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Evaluation of the Aquifer Characteristics of Nteje and Environs, Anambra Basin, South Eastern, Nigeria

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Abstract

Hydro-geophysical investigation of Nteje in Anambra East Local Government and environs were carried out with a view to ascertaining aquifer characteristics in thirteen (13) communities. Field data revealed four to five geo-electric units consisting of saturated aquiferous zonesmade up of one unconfined and three or four confined aquifers.The predicted watertable ranges from 21.5m to 102m with linear increase from NW to SE of the study area.The Isopach map shows that the aquifer is thicker at the NE and NW parts where there are more clusters of the peak contours when compared to the other parts of the study. The aquifer thickness map shows that there are concentrations of sediments. The transmissivity T_C calculated from VES result ranges from 0.4750 m^2/day to 61.4161 m^2/dayand the conductivity varies from 0.0080 m/day to 1.4907 m/day.This implies that the aquifer at Umeri will be adequate for regional water scheme.
KEY WORDS: Geo-electric layers, aquifer, Correlation, Transmissivity

1. Introduction

The area of study comprises Awkuzu, Aguleri, Achalla, Umueri, Nteje, Nando, Nsugbe, Umunya, Nkwelle, Umueze-Anam and Igbariam (Fig 1.0 and 1.1) It lies between latitudes 6^o12^IN- 6^o22^I N and longitudes 6^o47^I E- 7^o00^I E. It is about 24km southeast of Awka, the Capital City of Anambra State, Nigeria. The study area is accessible through Enugu-Onitsha express road and those that run through Awkuzu, Nteje, and Umuatulu-Umueri and Aguleri Junction. Also there are minor roads passing through Abba junction, Ukwulu, Igbariam campus, Nando down to Otu-ocha via Aguleri Junction.

The study area experiences both rainy and dry seasons and may be affected by erratic changes in temperatures. The rainy season, usually accompanied with thunderstorm, starts in April and ends in October. The mean annual rainfall ranges from 1700mm to 2100mm and has double maxima regime in July and October with persistent characteristic drop in the month of August, commonly referred to as August break (Egboka and Nwankwo, 1985; Iloeje, 1985; Ogbukagu, 1976). Okoro, *et al*. (2010) evaluated the aquifer characteristics of Nanka Sand and ascertained that the Formation has 3-5 geoelectric Units. Oseji*et al*. (2007) discussed the extent and distribution of groundwater resources in parts of Anambra State and reported that the state is underlain by four different geologic formations of varying water storage and yielding capacities.Ogbukagu (1976) reported that the high sodium ion in the Nanka sand area is probably due to the chemical breakdown of feldspar flakes. In this study we present report of detailed geophysical (VES METHOD) and groundwater prospection in the Nteje area of the Anambra basin and discussed parameters such as aquifer zones or depth to water table, aquifer thickness, sites for optimum groundwater yield from boreholes and the relationship between watertable and topography and therefore the direction of groundwater flow in the study area.

2. GEOLOGIC SETTING

The Study area is located within the Anambra Basin which is one of the seven large sedimentary domains of Nigeria. It shares the singular distinction of belonging exclusively to Nigeria. Anambra Basin is a Cretaceous sedimentary domain partly sandwiched between Niger Delta, Benue Trough and Mid Niger Basin. The evolution of this Basin followed the subsidence of a platform in the southern Benue trough, concurrent with the lateral translocation of the depocentre during the Santonian thermo tectonic event that folded and elevated the Abakalilki region (Egoka and Nwafor, 1985). The stratigraphy of the Basin shows that it contains six separate and distinct Formations. The lithologies of these Formations range from shale, sandstone, coal seam and shaly sandstone with small intercalations of calcareous limestone (Okoro, *et al., 2010?)*. The Ameki Formation which outcrops in most of the study area, embodied grayish–green sandy clay which is characteristically fossiliferous.It is also associated with white clay sandstone and calcareous limestone. The thickness of Ameki Formation was determined to be around 1,400m in certain section of its transgression (Onwuemesi and Egboka 2006). It is typically found around Otu-ocha, Nsugbe, Nkwelle and some part of Umueri. Deriving from its thickness the Formation occupies a substantial area of the Eocene strata which covers the Imo Formation. Ameki Formation is also present in southwest Nigeria.

3. METHODOLOGY

The Vertical Electrical Sounding (VES) method of electrical resistivity was employed using the Schlumberger electrode configuration (Fig.2). A maximum of current electrode spacing of AB/2 of 150m was fixed in this work in view of the shallow nature of the basement rocks of the area. A total of 13 sounding stations (appendix I) were carried out within the study area (Fig.1.1). The ABEM Terrameter SAS 300 was used in the data acquisition. The potential differences obtained from the current electrodes and potential electrodes placed that a specified istance is recorded.The Schlumberger electrode configuration was adopted in the field to determine the thickness of the vertical sections and their corresponding resistivity values. This approach has been applied extensively in groundwater exploration(Aboh*et al.,* 2000*;* Edet*et al.,* 2002*;* Onwuemesi*et al.,*2006; Anudu*et al.,* 2008; Oseji*et al.*, 2009; Okoro*et al.,* 2010; Akpoborie*et al.*, 2011). The measurements were made with great care. Measurements were not taken close to electric power lines so as to avoid electromagnetic effect on the reading.Battery was checked at intervals and recharged when the current has dropped.Care was taken to make sure that the profiles were taken in straight line and that the cable neither touched nor crossed each other. Measurements were taken to maintain the required AB/2 and MN/2 ratio AB ≥5MN and looping done at appropriate length.

4. Results, Interpretation and Discussion

4.1 QUANTITATIVE INTERPRETATION

The interpretation of the resistivity data of the thirteen (13) stations represented as V1-V13 shows basically four geo-electric horizons with the exception of VES 6, 7, and 13 with only three..Below are detailed descriptions of the some of the VES results.

VES 1 (Ukpo)

The data obtained from the Ukpo area were plotted and interpreted (Fig. 3a). From the VES curve, the VES showed four different geo-electric layers (Table 1a).The first layer is the top soil with a thickness or depth of 2.27m with resistivity value of about 649 Ωm. The second horizon has a lower resistivity value of 107 Ω-m, which indicates high conductivity and is interpreted as shally sandstone and the depth is 21.5m. Below this horizon is the saturated sandstone which has resistivity of 1012 Ω-m. It is interpreted as water saturated sandstone which is the prospective aquifer unit of interest.The last layer whose bottom was not reached has a low resistivity value of 127 Ω-m and was interpreted as shale.

VES 2 (Igbariam)

The data obtained from the Igbariam Campus location were plotted and interpreted (Fig.3b). From the VES curve plotted, the VES showed four different geo-electric layers (Table 1b).The first layer is the top soil which has depth of 1.10m with low resistivity value of about 37.6 Ωm. The second horizon has a higher resistivity value of 650 Ωm and the depth is 14.3m which is interpreted as dry sandstone. Below this horizon is the shale which has resistivity value of 36 Ωm with depth of 43.1m. The fourth horizon has a resistivity value of 102 Ωm and was interpreted as water saturated sandstone. It's thickness cannot be determined because the base was not reached it is water bearing.

VES 4 (Achalla)

Four geo-electric units were delineated in VES d curve (Fig.3d) and their values are shown in (Table 1d). The first horizon, the top soil, has a resistivity value of 43 Ωmand a depth of 3.21m. It is underlain by a unit which has resistivity value of 19.5 Ωmand a thickness of 36.03m. This layer is shalysandstone. Saturated sandstone which is aquiferous, was encountered at depth of 92.4m and resistivity value of 101.9 Ωm. The last layer has a lowest resistivity value of 10.01 Ωm.

