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Geoelectric Parameters, Subsurface Geology and Groundwater Resources in Some Parts of Mbano, Mbaise and Onuimo in Imo State- Nigeria: An Integrated and Comparative Study.

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Abstract
An electrical resistivity and geologic investigation was carried out in selected parts of Mbano, Mbaise and Onuimo in Imo state Nigeria. Vertical electric surrounding (VES) technique was used along with lithologic logs from available water wells within the area in constructing the subsurface geology, water resources and their special relationship. Also the relationship between the VES and the lithologic logs was investigated. It was established that the VES data could be used in broadly constructing the geology of the subsurface, finding the depth to water table as well as estimating the thickness of the potential aquifers. The study was ale to identify the sources of surface water within the study area by superimposing water table and lithology at each location. The Benin formation is by far the most aquiferous unit, consisting mainly of massive continental sand, sandstone and gravels. It has a very extensive deep unconfined aquifer which covers more than half o the Imo river basin. The geoelectric layers show appreciable continuity of some layers. A comparison of the lithology of an area with the geoelectric section shows that the wells is sited in Imo shale and therefore likely tapping the sandy units of the upper middle part of the basin.

Keywords: Geoelectric parameters, Subsurface geology and Groundwater resources, Vertical electric surrounding (VES) technique, Aquiferous units, Imo state Nigeria.

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I. Introduction

The subsurface forms the base upon which most urban and rural development activities take place, the base for structural foundations; source of water and waste disposal and even solid mineral development. A proper understanding of this subsurface geology is of vital importance in development especially as it relates to the topography and hydrology of the area. Groundwater is described as water found in streams and aquifer (Anomohauvan,2011)

Geophysical methods are increasingly being used for subsurface characterization as they offer the potential to derive basic characteristics and properties of geological formation (Vereekon et al, 2005). The resistivity geophysics approach is used as the key to exploration because it can give detailed information about the subsurface layer by passing current down the subsurface and also, its low cost of exploration (bayewu, 2018).

Assessment of water resources potential of a place relies on certain aquifer characteristics which include hydraulic and nativity (k), transitivity (T) and storativity, aquifer depth, aquifer thickness. They are needed to execute proper water planning and management and also in the determination of the natural flow of water through an aquifer and its response to fluid extraction (Nwosu et al., 2013, Mbonu et al., 1991).

Also important in the assessment of groundwater potential are aquifer parameters of transverse resistance and longitudinal conductance known as Dar Zarrouk parameters. These parameters have been proved to be powerful interpretational aids in groundwater survey (Zhody et al., 1974).

When electric current flows parallel to the geoelectrical boundaries, the parameter that influences current flow is the longitudinal conductance, S and when the current flows normal to the bed boundaries, the transverse resistance, T is significant

$S=h/p$

$T=hp$

The paucity of surface water in these areas create concern to the inhabitants of this region. To optimally improve the situation, an integrated development of both surface and groundwater is important and this requires a thorough understanding of the two. Aquifer depth, thickness, lateral extent and flow properties are the essential but more elusive factors in successful groundwater development. Although the surface geology and hydrology of the area have been extensively studied ad discussed by many authors, much work needs to be done on the subsurface geology. This work is aimed at establishing the depth to potential aquifer in the area, to investigate the relationship between the geoelectric and geologic sections, in order to qualitatively ascertain the resolution ability of the vertical electric surrounding (VES) and to check its reliability in locating groundwater and detect lateral variation in lithology within the area. The study also seeks to determine factors that control geoelectric parameters in the area.

The study area

The study area: Imo river basin lies between latitudes 4^0 26' and 6^0 01' and between longitudes 6^0 50' E and 7^0 46' E and covers an area of about 9100km^2. it comprises of selected towns and villages in and around Mbano, Mbaise and Onuimo LGA of Imo state.(Fig.1)

The terrain of the study area is characterized by two type of land forms: high undulating and nearly flat topography. Borehole lithologic logs reveal that the undulating hills and ridges are underlain by a succession of thick unconsolidated sand stones and relatively thin clay units belonging to the Benin formation.

The sediments of Benin formation are lenticular , unconsolidated, coarse to medium fine-grained sand with localized beds of fine sands and clayey sand. The sand units are mostly coarse grained, pebbly, poorly sorted and contains lenses of fine-grained sands (Onyagocha, 1980).

The very porous and permeable character of the Benin formation (coastal plain sands), the overlaying lateritic earth and the weathered top of thin formation as well as the underlying clay shale member of the Bende Ameki series provides the hydrologic condition contributive to aquifer formation in the area.

Selected towns and villages within the study are include Ikpa-Mbeke, Umuzolo-Izihe, Agwunadim-Umaukwu Obolo and Obiohuru I (Mbano LGA) Unoagba-Onicha, Umumbiri- Oparanadum, Nkwo Obohia and Umuaghara Onicha (Ahiazu Mbaise and Ezinifitte-Mbaisa Ukwe I, Okwelle 2, Okwelle I, Amuro II) in Onuimo LGA of Imo State –Nigeria.

