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EVALUATION OF GROUNDWATER POTENTIAL USING AQUIFER CHARACTERISTICS ON PARTS OF BOKI AREA, SOUTH – EASTERN NIGERIA.

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ABSTRACT

Vertical Electrical Sounding (VES) and pumping test (constant discharge and recovery test) was carried out in parts of Boki Local Government Area to evaluate the groundwater potential, using aquifer characteristics of the study area. Sixteen (16) VES point was employed for this study using the Schlumberger array, with a maximum spread of 400-600m. The stimulated result from the field data shows 3-5 layers resistivity model with the following curve types A, AK, KH, KHA, QH, QHA and QHK. The geoelectric properties include resistivity of the various layers ranging from 33.58 - 2.29 x 105Ωm, thickness from 0.2 - 50.2m, depth to basement varies from 2.99 - 74.60m across the study area. The litho logs show a top layer comprising of laterite, gravel/gravelly sand and intercalations of siltstones, the layers underneath are made-up of clay, weathered basement containing migmatites and gneisses, fractured and unfractured basement are made up of granitic and metamorphic rocks. The weathered and fractured layers constitute the aquiferous layers in the study area. Hydraulic parameters show transmissivity (T) range of 4.1x 10-5 - 1.92 x 10-1 m 2 /day, specific capacity (SC) ranges from 2.09-21.42m2 /day, hydraulic conductivity (K) varies from 2.6 x 10-5 - 3.0 x 10-3m/day and mean static water level (SWL) of 7.39m. Iso resistivity map of saprolite, fractured basement map, isopach map and the transmissivity map show that the studied area falls within the low-moderate groundwater potential zone.

KEYWORDS: Evaluation, Groundwater potential, Boki, South–Eastern, Nigeria

INTRODUCTION

In the basement complex of the Obudu Plateau, ground water constitutes the most reliable and major source of water for agricultural and domestic uses. It is found within the fractured / or weathered basement and are tapped by the use of hand-dug wells and boreholes. The discontinuous nature of the basement aquifers system makes detailed knowledge of the subsurface geology, it depth of weathering and structural disposition inevitable (Adiat et.al, 2009). Therefore, there is a need for the application of geophysical and hydrological techniques such as electrical resistivity, seismic refraction, magnetic, electromagnetic, ground probing radar, pumping test, and down-hole logging in water project (Anomohanran, 2013). The electrical resistivity method (vertical electrical sounding) is used in determining the resistivity distribution of the subsurface, it is simple to apply in the assessment of groundwater occurrence (Okongbo *et al*. 2011). A combination of Geophysical methods, hydrogeologic parameter analyses and geological surveys will further provide the needed information. The development of ground water can be viewed as a sequential process with three major phases. There exploration phase, evaluation stage and the exploitation phase (Freeze and Cherry, 1979). The exploration phase involves the use of surface and sub-surface geological and geophysical techniques in search for suitable aquifers while the evaluation phase involve encompasses the measurement of hydro geologic parameters, the design and analyses of wells and the calculation of aquifer yield. Finally, the exploitation or

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management phase considers the impact between groundwater exploitation and hydro geologic system.

The aim of this work is to analyze the groundwater potential and aquifer characteristics of the study area, using electrical resistivity and pumping test to delineate groundwater aquifers for the citing of boreholes and the computation of the specific yield of the various boreholes.

LOCATION OF STUDY AREA

The study area is located between longitudes 6° 0' 0”–6° 26' 30"N and latitude 8° 30' 20”– 9° 27' 0”. The Boki area is an extension of the basement complex of the Obudu plateau, South –Eastern Nigeria, with the following dominant rock types Phylites, Hornblende schist, Gneisses, Migmatites, Igneous intrusive such as Granitoid, Dolerites. These rocks display Porphyroblastic, Granoblastic, Xenoblastic textures in metamorphic rocks while porphyritic, xenomorphic, and mortar features are present in igneous rocks. Ukaegbu and Oti (2005) had observed that polydeformation has resulted in multi –directional orientation of planar and linear structure in the basement rock of southern Obudu Plateau (Fig1).