VES d (NneyiUmeri)

Four horizons were delineated in VES f curve as shown in (Fig.3f) as well as (Table 1f). The first layer has a resistivity value of 110 Ωm and a depth of 1.52m. This layer is the top soil. The next layer has a low resistivity value of 31.7Ωm. This layer is interpreted to be shally sandstone with depth of 55.3m. The third layer has a lower resistivity value of 16.1 Ωm and has the depth value of 96.5m. This layer was interpreted as water saturated sandstone which is the aquiferous unit in the area. The fourth layer which is the last has the lowest resistivity value of 1.4 Ωm and was interpreted as shale.

Otuocha VES 3: The geo-electric section of Otuocha has a top layer of about 1.33m thickness, and resistivity (ρ) of 389.2 Ωm. It also has shaley sandstone with resistivity (ρ) of 103.3 Ωm and depth of 5.49m, while its borehole section has thickness of about 8m and is interpreted as top lateritic sand. The next geo-electric layer is dry sandstone of resistivity (ρ) 6150 Ωm and thickness of 50m, which is medium-fine-grained to well-sorted sandstone in the borehole section which is about 45m thick. The water saturated unit of the geo-electric section has resistivity (ρ) 1092 Ωm, and is well-sorted fine-grained sandstone in the borehole litholog about 97m thick.

Awkuzu VES 13: In the geo-electric section, the top layer consisted of thin lateritic soil, about 1.5m thick and resistivity (ρ) of 124 Ωm, while it has thickness of about 5m in the borehole section. The next layer has about 4.4m thickness and resistivity (ρ) of 2084 Ωm for the geo-electric unit, and is interpreted as dry sand. While in the borehole section, it has about 4.9m thickness. The third layer is shaley sandstone with resistivity (ρ) of 87 Ωm in the geo-electric unit, and thickness of about 60m, while it has thickness of 75m in the borehole section.The water saturated unit for the geo-electric section has thickness of 60m, resistivity (ρ) of 1604 Ωm, while in the borehole section, it has thickness of about 58m and is well sorted fine sand.

Correlation: The depth to the top of the aquifer (watertable) deduced from the geoelectric section was subtracted from the topographic elevation measured from the mean sea level as presented in Table 2.The Isopach map (Fig 4)shows that the aquifer is thicker at the NE and NW parts where there are more clusters of the peak contours when compared to the other parts of the study. The conditions supporting the accumulation of groundwater are therefore more favourable in these areas. The aquifer thickness map (Figs 4bi and 4bii) show that there are concentrations of sediments in this area.Figures 4ci-4di and ii show that transmissivity has the highest value at Umeri. This implies that the aquifer of the area will be adequate for regional water scheme. The aquifer conductivity map (Figs 4di and 4dii) also shows similar distribution.There is also regional correlation of geo-electric points (VES 1, 3, 8, and 13) along NW-SE direction (Fig. 4ei). The top soil consists of sand and lateritic soil is relatively thin ranging in thickness between 1.33m and 3.21m. The water saturated sandstone has thickness which ranges between 48.9m to 89.5mThus; the aquiferous units here have thickness range value of about 93.6 to 106.9m. Generally, the aquiferous units in Fig. 4ei are continuous..

5. Conclusion and Recommendations

It is obvious that civilization and industrialization will continue to require increasing amount of research work and investigation in discovering the abundance natural resources of the earth and the possible ways of harnessing them. Geophysical investigation for groundwater in some parts of Anambra East Local Government Area to ascertain the depth to watertable, the variation of aquifer depths from geo-electric units, and also variation of watertable with topography as well as determining the direction of groundwater flow have been undertaken in the Nteje area. The predicted watertable in the area ranges from 21.5m to 102m with linear increase from NW to SE.. The watertable contour map shows that groundwater mainly flow in a radial pattern from the watertable mound. The transmissivity T_c calculated from VES ranges from 0.4750m2/day to 61.4161m2/day and the conductivity varies from 0.0080m/day to 1.4907m/day.

In conclusion, the result of the investigation shows that the regional water project be sited at Umeri where there are high values of aquifer thickness and transmissivity.

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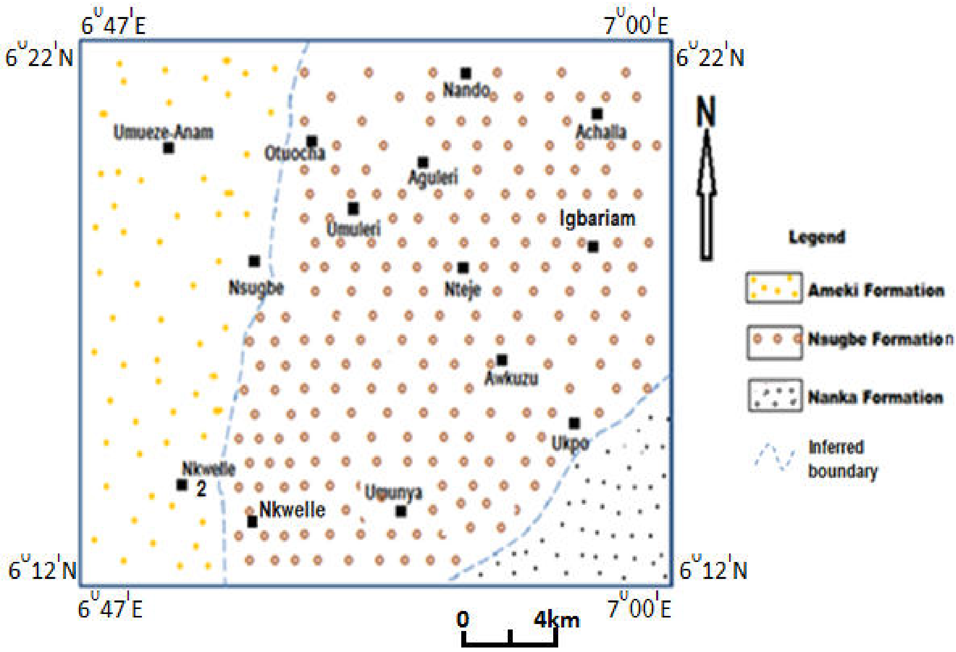


Fig.1.0: Geological map of the study area (Modify after Okoro et al. 2010)

