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Groundwater Exploration for Sustainable Water Supply Development in the Rural Communities of Imo State in the Imo River Basin, Nigeria.

KEYWORDS Groundwater, Resistivity, Sustainable, Aquifer, Transmissivity.

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ABSTRACT *In a bid to address the water challenges of the rural communities of Ikeduru in Imo State, 20 vertical electrical soundings were done in the area using the Schlumberger array and maximum electrode spread of 700m. Five of the stations were sited near existing boreholes for correlation. The Allied Ohmega Ω earth resistance meter was used to acquire data which was analyzed using the Geosciences Incorporation 1D Software package. The hydraulic conductivity obtained ranges from 15.90m/day to 191.80m/day while transmissivity values are quite high and characteristic of Coastal Plain Sands. It ranges from 1093.2m^2/day to 1097.1 m2/day. The study area was demarcated into three groundwater prospect zones. Zone A is prolific in groundwater yield. The mean aquifer resistivity and thickness are 4602Ωm and 33.74m respectively. The depth to aquifer ranges from 60m to 144m corresponding to the deeper aquifer. Zone B is the medium high yield zone and covers the rural communities of Umudim, Atta, Ngugo, Iho and Akabo. The average resistivity is 3981Ωm and the mean thickness is 22.35m. The aquifer is relatively shallow when compared to Zone A. Zone C (Low yield) covers communities in the central part of the study area. The average resistivity of the aquifer layers is relatively high with value of 5041Ωm. The mean aquifer thickness is the smallest with value of 7.21m. For sustainable water development in the study area, it is recommended that standard water wells be sited in zones A and B.*

INTRODUCTION

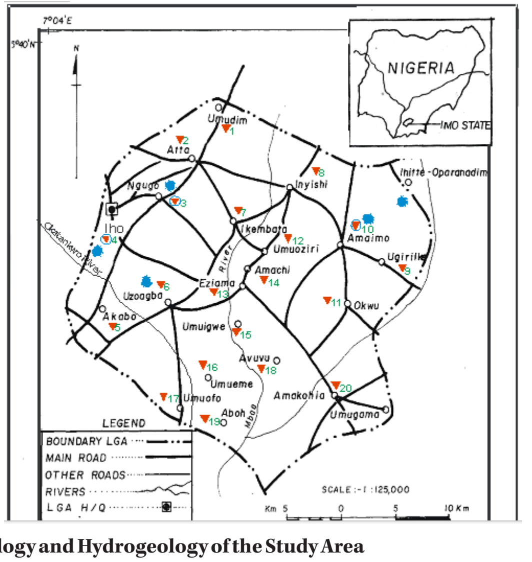
Groundwater has remained a more reliable source of potable water than surface water owing to the deteriorating quality of surface water caused by pollution (Nwosu et al., 2013). Groundwater is that part of precipitation that infiltrates into the ground, percolating downwards through unconsolidated materials and pores in bedrock until it reaches the water table. The saturated unconsolidated rock capable of yielding water is referred to as aquifer. Some aquifer parameters are very useful in assessing the groundwater potential of a place. These include the hydraulic conductivity, the transmissivity and aquifer thickness (Nwosu et al., 2013). The rural communities of Ikeduru Local Government Area of Imo State Nigeria have witnessed proliferation of both domestic and private commercial, shallow and substandard water boreholes. Nwachukwu et al. (2013) observed that poor distribution, planning and management of public water wells are challenges to sustainable water development and noted that over 60% of water wells in Imo River Basin is either abortive or not functional. This worrisome situation is equally observable in Ikeduru Local Government Area. This is compounded by the fact that the Okatankwo river which is fed by flood dries up during the dry seasons while the Mbaa river is highly polluted. Ekine and Iheonunekwu (2007) and Odoh et al. (2009) observed that inability to carry out proper geophysical study before drilling water boreholes account for borehole failures. This is also the case in the study area. Availability of predrilling geophysical survey results assists individuals, organizations and communities to know areas mapped out as difficult for groundwater development and thus plan alternative water source for such areas. This will save the cost of drilling abortive boreholes and thus reduce economic waste as well as cases of failure, abortive or abandoned public wells or nonfunctional domestic water wells (Nwachukwu et al., 2013).

A good number of literature materials show that Vertical Electrical Sounding (VES) has proved to be effective in solving groundwater problems. These include the work of Onuoha and Mbazi (1988), Mbonu et al. (1991), Mbipom et al. (1996), Ekine and Osobonye (1996), Eze and Ugwu (2010). Nwosu et al. (2013) also used VES data and pumping test analysis to evaluate groundwater potentials in Okigwe district of Imo State.