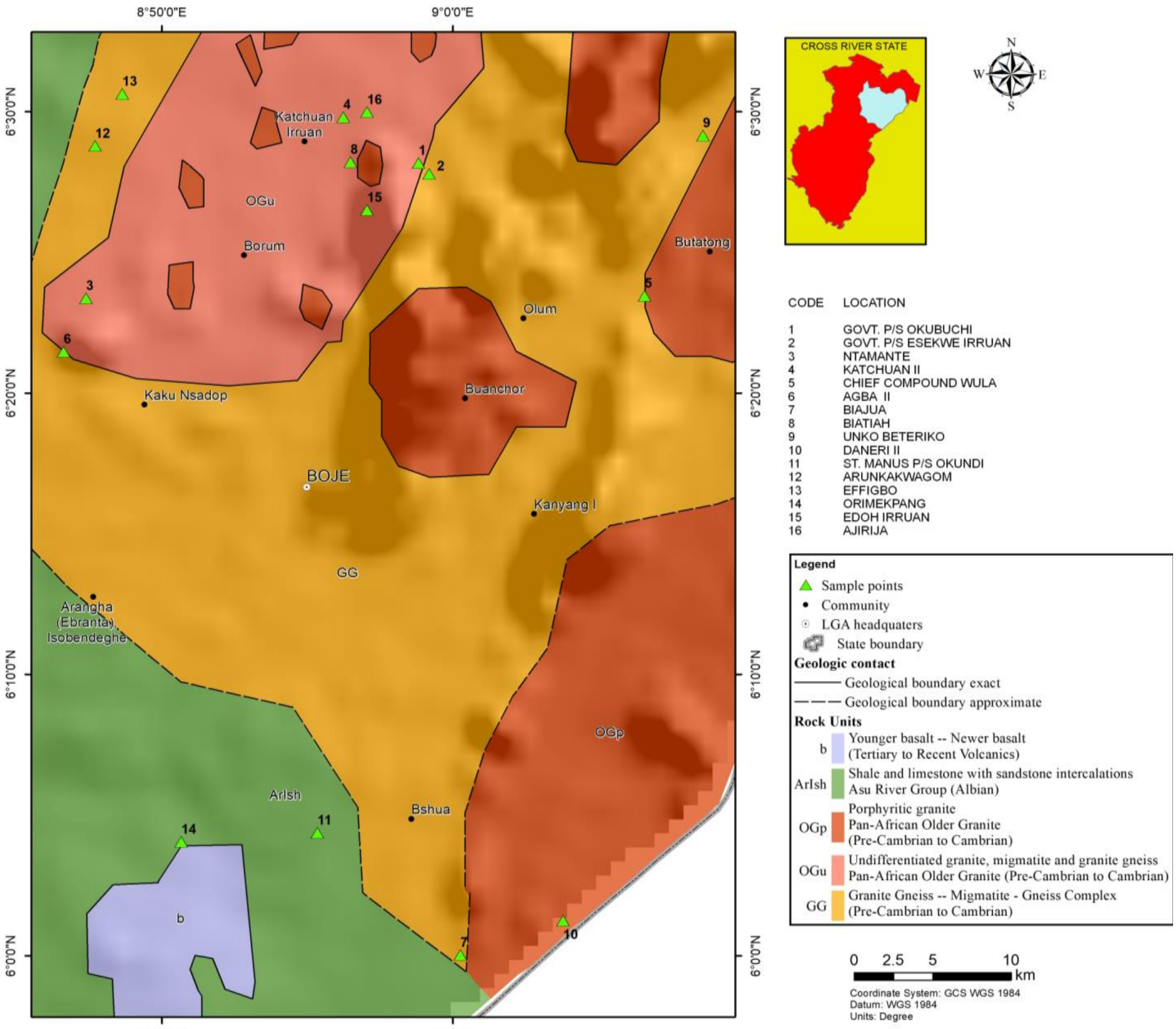


Fig. 1: Geologic/Sample location map of the study area.

MATERIAL AND METHOD

The acquisition of data was carried out in three phases, namely:

Geological or surface survey

Geophysical survey (VES)

Hydrogeology survey (pumping test)

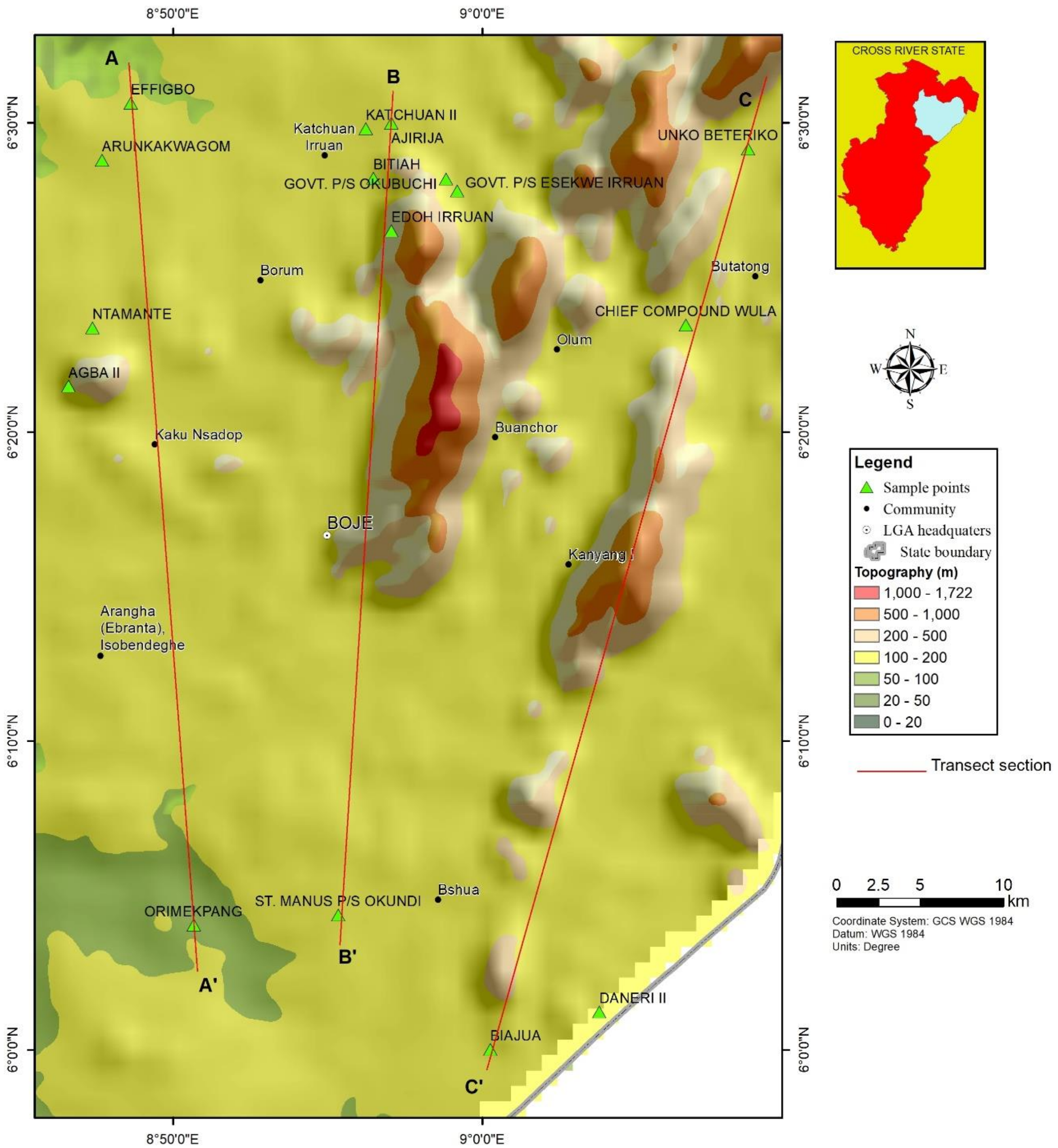


Fig. 2: Topographic map, Transverse points, VES points, Borehole locations.