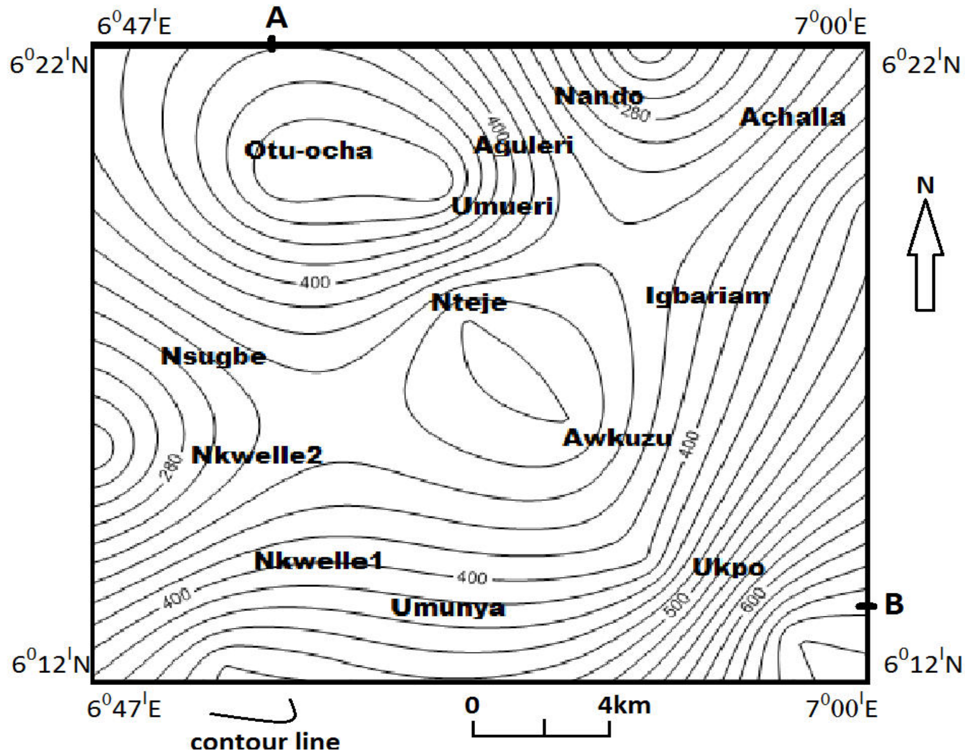


Fig. 1.1: Topographic map of the study area

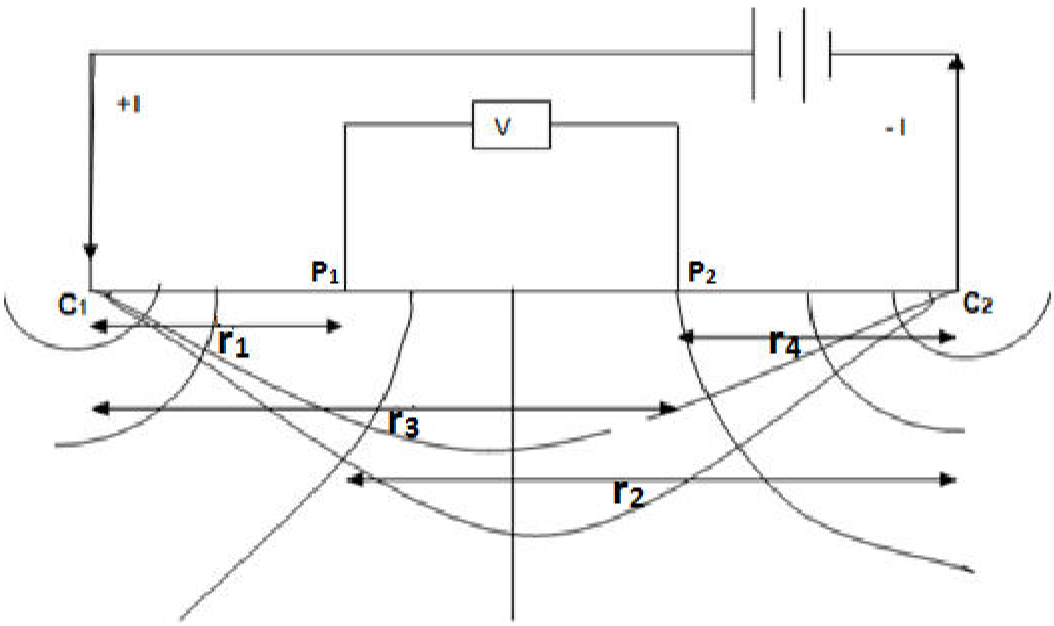


Fig. 2: Sketch diagram of Schlumberger array.

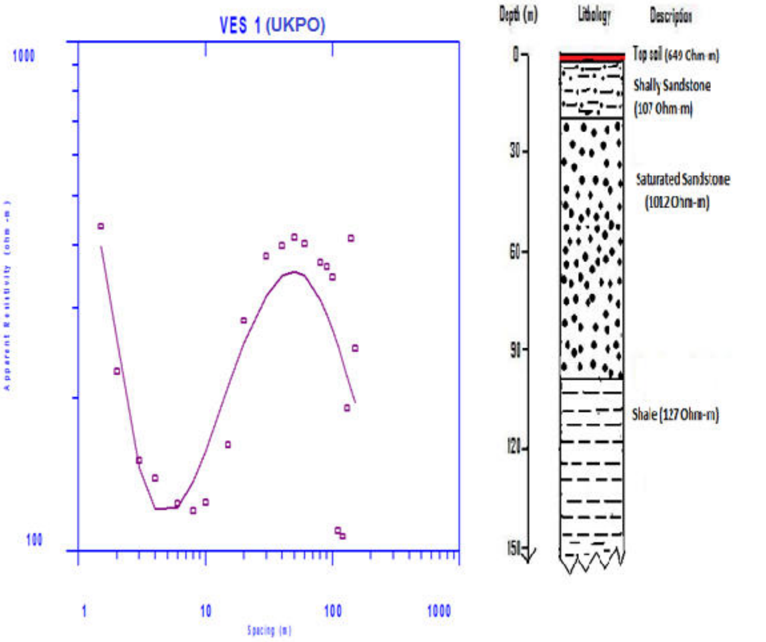


Fig 3a: Geoelectric curve and section at VES 1

Table 1a:Geoelectric parameter at VES 1

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	649	2.27	2.27	Top soil
2	107	19.23	21.5	Shally Sandstone
3	1012	79.6	101.1	Water Saturated Sandstone
4	127		150	Shale

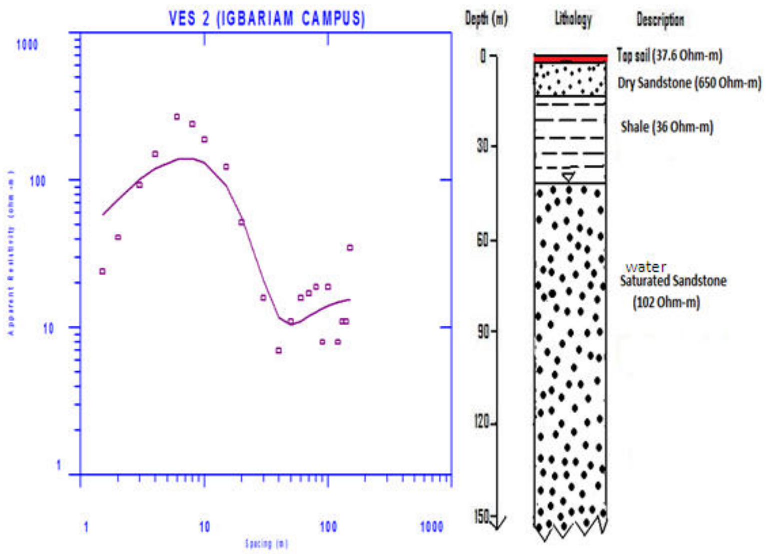


Fig 3b: Geoelectric curve and section at VES 2

Table 1b:Geoelectric parameter at VES 2

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	37.6	1.1	1.1	Top soil
2	650	13.2	14.3	Dry Sandstone
3	36	28.8	43.1	Shale
4	102		150	Water Saturated Sandstone