This study is aimed at establishing baseline geophysical information using the VES data that will ensure sustainable water supply development.

Location and accessibility of the Study Area

Ikeduru Local Government Area is one of the 27 local government areas of Imo State, Nigeria and is made up of more than twenty autonomous communities. The headquarters is located at Iho. The area lies between longitudes 7^{0}04´E and 7^{0}15´E of the Greenwich Meridian and latitudes 5^{0}28´N and 5^{0}40 N of the Equator (Fig. 1). Ikeduru has an estimated population of 149,316 people (Onyekakeyah, 2010). It covers a land area of about 1500km^2. It has good road network and is therefore accessible.



Geology and Hydrogeology of the Study Area

The Geology of the Imo River basin in which the study area is located has been extensively discussed by many scholars. Readers can refer to Onyeagocha (1980) for details including age and stratigraphic units of the basin as well as its potential for groundwater development. Nwachukwu et al, (2010) explained that the basin is a 140km N-S trending sedimentary syncline located at the central part of south-eastern Nigeria. The southern part of the basin belongs to the Benin Formation covering parts of Imo and Abia States (Fig. 2). The age of the Benin Formation is Oligocene to Recent. This Formation forms the prospective horizon. Other major stratigraphic units in the basin are the Ogwashi-Asaba Formation, the Bende-Ameki Formation, Imo Shale Formation, Nsukka Formation and Ajali Formation.

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The Ogwashi – Asaba Formation is made up of variable succession of clays, sands and grits with seams of lignite. The Ameki Formation consists of greenish –grey clayey sandstones, shales and mudstones with interbedded limestone. This Formation in turn overlies the impervious Imo Shale group characterized by lateral and vertical variations in lithology. The Imo shale of Paleocene age is laid down during the trangressive period that followed the cretaceous. It is underlain in succession by Nsukka Formation, Ajali sandstones and Nkporo Shales (Maduagwu, 1990).

Due to the porous and permeable nature of the Benin Formation coupled with the overlying lateritic earth and weathered top of this Formation as well as the underlying clay/shale member of the Bende – Ameki series, this geologic zone provides the hydrologic condition that favour aquifer formation (Mbonu et al., 1990).

The sediments of Imo Shale Formations consist of well laminated plane shale with a grey to light green colour. The shale contains occasional intercalations of thin bands of calcareous sandstones, marls and limestone. Groundwater exploitation is very difficult in this Formation.

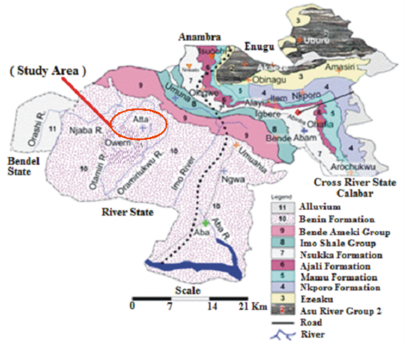

Figure 2: Geologic Map of Imo River basin, showing the Study Area (adapted from Nwachukwu, 2010)

MATERIALS AND METHODS

A total of 20 Vertical Electrical Soundings (VES) were carried out in the study area and at least one sited in each rural community (Fig. 1). The field procedure involved the use of Schlumberger electrode configuration with maximum electrode spread of 700m. The Allied Ohmega Ω earth resistance meter and accessories were used to conduct the survey with necessary precautions adopted. It is a high quality earth resistance meter capable of accurate measurement over a wide range of conditions and has a maximum power output of 18 watts. The instrument is powered by a large capacity rechargeable battery providing several days of use without recharging in average terrain conditions. Details of field procedure and suitability of VES method in groundwater prospecting abound in many literature materials such as Ekine (2010), Dobrin and Savit (1988), Telford et al. (1990), Fetter (2007). The current electrodes were expanded systematically from the station point keeping the potential electrode spacing constant until it became necessary to increase it. With this procedure called electric drilling the properties of the subsurface is explored. After initial manual computation, the field data were subjected to computer interpretation using the Advanced Geosciences Incorporation (AGI) ID Software package. The result is a display of 12 geoelectric layers which were constrained to six or seven layers depending on the significant value of resistivities and thicknesses.

Five pumping test data and borehole lithologic log (Fig. 8) were integrated in this study to enhance interpretation. This led to delineation of prospective aquifer layers. The mean resistivity, mean thickness and depth to water table were determined. Groundwater prospect map was constructed by correlation with other aquifer parameters.

