 1750 to 3000 G.W.Y.I., implying moderate yield, while 3000 G.W.Y.I. and above stands for high yield From the results, it is concluded that the north-eastern and the central region of the area has the highest prospect while part of the north western, north central and the south eastern part has medium prospect and the rest of the area has prospect for low yield except for the south western end. Part of the south western and the middle part of the north eastern part has lean or least prospect for groundwater. The boreholes data and hand pump well across the entire study area, were used to validate the accuracy of the groundwater yield capacity map.

5. FUTURE SCOPE

This work shows that Dar-zarrouk parameters is a useful techniques in determining groundwater yield capacity but will don't need to limit ourselves to this alone, there is need for drilling of borehole on where will have high, moderate and low groundwater yield map apart from the existing borehole data used to validate the accuracy of the groundwater yield generated in order to ascertain our presumptions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Olorunfemi MO, Fasuyi SA. Aquifer types and the geoelectric/hydrogeologic characteristics of part of the central basement terrain of Nigeria (Niger State). Journal of African Earth Sciences. 1993; 16:309-317.
2. Ilugbo SO, Adebiyi AD. Intersection of lineaments for groundwater prospect analysis using satellite remotely sensed and aeromagnetic dataset around Ibodi, Southwestern Nigeria. Int. J. of Phys Sci. 2017;12(23):329-353.
3. Amudu GK, Onwuemesi AG, Ajaegwu NE, Onuba LN, Omali AO. Electrical resistivity investigation for groundwater in the Basement Complex terrain: A case study of Idi-Ayunre and its environs, Oyo State, Southwestern Nigeria. Natural and Applied Sciences Journal. 2008;9(2):1-12.
4. Amadi AN, Olasehinde PI. Application of remote sensing techniques in hydro-geological mapping of parts of Bosso Area, Minna, North Centra Nigeria. International Journal of the Physical Sciences. 2010;5: 1465-1474.
5. Banks D, Odling NE, Skarphagen H, Rohr-Torp E. Permeability and stress in crystalline rocks. Terra Nova. 1996;8:223-235.
6. Caine JS, Evans JP, CB. Forster, Fault zone architecture and permeability structure. Geology. 1996;24:1025-1028.
7. Evans JP, Forster CB, Goddard JV. Permeability of fault-related rocks and implications for hydraulic structure of fault zones. J. Struct. Geol. 1997;19:1393-1404.
8. Henriksen H, Braathen A. Effects of fracture-lineaments and *in situ* rock stresses on groundwater flow in hard rock. A case study from Sunnfjord, Western Norway. Hydrogeol. J. 2006;14:444-461.
9. Olorunfemi MO, Olarewaju VO, Alade O. On the electrical anisotropy and ground-water yield in a basement complex area of S.W. Nigeria. J. Afr. Earth Sci. 1991;12(3): 462-472.
10. Olorunfemi MO. “Voyage on the skin of the earth”: A geophysical experience. Inaugural Lecture Series 211, Obafemi Awolowo University, Ile-Ife. 2007;1-2.
11. Kunetz G. Principles of Direct current prospecting. Geophys. Monogr. 1966;1(1): 103.
12. Barker R, Blunk I, Smith I, Geophysical consideration in the design of U.K. National resistivity sounding database. First Break, 1996;14(2):45-53.
13. Vander Velpen BPA. RESIST Version 1.0. M.Sc. Research Project, ITC, Delft Netherland; 2004.
14. Ghosh DP. The application of linear filter theory to the direct interpretation of geoelectrical resistivity sounding measure-ments. Geophys. Prospecting. 1971;19: 192-217.
15. Ilugbo SO, Adebo BA, Olomo KO, Adebiyi AD. Application of Gis and multi criteria decision analysis to geoelectric parameters for modeling of groundwater potential around ilesha, Southwestern Nigeria. European Journal of Academic Essays. 2018;5(5):105-123.

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