Table 1c:Geoelectric parameter at *VES* 3

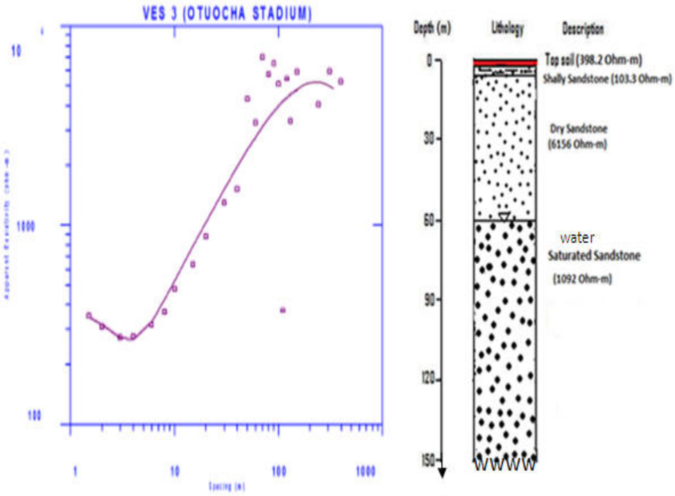


Fig 1c: Geoelectric curve and section at VES 3

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	43	3.21	3.21	Top soil
2	19.5	32.82	36.03	Shally Sandstone
3	101.9	56.37	92.4	Water Saturated Sandstone
4	10.01		150	Shale

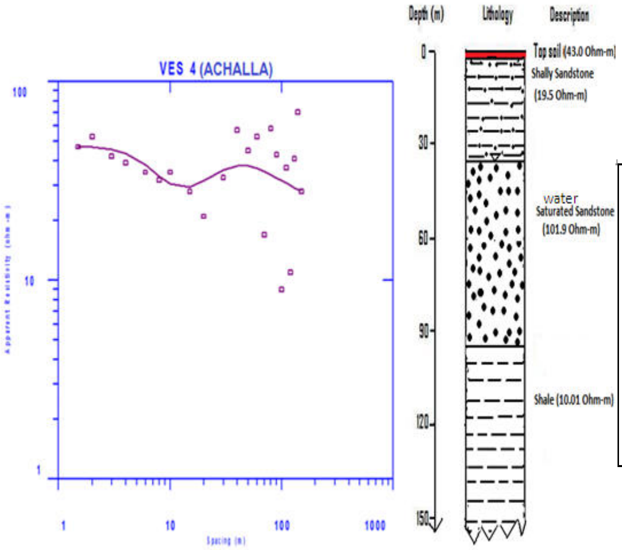


Table 1d:Geoelectric parameter at *VES* 4

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	389.2	1.33	1.33	Top soil
2	103.3	5.49	6.82	Shally Sandstone
3	6156	53.68	60.5	Dry Sandstone
4	1092		150	Water Saturated Sandstone

Fig 3d: Geoelectric curve and section at VES 4

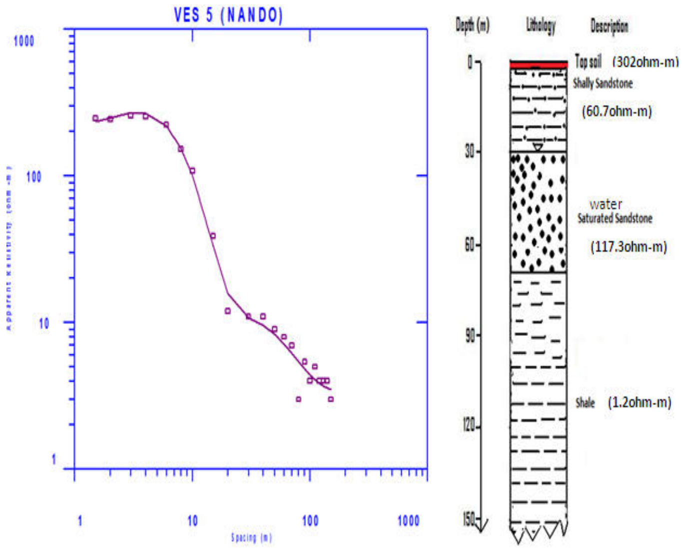


Table 1e:Geoelectric parameter at VES 5

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	302	3.47	3.47	Top soil
2	60.7	26.83	30.3	Shally Sandstone
3	117.3	41.8	72.1	Water Saturated Sandstone
4	1.2		150	Shale

Fig 1e:Geoelectric curve at VES 5

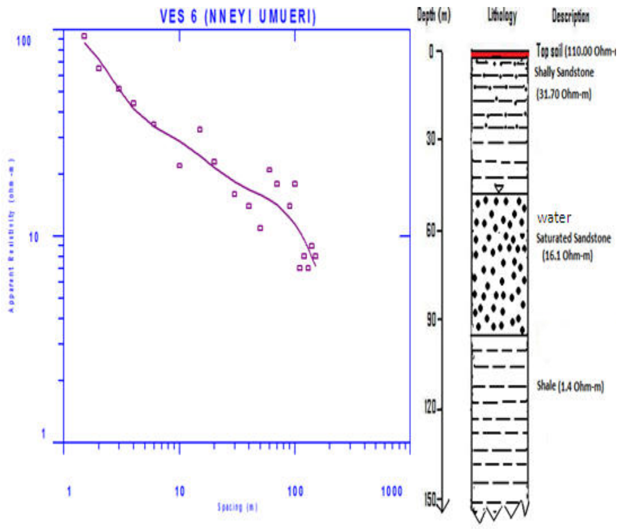


Table 1f:Geoelectric parameter at VES 6

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	110	1.52	1.52	Top soil
2	31.7	53.78	55.3	Shally Sandstone
3	16.1	41.2	96.5	Water Saturated Sandstone
4	1.4		150	Shale

Fig 1f:Geoelectric curve at VES 6

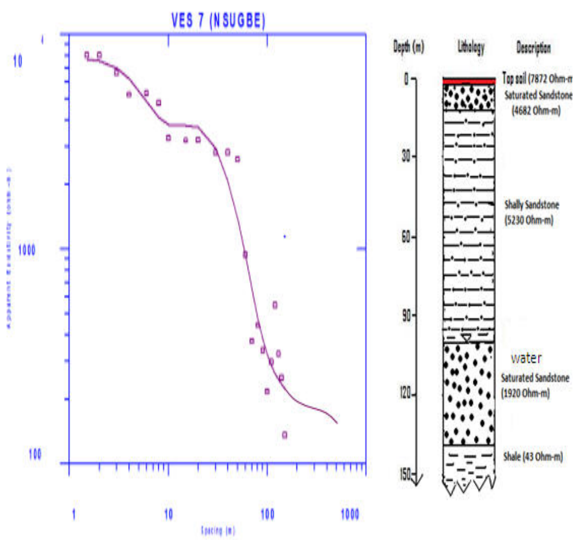


Table 1g:Geoelectric parameter at VES 7

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	7872	2.93	2.93	Top soil (Dry SSt)
2	4682	12.27	15.2	Water Saturated Sandstone
3	5230	86.8	102	Shally Sandstone
4	1920	38	140	Water Saturated Sandstone
5	43		150	Shale