In geophysical survey, Vertical Electrical Survey (VES) was carried out in 16 pre-determined communities (three VES points per sampled location) within parts of Boki Area in South-Eastern Nigeria. The Schlumberger array, with a maximum spacing of about 400- 600m between the current electrodes (fig 2) was employed. The process of carrying out resistivity involves the passage of current from the Geotron G41 terrameter into the ground through steel electrodes (current electrodes). The electrode where progressively expanded about a fixed point along the transverse line while maintaining the ratio of 1/5 of the potential electrode spacing to the current spacing. Data generated were collected along the course of traversing the survey line. The field data collected was recorded for each traverse line and was multiplied by the geometrical factor for the Schlumberger array ($G=\pi/4[L^2-a^2]/a$) to find the apparent resistivity. The data was analyzed and interpreted using a computer designed software called Interprex ID.

In hydrogeology survey, 16 wells (single wells were used due to the absences of Observation Wells) within the pre-selected communities, was pumped at a constant rate until a near steady/steady state was attained using 1.0Hp (horse power) submersible Pump, dip meter and a stopwatch was used to measure the corresponding changes (drawdown) in the water level and the respective time. Prior to the pumping, the static water level (SWL) was obtained using the dip meter, coordinates and elevation was equally obtained using the Global position system (GPS) whiles a calibrated (20) twenty liters container was used in estimating the pumping rate. For the recovery test, the submersible pump was switched off, the aquifer allowed to recharge and the corresponding time and water level measurement was noted. The data generated was subjected to topographical and analytical analysis in estimating transmissivity of the aquifer (T), hydraulic conductivity (K), specific capacity (SC), thickness (B) and drawdown(s). Transmissivity of the aquifer was computed as follows

$T = KB$

Where

T = transmissivity in m^2/day

K = hydraulic conductivity in m/day

B = depth in m

Similarly, transmissivity was computed using Cooper-Jacob straight line equation, where transmissivity (T) is given by the equation:

$T = 2.3Q/4\pi\Delta s$

Q = Constant pumping rate

Δs = Drawdown difference per log cycle. From the time- drawdown curves plots; Δs is given by the equation:

$\Delta s = S_2 - S_1/\log T_2 - \log T_1$

Where

S_2 = drawdown at point 2

S_1 = drawdown at point 1

$\log T_2$ = logarithm cycle of time 2

$\log T_1$ = logarithm cycle of time

Specific capacity (SC) is expressed mathematically as follows:

$SC = Q/s$ in m^3/day

Where

Q = Discharge rate in m^2/day

s = Drawdown in m

Hydraulic conductivity (K) is computed as follows:

$T = kb$

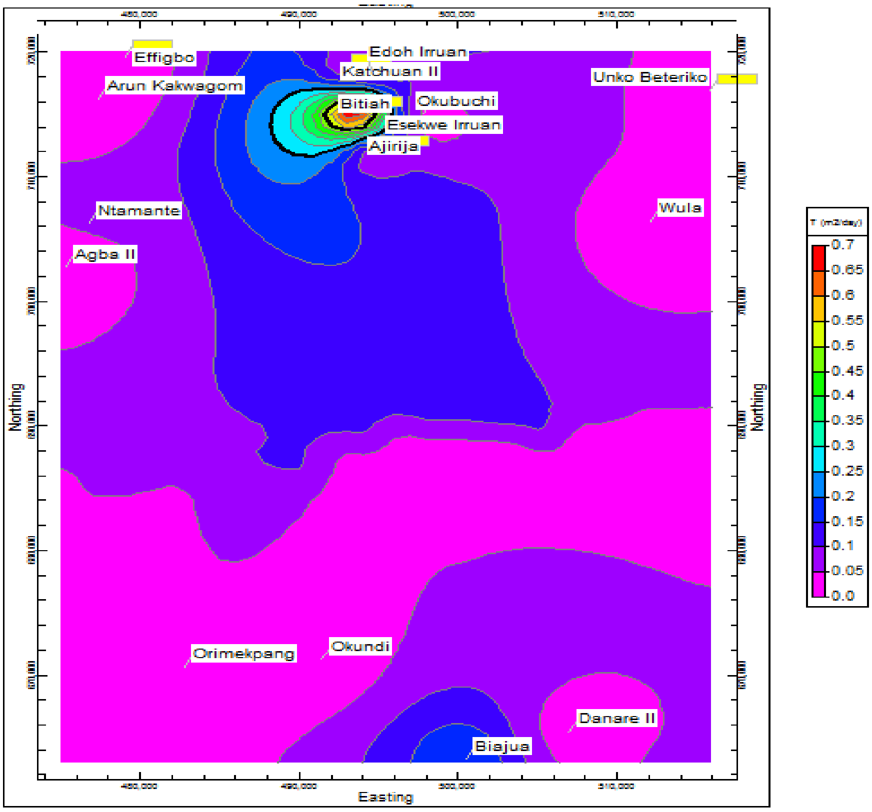
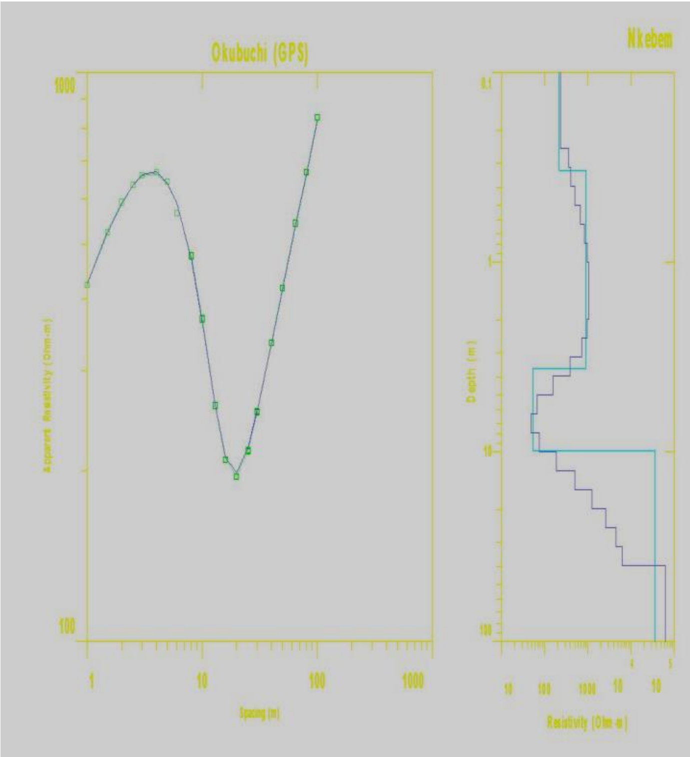


Fig. 3: Transmissivity Map of the study Area.