Determination of Aquifer parameters from Pumping Test and VES Data

Table 1 shows the pumping test data obtained for the study area from Imo Water Development Agency (IWADA, 1999). The two boreholes at Amaimo were drilled by two different companies. Amaimo 1 was drilled in 1981 by Swischenstrick – stock and the well discharge recorded is 6110 m3/day while Amaimo 2 drilled one year later has well discharge of 2291 m3/day. Amaimo 1 borehole which produced higher ground water yield was used for necessary computation of the aquifer parameters.

Table 1: Pumping test data of boreholes located in the study area

LOCATION	TOTAL DRILLED DEPTH(m)	STATIC WATER LEVEL(m)	SCREEN LENGTH(m)	MAXIMUM DRAW DOWN(m)	WELL DISCHARGE
NGUGO	116.0	47.3	18.30	3.40	1571
IHO	85.0	53.0	15.20	3.10	6110
AMAIMO 1	86.0	45.4	18.30	3.70	6110
AMAIMO 2	183.0	40.0	21.30	9.80	2291
UZOAGBA	110.0	33.5	15.2	12.20	3928

Using parameters in Table 1, the hydraulic conductivity was computed by applying equation 1.

$$K = \frac{1.18Q}{hS_{mw}} \qquad (1)$$

where Q = well discharge
S_{mw} = maximum draw down
h = Screen length

The Transmissivity is obtained using equation 2

$$T = Kh \qquad (2)$$

For VES data, the hydraulic conductivity is determined from equation 3

$$K = \frac{T}{h} \qquad (3)$$

where T = average transmissivity from pumping test analysis
h = aquifer thickness

The Transmissivity of the aquiferous layers is calculated from the analytical relationship derived by Niwas and Singhal (1981) given by equation 4

$$T = K\sigma R \qquad (4)$$

where = electrical conductivity of the aquiferous layer
R = transverse resistance of the aquiferous layer

The result obtained are shown in Table 3.

RESULTS AND DISCUSSION

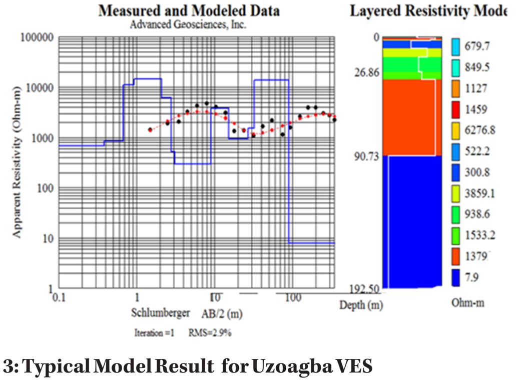

Fig. 3: Typical Model Result for Uzoagba VES

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Table 2: Analysis of Uzoagba VES

LAYER	DEPTH (m)	THICKNESS (m)	RESISTIVITY (Ohm-m)	LITHOLOGY	COLOR
1	3.00	3.00	849.5	Red earth Sand	Blue
2	8.90	5.90	300.8	Brownish red earth Sand	Blue
3	15.30	6.40	3859.1	Brownish red earth sand	Orange
4	26.86	11.50	938.6	Red earth sand	Green
5	32.60	5.80	1533.2	Medium coarse Sand	Green
6	90.73	58.10	1379.0	Coarse sand	Red
7	192.50	101.8	7.9	Clay	Blue

The modeled results of the VES data interpretation for Uzoagba is shown in figure 3. Table 2 shows the analysis of the modeled result while Table 3 shows the summary of the parameters determined for the aquiferous layer in each rural community surveyed. The variation of resistivity of the aquiferous layers in the study area is shown by the resistivity contour map (Fig 4). The results obtained are consistent with previous works done in some parts of Imo River Basin. Akaolisa and Selemo (2009) used VES technique to study Sand and Gravel deposits around the permanent site of the Federal University of Technology Owerri in the Benin Formation of the Imo River Basin. They recorded sand and gravel in all the VES points but in varied thicknesses. They observed high resistivity values within the depths of 30m to 100m and beyond and attributed this to the presence of fresh water saturated sand and gravel. The authors concluded that the groundwater potential of the study area could be utilized for regional water supplies. Fig. 5 is the depth contour map of the aquiferous layers. Deeper aquifers are recorded in the North-central to North-eastern parts and Southern part of the area. Nwachukwu et al. (2012) recorded that the geological and geophysical assessments of Owerri West area of Imo River Basin confirmed that the area has near surface aquifer with average depth of 50m (164ft). The Isopach Map in Fig. 6 shows the variation of aquifer thickness. The highest value of 69.0m is recorded at Ikembara while the least value of 5.70 is observed at Umuoziri. The transmissivity values are quite high and fairly uniform, characteristic of the Coastal Plain Sands Formations. Ekwe at al. (2010) estimated aquifer hydraulic characteristics for the middle Imo River Basin aquifers and recorded hydraulic conductivity of 20 – 26.41m/day and transmissivity of 500 – 1370m2/day. A close agreement with these values can be noticed in Table 2 for these parameters. Groundwater prospect map constructed for the area integrates the analytical results of pumping test data and well information together with aquifer parameters from VES results to demarcate the entire study area into three groundwater prospect zones (Fig.7) namely: Zone A (prolific yield), Zone B (medium high yield) and Zone C (low yield).