Fig 1g:Geoelectric curve at VES 7

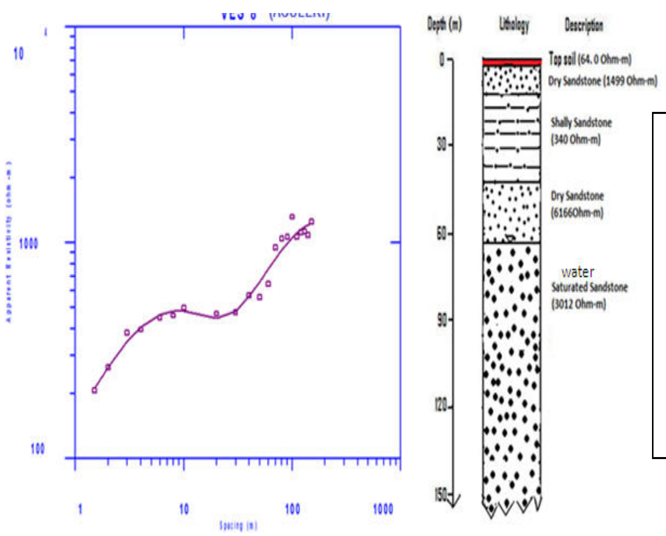
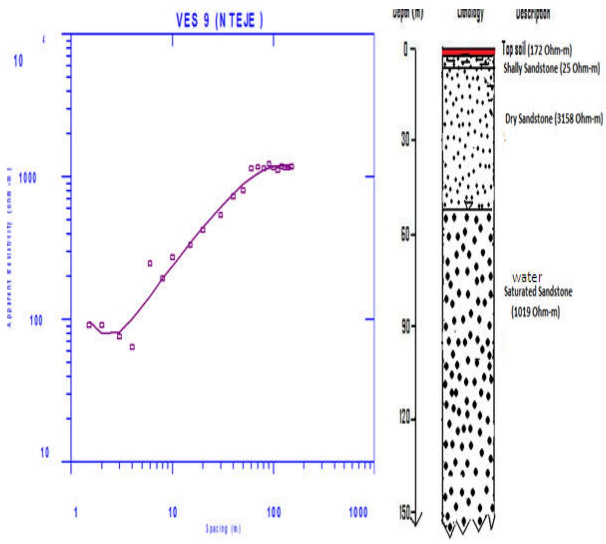


Table 1h:Geoelectric parameter at VES 8

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	64	3.21	3.21	Top soil
2	1499	8.94	12.15	Dry Sandstone
3	340	28.85	41	Shally Sandstone
4	6166	22.4	63.4	Dry Sandstone
5	3012		150	Water Saturated Sandstone

Fig 3h: Geoelectric curve at VES 8



LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	172	2.25	2.25	Top soil
2	25	4.06	6.31	Shally Sandstone
3	3158	50.09	56.4	Dry Sandstone
4	1019		150	Water Saturated Sandstone

Fig 3i: Geoelectric curve at VES 9

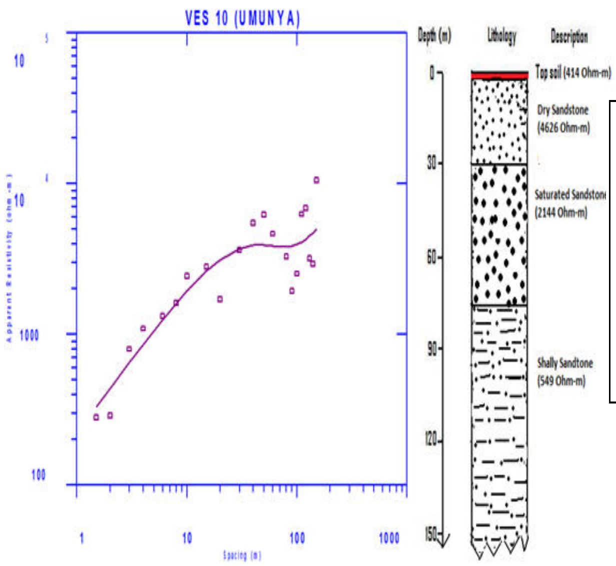


Table 1j: Geoelectric parameter at VES 10

LAYER	RHO(Ωm)	THICK (M)	DEPTH (M)	REMARKS
1	414	2.771	1.05	Top soil
2	4626	30.25	31.3	Dry Sandstone
3	2144	43.8	75.1	Water Saturated Sandstone
4	549		150	Shally Sandstone

Fig 3j: Geoelectric curve at VES 10

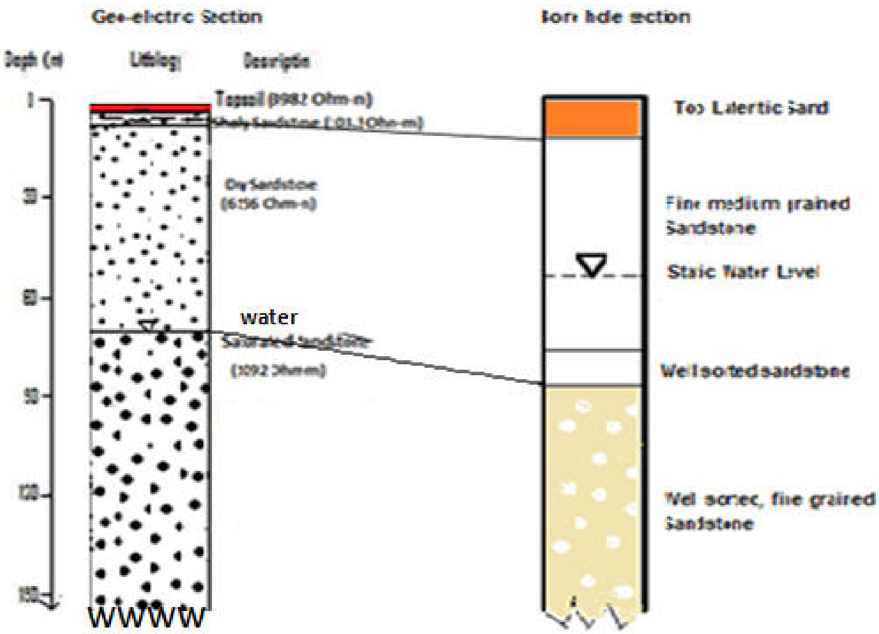


Fig 4a.Comparison of Otuocha Geo-electric Section (VES c) with Borehole Litholog

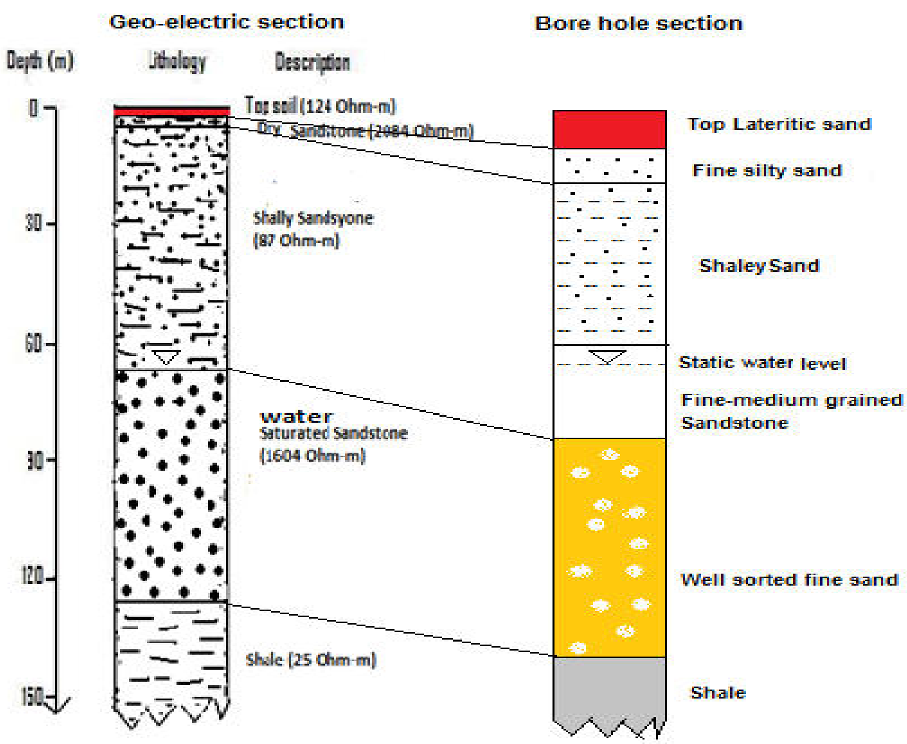


Fig 4b: Comparison of Awkuzu Geo-electric Section (VES 9) with Borehole Litholog.