The value of k varies from 0.0000025m/d to 0.0034m/d as shown in table 2.

RESULT AND DISCUSSION

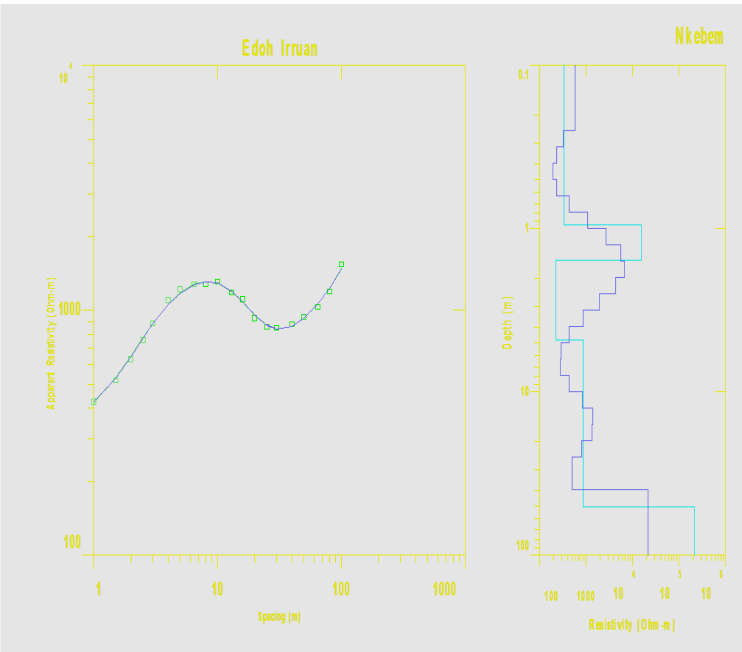
From the geo-electric curves simulated, the curve type varies from K, A, H, KH, HKA, QHA, QHK and HAA type, showing that the sub surface formation varies in composition (complex). The resistivity curve shows a 3, 4, 5 geoelectric layers within the study area. Fig 4 and 5 are typical ID resistivity curves of sampled VES stations showing apparent resistivity, calculated result and computed model. Table 1 shows a summary of the geo electric properties of the sample location.



No.	RES	Thickness	Depth
1	219.57	0.32	0.32
2	918.63	3.31	3.63
3	55.22	6.29	10.6
4	37016	-	

XXX = Observed apparent resistivity
_____ = Calculated apparent resistivity
= Computed apparent resistivity

Fig. 4**. Okubuchi Schlumberger Configuration`**



No.	RES	Thickness	Depth
1	211.43	1.92	1.92
2	325.22	22.7	24.6
3	80126		
4		-	

XXX = Observed apparent resistivity

_____ = Calculated apparent resistivity

= Computed apparent resistivity

Fig. 5: Edoh Irruan Schlumberger Configuration

TABLE 1: Geoelectric Properties of the Study Area

S/N	Location	No oflayers	Curve type	Resistivity ρ1	ρ2	ρ3	ρ4	ρ5	ρ6	Thickness h1	h2	h3	h4	h5	Depth to basement
1	Govt. PS, Okubuchi	4	KH	219.57	918.63	55.22	37016			0.327	3.313	6.228			9.87
2	EsekweIrruan	3	A	211.43	325.22	80126				1.922	22.748				24.67
3	Ntamante	4	HK	163.29	659.73	39.54	3.01E+05			4.96	3.52	8.75		α	17.23
4	Katchuan II	5	HKA	1169.5	565.80	3519.2	116.41	2145.9		1.9218	3.117	3.719	9.667		17.70
5	Wula	6	KQA	111.08	300.82	92.805	772.31	1821.3	2.29E+05	1.41	0.62	4.28	28.0	16.71	51.03
6	Agba II	4	HK	342.73	254.61	204.11	304.04			1.94	22.43	50.23			74.60
7	Biajua	6	QHK	754.12	293.9	252.16	9.710	758.01	0.1717	0.26	8.034	0.459	5.43	17.86	31.63
8	Biatiah	3	K	451.48	692.3	3974				1.94	10.64				12.58
9	UnkoBeteriko	3	H	7248	89.659	699.9				3.92	0.79				4.70
10	Daneri II	4	KH	2318.0	3262.0	56.70	1350			2.07	1.179	0.880	α		4.13
11	Okundi	5	QHA	1537.3	1002.4	159.04	13116	21.43		0.60	11.57	5.49	17.90	α	35.56
12	Arunkawa `Gom	6	HAA	1427.1	241.48	7039.8	60.29	2039.4	137470	0.4618	2.47	0.28	8.28	8.99	20.48
13	Effigbo	5	KH	286.5	109.52	2136.1	179.91	39905		5.885	3.191	11.414	18.847	α	39.34
14	Orimekpan	4	AAA	857.34	1197.2	310.95	11310			1.40	18.6	18.8	α		38.89
15	EdohIrruan	5	KHA	342.66	1560.3	228.75	890	2.21E+05		0.94	0.62	3.21	46.8	α	50.86

GEOELECTRIC SECTIONS

The VES results were used in the preparation of 2-D geoelectric sections, which shows the resistivity of the various subsurface layers and their respective thickness (Fig 6-8). Each section was prepared in accordance to the VES points in each transverse. The geoelectric section is made up of 3-5 subsurface geoelectric units, inferred as laterite, gravel and gravelly sand; clay weathered and fractured basement, and fresh basement. The study area is made up of two aquifer type. Type1 are aquifer found on the overburden/weathered layers and are mostly exploited using hand dug well as a result of their near –to-surface depth while Type 2 aquifers are found on the fractured rocks of the basement complex. From the correlation of the geoelectric section along transverse section A-A[1] (fig, 6) with the following sampled points (VES 13,12,6,14 respectively), the resistivity curves show a 3–5 layer model with the following curve types KH, HAA, HK, AK along the transverse line. These layers are laterite, gravelly sand, clay, weathered basement and the un-weathered basement. The aquiferous layer for this transverse area is the weathered basement with resistivity values ranging from 60Ωm to310Ωm and thickness values ranging from 12m at VES 12 to approximately 19m at VES 6. The area will support hand-dug wells as a result of the depth of the aquifer to the surface. The resistivity of the sampled area shows that the weathered basement has high clay content therefore; the aquifer yield will be low despite the size of the thickness of the overburden.