Zone A is prolific in groundwater yield. It covers the rural communities of Ikembara, Inyishi, Ugirike, Okwu, Amachi, Abo, Umuofor, Umueme and Avuvu located in the North-eastern and Southern parts of Ikeduru. The mean aquifer resistivity and thickness are 4602Ωm and 33.74m respectively. The depth to aquifer ranges from 60m to 144m corresponding to the deeper aquifer. Transmissivity is high in this zone.

Zone B (Medium high yield) located in the North-western part covers the rural communities of Umudim, Atta, Ngugo, Iho and Akabo. The average resistivity is 3981Ωm and the mean thickness is 22.35m. This zone is characterized by high transmissivity values. The aquifer is relatively shallow when compared to Zone A.

Zone C (Low yield) covers communities of Amakohia, Umuigwe, Eziama and Umuoziri in the central part of the study area. The average resistivity of the aquifer layers is relatively high with value of 5041Ωm. The mean aquifer thickness is the smallest of about 7.21m.

It is noteworthy that the water borehole in Uzoagba drilled in 1977 by Hydro-Tech is no more functional. This could be linked to lack of maintenance. Nwachukwu et. al (2013) developed a groundwater prospect model for Imo River Basin and demarcated prospect zones. The result of the present study is in line with their findings as Zone A falls within the area marked as prolific groundwater yield zone. Kumar et.al (2010) used remote sensing and Geographic Information System (GIS) to delineate groundwater potential zones in Kurmapalli Vagu Basin, India. They identified five potential zones in the Basin ranging from very good to poor zones. Egwebe and Ifedili (2006) investigated groundwater in Okija in Amiki Formation Southeastern Nigeria and established a depth to aquifer ranging from 58.58m – 79.74m and thickness of 61.16m - 73.21m. They recommended a drill depth of 73m which should be carried out by a professional driller and supervised by a hydrogeologist for successful water supply project. They concluded that inferences can be made from VES results on sub-surface stratification as well as identify possible aquifers.

For sustainable groundwater development in the study area, it is recommended that standard water wells be sited in zones A and B. Alternative water development project can be embarked on in Zone C such as surface water development project utilizing the Mbaa River. This however, will involve huge expenditure in terms of construction and purification of the surface water.

Based on the results of this study, we have succeeded in developing groundwater prospect map for Ikeduru Local Government Area which can help reduce the incidence of abortive wells, substandard domestic wells and non-functional wells. It is also a vital tool to government in water development planning and management decision making.

Table 3: Summary of the modeling results for all the VES stations

VES Numbers	Location	Depth to aquifer (m)	Resistivity of aquifer layers ρ (ohm-m)	Thickness of aquifer h(m)	Hydraulic Conductivity K (m/day)	Transmissivity T (m^3/day)
1	Umudim	62.70	9695.00	16.70	65.57	1095.00
2	Atta	66.30	7774.10	34.90	31.40	1096.30
3	Ngugo	53.27	4465.50	24.00	45.63	1095.10
4	Iho	51.71	252.00	17.22	63.59	1095.00
5	Akabo	59.16	266.00	34.00	32.20	1096.00
6	Uzoagba	90.73	1533.20	63.67	188.79	1095.00
7	Ikembara	144.00	613.00	69.00	15.90	1097.10
8	Inyishi	77.70	8706.80	48.70	22.50	1096.90
9	Ugirike	75.00	2495.00	23.52	46.50	1095.10
10	Amaimo	59.00	1437.00	7.20	151.80	1093.30
11	Okwu	89.00	1463.00	24.60	44.51	1095.00
12	Umuoziri	15.70	2385.00	5.70	191.80	1093.20
13	Eziama	41.74	19798.60	7.53	145.40	1094.90
14	Amachi	90.25	4524.80	45.10	24.30	1097.00
15	Umuigwe	31.00	2700.00	9.50	115.30	1094.50
16	Umueme	89.00	1463.00	24.60	44.51	1095.00
17	Umuofo	70.51	13422.30	26.24	41.73	1095.30
18	Avuvu	49.35	5836.20	16.27	67.30	1095.00
19	Aboh	94.40	2890.00	25.60	42.77	1094.90
20	Amakohia	38.70	3208.00	7.50	146.00	1095.00