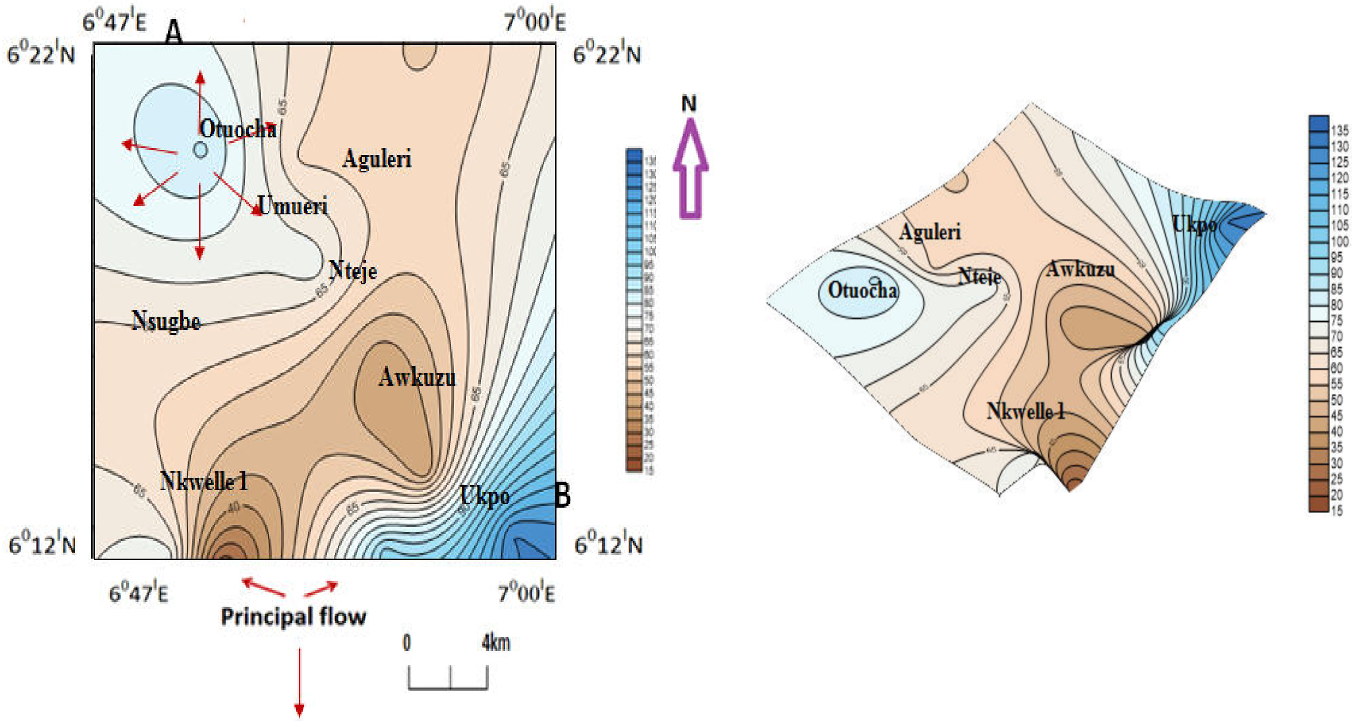


Fig. 4ai: Map of Watertable with reference to mean sea level and 3d Watertable map.