Fig 6: Geoelectric sections for traverse A-A[1]

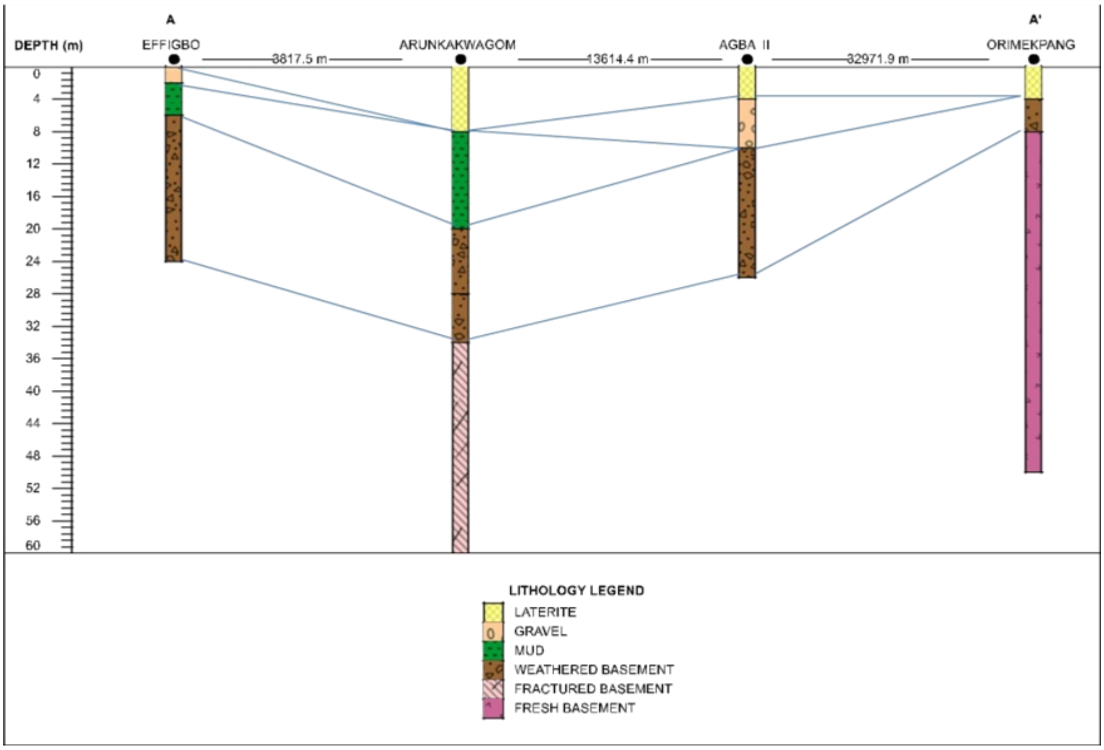


Fig 7: Geoelectric sections for traverse B–B[1]

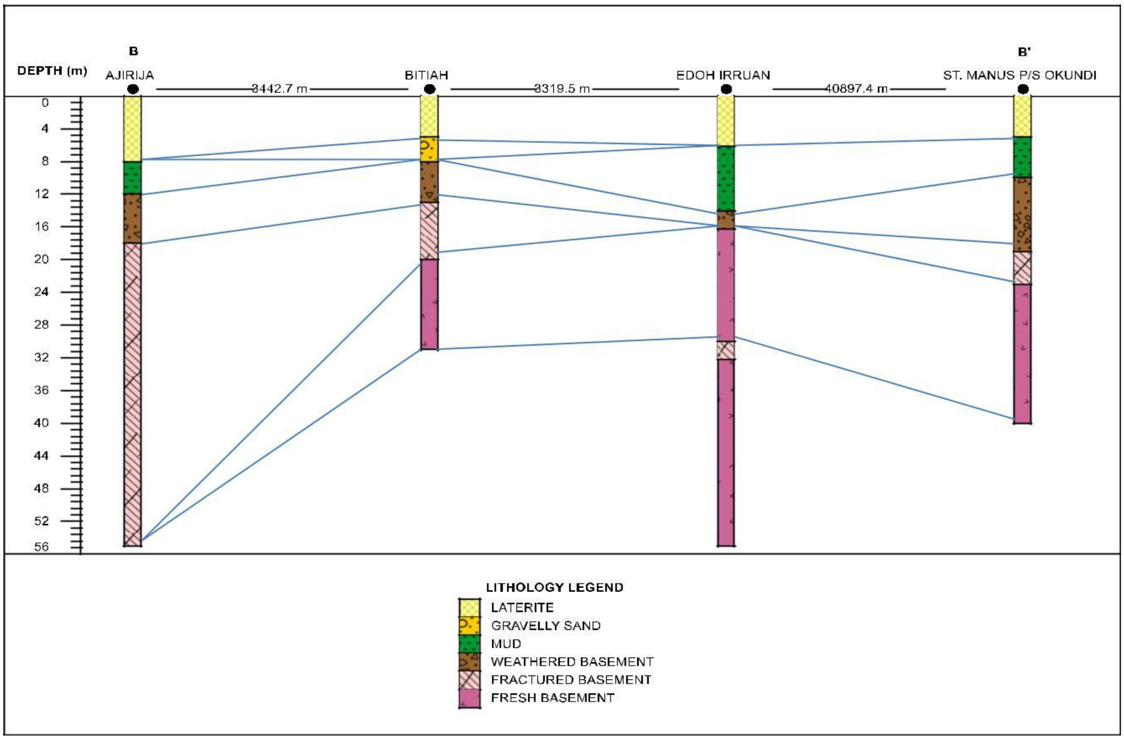
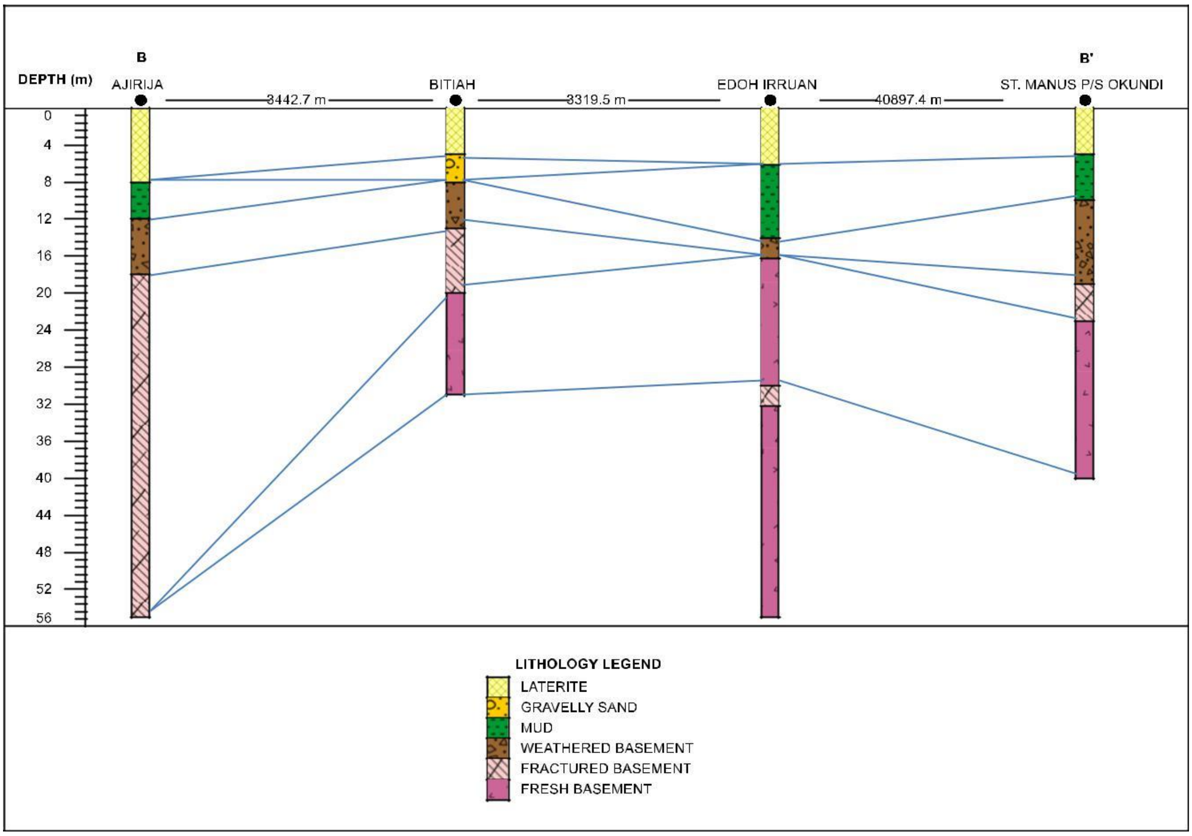