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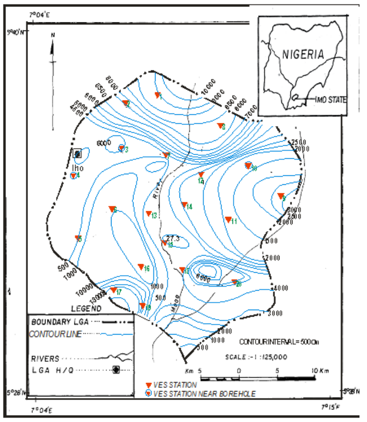


Fig. 4: Resistivity Contour Map of the Aquiferous Zones in the Study Area

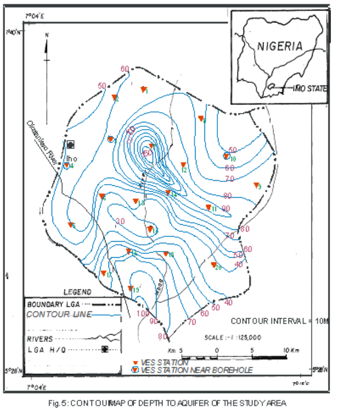


Fig.5: CONTOUR MAP OF DEPTH TO AQUIFER OF THE STUDY AREA

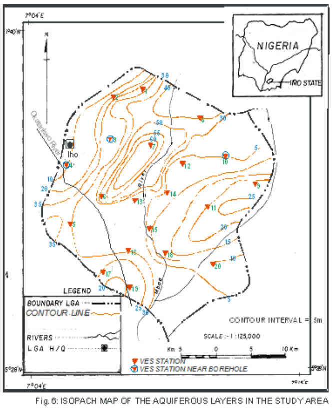


Fig.6: ISOPACH MAP OF THE AQUIFEROUS LAYERS IN THE STUDY AREA

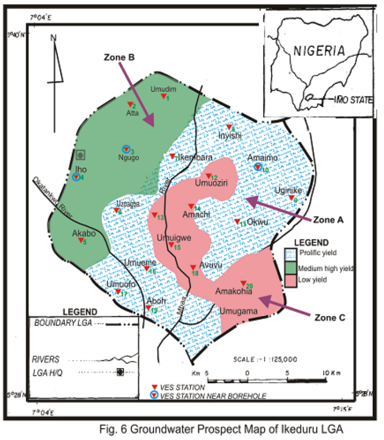
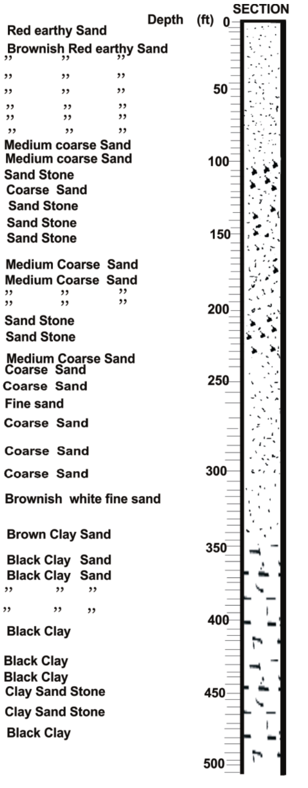


Fig. 6 Groundwater Prospect Map of Ikeduru LGA

DEPTH (m)	RESISTIVITY (Ohm-m)	LITHOLOGY
3.00	849.5	Red earth sand
8.90	300.8	Brownish red earth Sand
15.30	3859.1	Brownish red earth sand
26.80	938.6	Red earth sand
32.60	1533.2	Medium coarse Sand
90.70	1379	Coarse sand
192.50	7.9	Clay



Lithologic Log of Uzoagba Borehole Ikeduru L.G.A.

Fig. 8: Correlation of geoelectric section with lithologic log from Uzoagba

CONCLUSION

Integration of pumping test analysis and VES results has successfully demarcated Ikeduru L.G.A. into three groundwater prospect zones. This result will enable individuals and organizations wishing to embark on groundwater development project to invest in prospective areas and avoid waste of resources in difficult zones. Standard water boreholes can therefore be drilled for the communities to ensure sustainable water supply. The result of this study will also enable government formulate policies and proper groundwater development program for the rural communities in Ikeduru Local Government Area.

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