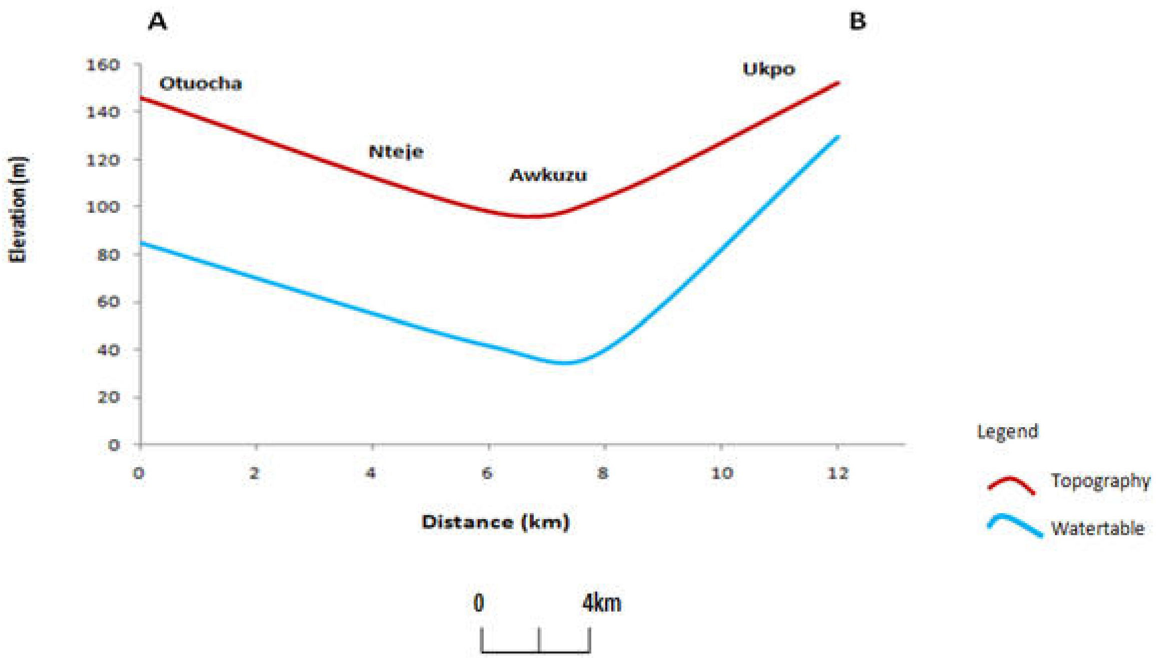


Fig.4aii: Cross section A-B showing configuration of water table and topography

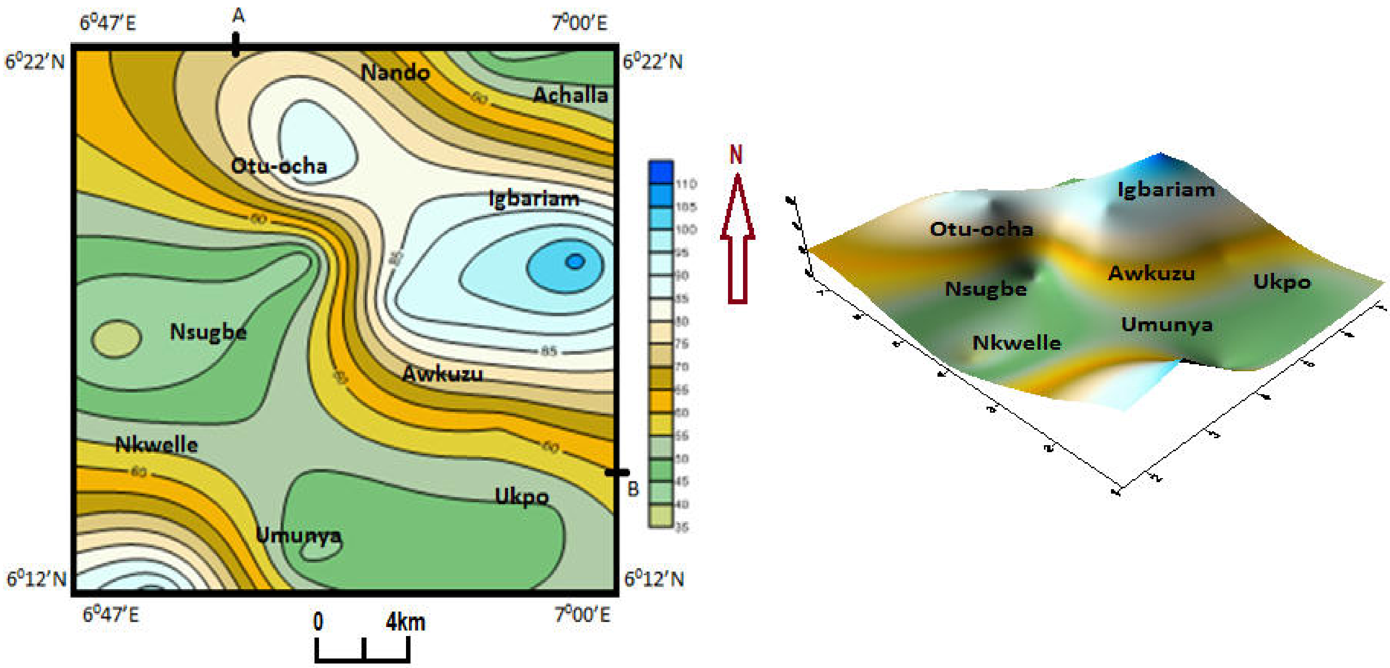


Fig 4bi: Aquifer thickness (Isopac map) and 3D Aquifer thickness Map.

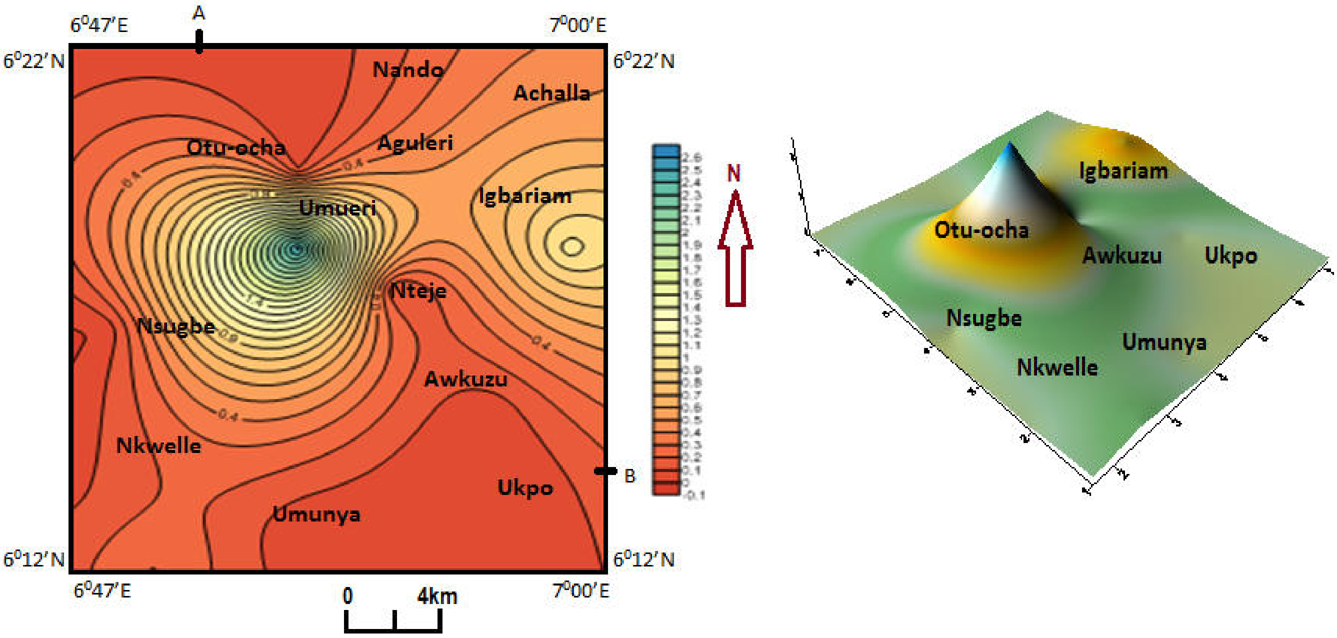


Fig 4ci. Aquifer transmissivity map and 3D transmissivity map of the area.

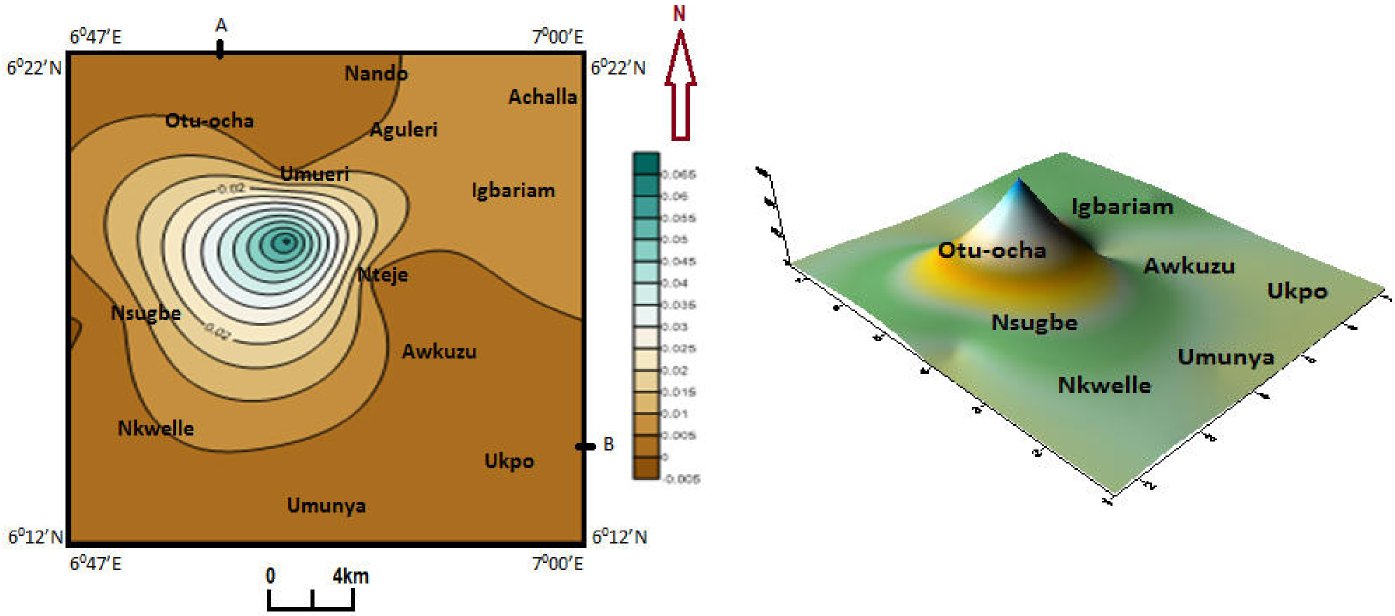


Fig 4di: Aquifer conductivity map and 3D Aquifer conductivity map of the area.