Fig. 8: Geoelectric sections for transverse C-C^1.



Transverse section B-B^1(fig,7) with the following (Ves16, 8, 15 and 11 respectively). The geoelectric sections shows 3-5 layers model with a curve type of KH, k, KHA and QHA.VES 15 showing a confined aquifer. The probable aquiferous layer for this transverse section would be the weathered layered and the fractured basement. The sampled section will support both motorized and hang dug well. The thickness of the aquiferous unit ranges from 4m at VES 15 to 32m at VES 16 with the fractured basement resistivity ranging from 890Ωm to 4153Ωm.The geoelectric layers include laterite, gravelly sand clay, weathered basement, fractured basement and the fresh basement.

The transverse C-C^1(fig,8) shows three locations within the study area namely (VES 9, 5, and 7) with a resistivity range of 89.59 to 229000Ωm. The geoelectric section shows show 3-5 layers model with the following curve type H, KQA, QHK. The geoelectric layers are interpreted as laterite, clay, weathered basement, fractured and un-weathered basement, with VES 7 showing a multi aquifer system at a depth of 20.5m-27.5m and 30m-33m. The possible aquiferous layer for VES 9 and 7 is the unconfined weathered basement while water can be tapped from a combination of the weathered and fractured basement in VES5.

ISOPACH AND ISO RESISTIVITY MAP OF THE AQUIFEROUS LAYERS

The overburdens are laterite, gravel /gravelly sands, clays, weathered basement. The overburden thicknesses (depth to basement) range from 2.99m at (lowest thickness) to 74.06m at (highest thickness) with an average thickness of 27.26m within the study area. The overburden thickness at each sounding location was gridded and contoured to produce an Isopach map (Fig.9) of the overburden. An isopach map shows the spatial distribution of thicknesses within a locality. The map was broken into four zones based on ground water potentials. They zones are Zone A (high:65 and above), B (moderate:45-65), C (low:25-45), and finally D (minimal;0-25). The zones weighted as follows Zone A 6.3%, B 37.5%, C 31% and D 25%. Based on the zoning the study area could be classified into low to moderate ground water zone. According to Olurunfemi and Okhue (1992), Oyedele and Olayinka (2012), a minimum overburden thickness of 25m is required for viable ground water abstraction in the basement terrain. In the study area, the overburden thickness varies from 2.99 to 74.06m; an overburden thickness of 25 to 72m occurred in 74% of the study area, showing a very thick overburden and thus should support productive groundwater abstraction. However, according to Lenkey et.al (2005) a thick weathered layer (containing less percentage of clay) above the basement rock will constitute a water bearing layer.

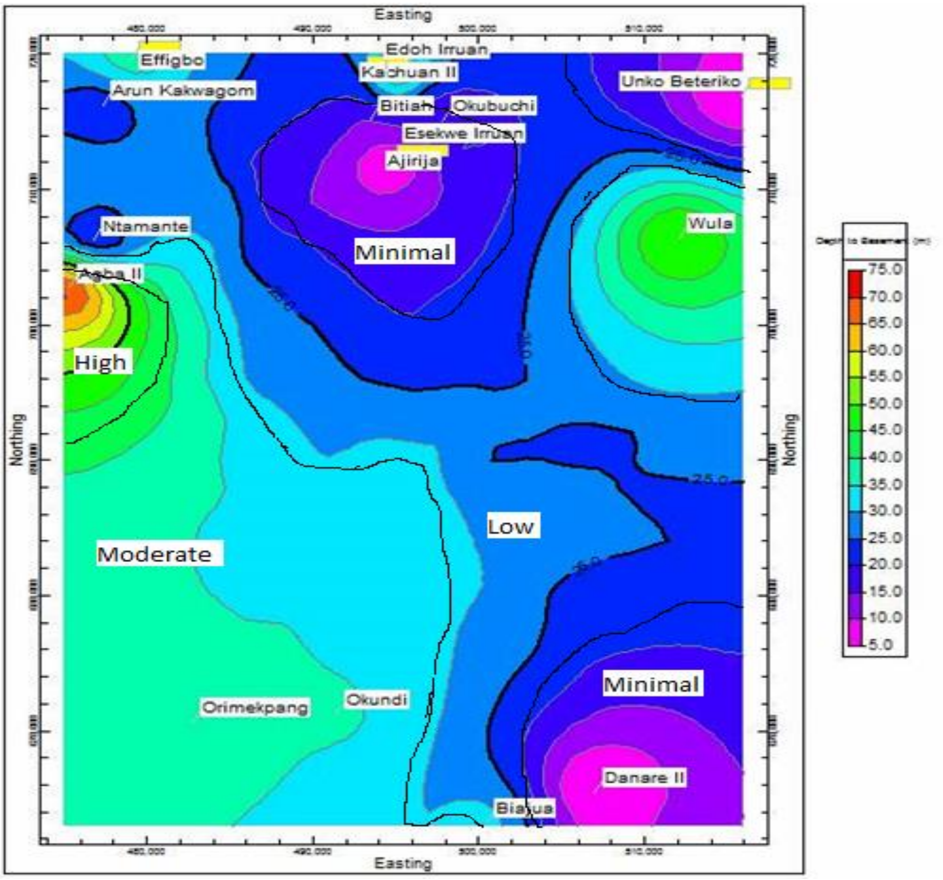


Fig.9: An Isopach Map of the Study Area.

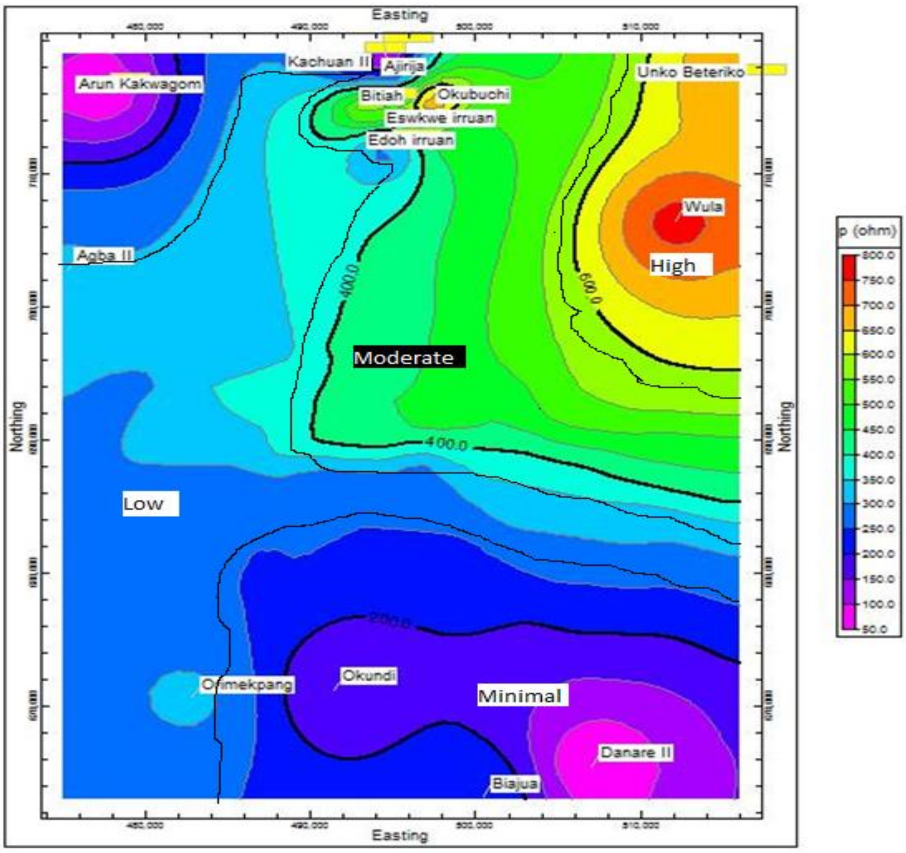


Fig.10: Iso resistivity map of weathered basement within the study area

An Iso- resistivity map of the weathered basement (saprolite) was produced to show the spread of resistivity at a common depth within the study area and presented as Fig.10.The resistivity values of the saprolite (weathered basement) ranges from 33.58-918.63Ωm, an indication of the present of laterites/clay, clayey/clay and sandy clay. The Iso-resistivity map show that the resistivity of the weathered basement is broken into the following zones in terms of groundwater potential: high groundwater potential (>650Ωm), moderate (400-650Ωm), low (150-450), minimal (33.58-150).

Wright (1992), Mallam(2004) and Adelusiet.al,(2004) had developed a scheme for ranking of ground water potential as a function of saprolite (weathered basement) resistivity as presented in the Table 2.

Table 2: Aquifer potential as a function of saprolite resistivity

Saprolite resistivity (Ωm)	Aquifer characteristics
<20	Clayey with limited aquifer potential
20 – 100	Optimum weathered and groundwater potential
101- 150	Medium aquifer conditions and potential
151- 300	Limited weathering and poor groundwater potential
> 300	Negligible

Source: Oyedele et.al. (2012)

From the table 2, the study area has 21.43% in the optimum weathered and ground water potential zone, 7.14% in the medium aquifer conditions and groundwater potential while 50% of the area within the study area is in the negligible zone with no appeal for groundwater potential. Finally, the limited weathering and poor groundwater potential zone constitute 21.43% of the study area. In the basement terrain, the aquiferous layers are usually found in the thick, porous weathered and the fractured part of the bedrock. The fractures are mostly associated with high ground water yield when compared with the overburden as a result of its relatively high permeability. A ranking scheme for aquifer potential, as a function of the fractured bedrock which was modified by Oyedele et al.,(2012) is shown in the table 3 below.