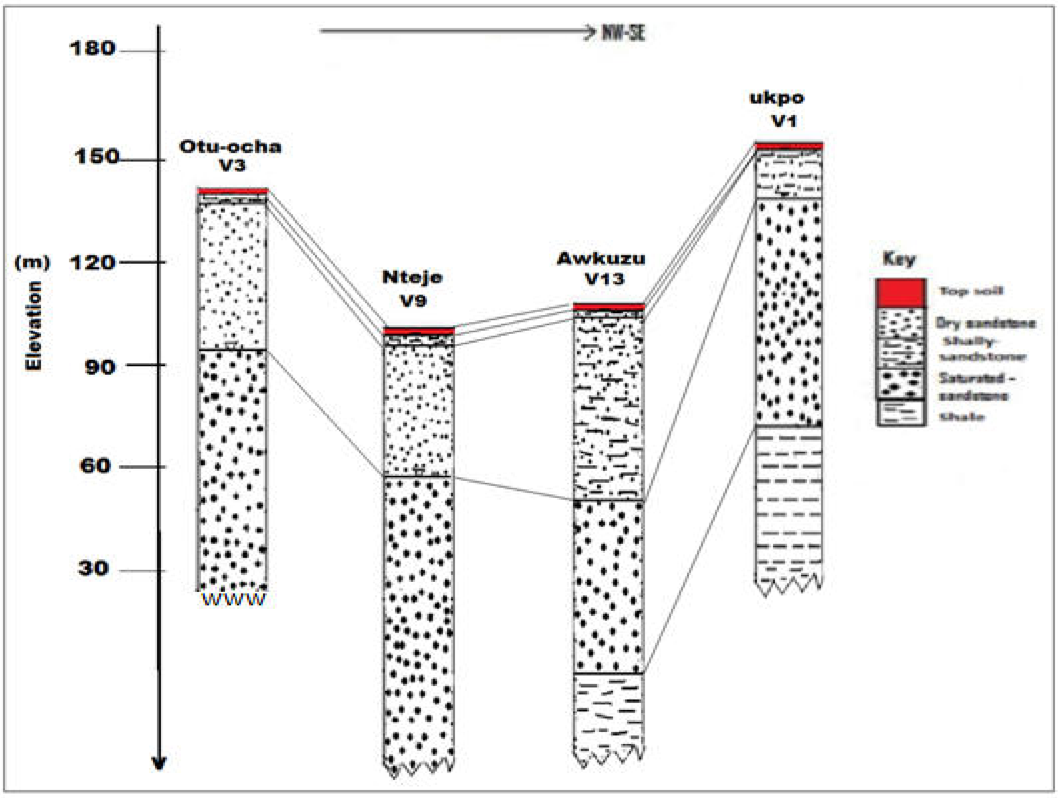


Fig. 4ei: Geo-electric modeling along NW-SE, Profile A-B

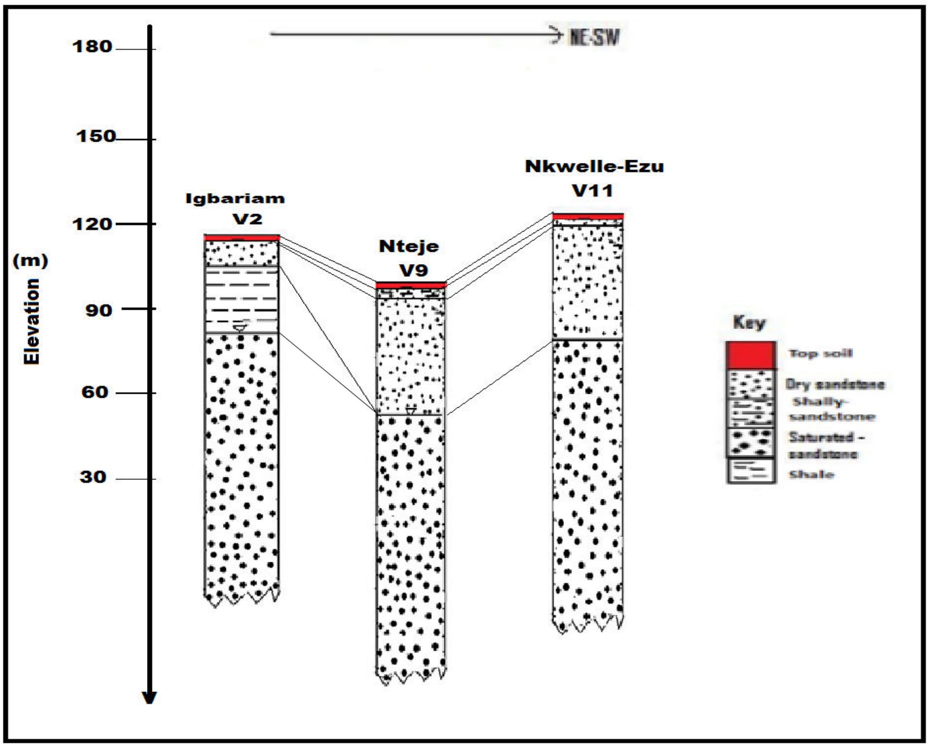


Fig.4eii: Geo-electric modeling along NE-SW, Profile C-D

Table 2: Watertable relative to mean sea level

VES NO	Town	Elevation (m)	Depth to water (m)	Water table w.r.t MSL (m)
1	**Ukpo**	152	21.5	130.5
2	**Igbariam**	116	43.1	72.9
3	**Otuocha**	146	60.5	85.5
4	**Achalla**	104	36.03	67.97
5	**Nando**	107	30.3	76.7
6	**Umueri**	128	55.3	72.7
7	**Nsugbe**	162	102	60
8	**Aguleri**	122	63.4	58.6
9	**Nteje**	98	56.4	41.6
10	**Umunya**	128	31.3	96.7
11	**Nkwelle 2**	122	50.3	71.7
12	**Nkwelle 1**	98	80.9	17.1
13	**Awkuzu**	104	64.2	39.8

Table 3: Aquifer parameter calculated from VES data.

VES NO	Town	b (m)	ρ (Ω)	R(Ωm)	S(Ωm)	Kc(m/day)	Tc (m2/day)
1	Ukpo	48.9	1012	49486.8	0.0483	0.0237	1.1597
2	Igbariam	106.9	102	10903.8	1.0480	0.2353	25.1529
3	Otuocha	89.5	1092	97734	0.0820	0.0220	1.9670
4	Achalla	56.37	101.9	5744.103	0.5532	0.2355	13.2765
5	Nando	41.8	117.3	4903.14	0.3564	0.2046	8.5524
6	Umueri	41.2	16.1	663.32	2.5590	1.4907	61.4161
7	Nsugbe	38	1920	72960	0.0198	0.0125	0.4750
8	Aguleri	86.6	3012	260839.2	0.0288	0.0080	0.6900
9	Nteje	93.6	1019	95378.4	0.0919	0.0236	2.2045
10	Umunya	43.8	2144	93907.2	0.0204	0.0112	0.4903
11	Nkwelle 1	99.7	322	32103.4	0.3096	0.0745	7.4311
12	Nkwelle 2	69.1	1007	69583.7	0.0686	0.0238	1.6469
13	Awkuzu	59.9	1604	96079.6	0.0373	0.0150	0.8963