HYDROLOGICAL ANALYSIS

From the pumping test exercise carried out, the results obtained from the various pumped location is presented as table 3. Using Cooper –Jacob straight line equation, the data was handle graphically and analytically resulting in the plotting of time- drawdown curve on a semi-log graph for the various locations and the computation and analyses of aquifer parameters, here presented as appendix 2 and Table 3 respectively.

Table 3: Computed transmissivity value for the study area

S/N	Location	Transmissivity	Specific discharge	Hydraulic conductivity
1.	Govt. PS, Okubuchi	0.00541	21.424	0.00055
2.	EsekweIrruan	0.00421	4.251	0.00017
3.	Ntamante	0.059	11.398	0.0034
4.	Katchuan II	0.0125	16.67	0.00071
5.	Wula	0.00263	15.807	0.000052
6.	Agba II	0.00373	10.725	0.00005
7.	Biajua	0.192	2.9108	0.0061
8.	BiatiahUnko	0.975	3.871	0.0776
9.	Beteriko I	0.00041	2.435	0.000087
10.	Daneri II	0.0258	3.184	0.0062
11.	Okundi	0.0262	7.376	0.00074
12.	ArunkawaGom	0.00845	16.386	0.00041
13.	Effigbo	0.00373	21	0.000095
14.	Orimekpan	0.002605	2.089	0.000067
15.	EdohIrruan	0.00013	3.038	0.0000025
16.	Ajirija	0.0013	2.8943	0.00041

Transmissivity (T)

T = kb

T =2.3Q/4ƛΔs ……………. (Cooper and Jacob 1946)

Table 3 show the computed transmissivity value for the study area, which ranges from 0.00013 to 0.975 m^2/day with an average transmissivity of 0.032m^2/day within the pumped locations. Fig.4 is a transmissivity map showing the spatial distribution of transmissivity within the pumped locations in the study area. Offodite (2002) suggested a transmissivity range of 5to 50m^2/day to represent high groundwater potential in crystalline rock while 0.0155m^2/s (10000gal/day/ft.) represent good aquifer for well exploitation (Cherry and Freeze 1979). However, the transmissivity range of the pumped wells within the study area was characterized by negligible to low ground water potential.

The table 4 shows the saturated hydraulic conductivities (k) values found in nature.

<table>
<tr><th>K(cm/s)</th><th>102</th><th>101</th><th>1</th><th>10-1</th><th>10-2</th><th>10-3</th><th>10-4</th><th>10-5</th><th>10-6</th><th>10-7</th><th>10-8</th><th>10-9</th><th>10-10</th></tr>
<tr><td>K(ft./d)</td><td>10^5</td><td>10^4</td><td>10^3</td><td>10^2</td><td>10</td><td>1</td><td>0.1</td><td>0.01</td><td>0.001</td><td>0.000 1</td><td>10^{-5}</td><td>10-^{5}</td><td>10^{-5}</td></tr>
<tr><td>Relative permeability</td><td colspan="4">Pervious</td><td colspan="4">Semi pervious</td><td colspan="5">Impervious</td></tr>
<tr><td>Aquifer</td><td colspan="4">Good</td><td colspan="5">Poor</td><td colspan="4">None</td></tr>
<tr><td>Unconsolidated Sand& Gravel</td><td colspan="2">Well sorted Gravel</td><td colspan="3">Well sorted Sand and or Sand Gravel</td><td colspan="4">Very fine Sand, Silt, Loess, Loam</td><td colspan="4"></td></tr>
<tr><td>Unconsolidated Clay& Organic</td><td colspan="3"></td><td colspan="3">Peat</td><td colspan="3">Layered clay</td><td colspan="4">Fat/ Un-weathered clay</td></tr>
<tr><td rowspan="2">Consolidated rocks</td><td colspan="4"></td><td colspan="3" rowspan="2">Oil Reservoir</td><td colspan="2" rowspan="2">Fresh Sandstone</td><td colspan="2" rowspan="2">Fresh Limestone, Dolomite</td><td colspan="2" rowspan="2">Fresh Granite</td></tr>
<tr><td colspan="4">Highly Fractures Rocks</td></tr>
</table>

From the computed hydraulic conductivity on the table 2 for the study area, the sampled location falls within the semi pervious zone with poor ground water potential.

THICKNESS OF THE AQUIFER

The aquifer thickness ranges from 2.2–50, 22m, the aquifers which is found within the weathered materials and fracture zones of the overburden has high clay content, which is very typical of the Obudu Basement Complex, as it is still undergoing weathering. Although the study area is characterized by zones of high over burden thicknesses, its high clay content places it within the low groundwater potential zones.

CONCLUSION

The use of geophysical and hydrogeological methods in the evaluation of the ground water potential, and aquifer characteristic in the study area have shown that the result from the field data shows 3-5 layers resistivity model with the following curve types A, AK, KH, KHA, QH, QHA and QHK. The geoelectric properties include resistivity of the various layers ranging from 33.58 - 2.29 x 105Ωm, thickness from 0.2 - 50.2m, depth to basement varies from 2.99 - 74.60m across the study area. The litho logs show a top layer comprising of laterite, gravel/gravelly sand and siltstone intercalations and the layers underneath are made-up of clay, weathered basement containing migmatites and gneisses, fractured and unfractured basement are made up of granitic and metamorphic rocks. The weathered and fractured layers constitute the aquiferous layers in the study area. Hydraulic parameters show transmissivity (T) range of 4.1x 10-5 - 1.92 x 10-1 m 2 /day, specific capacity (SC) ranges from 2.09-21.42m2 /day, hydraulic conductivity (K) varies from 2.6 x 10-5 - 3.0 x 10-3m/day and mean static water level (SWL) of 7.39m . Iso resistivity map of saprolite, fractured basement map, isopach map and the transmissivity map show that the studied area falls within the low-moderate groundwater potential zone.

RECOMMENDATION

As a result of the low-moderate aquifer potential of the study area, mechanized farming should be discouraged; however, two bore holes can be cited 50meters apart to improve the water supply within the farm.

The need for an observation wells in future study, this will help in the computation of storativity values.

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