Figure 1: Map of Imo State

Data acquisition method

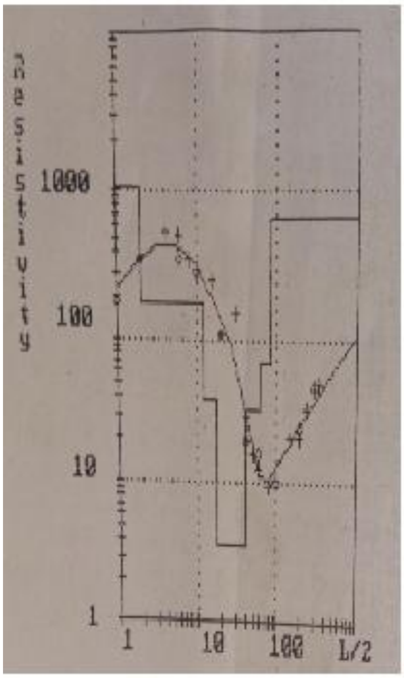
To provide this information above, a thorough hydro geophysical survey was carried out. The survey involves surface resistivity investigation and delineation of geoelectric sections. The depths to groundwater levels as well as aquifer thickness were also determined at the various survey stations. Borehole lithologic log data of existing water borehole were used in constructing the subsurface geology for comparison with the geoelectric sections. The vertical Electrical Sounding (VES) curves of some of the locations under investigation is presented in figures 2-11. The information from these maps provided data for determining the comparison and correlation necessary to achieve the goals and objectives of this work.

Table 1: APPARENT REISTIVITY VALUES FOR SOME SELECTIO AB/2 SPREAD SELECTED STATION IN MBANO L.G.A

S/N	VES STATION	NORTHINGS	EASTINGS	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm 1	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm
1	IKPA MBEKE	186457	541490	2.00 350	4.00 4.00 544	10 30	40 24	60 16	100 10	150 20	200 23	250 33	300 45
2	Umuzoho Ezihe	186757	525107	2.00 160	4.00 168	10 268	40 615	60 969	100 1468	150 1567	200 1095	200 774	
3	Ugwunadim Umuakwu Obolo	180849	531448	2.00 2235	4.00 4200	10 6214	40 3742	60 3114	100 4005	150 4356	200 2911	200 2814	200 2611
4	Obiohuri	193434	530967	2.00 338	4.00 125	10.00 260	40 930	60 1185	100 1821	150 1876	200 1624	200 1456	200 1210

Table 2: SUMMARY OF LITHO-GEOPHYSICAL AND HYDRO-GEOPHYSICAL CHARACTERIZATION RESULT FOR MBANO LGA

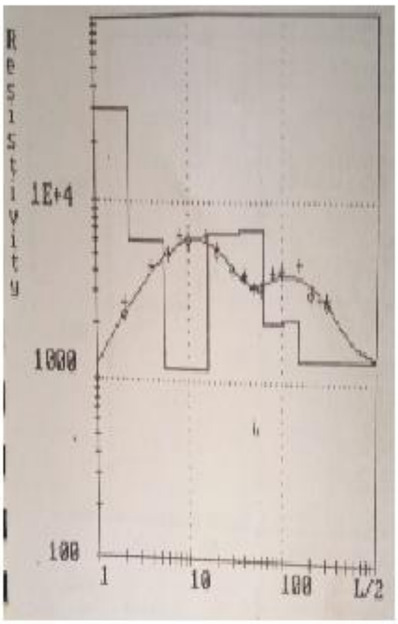
S/N	VES STATION	LAYER 1 DEPTH (m) P(Ωm)	LAYER 2 DEPTH (m) P(Ωm)	LAYER 3 DEPTH (m) P(Ωm)	LAYER 4 DEPTH (m) P(Ωm)	LAYER 5 DEPTH (m) P(Ωm)	LAYER 6 DEPTH (m) P(Ωm)	LAYER 7 DEPTH (m) P(Ωm)	LAYER 8 DEPTH (m) P(Ωm)
1	IKPA MBEKE	Top Soil 0.4 111	Sandy clay 2.0 1060	Clay/ sandstone 12.0 186	Clay 17.2 80.6	Shale 41.4 3.6	Shale 61.7 32.8	Shale 84.5 69	
2	Umuzoho Ezihe	Top Soil 0.4 61	Clay 7.2 186	Clayey sand 12.5 1570	Sand 30.3 8300	Salty clay 44.5 2150	Shale 64.0 582	Shale 90.9 298	Shale 790.9 87
3	Ugwunadim Umuakwu Obilo	Top Soil 0.4 451	Sand stone 2.3 30500	Sand 5.5 6060	Clayey Sand 16.2 6750	Sand 34.6 6750	Sand 64.6 7070	Silt 106.0 2050	Silt 150.0 2150
4	Obiohuri	Top soil 0.8 675	Clay 1.2 295	Shale 2.7 39.9	Shale 4.0 316	Sand stone 16.5 15500	Sand 32.2 5000	Sand/ silt 57.7 1190	



Resistivity (Ohm-m)	Depth (m)
111.0	0.4
1080.0	2.0
136.0	12.0
38.6	17.2
3.6	41.4
32.8	61.7
68.0	84.5
670.0	

Ikpa-Mbeke (Isiala Mbano LGA)

Fig. 2: VES for IKPA-MBEKE(ISIALA MBANO)



Resistivity (Ohm.m)	Depth (m)
451.0	0.4
10800.0	2.3
6060.0	5.5
1170.0	16.2
6750.0	34.6
7040.0	64.0
2030.0	106.0
2150.0	150.0
1290.0	

Agwunadim Amaukwu Obollo (Isiala Mbano LGA)

Fig.3: VES for AGWUNDIM-AMUKWU(ISIALA MBANO)

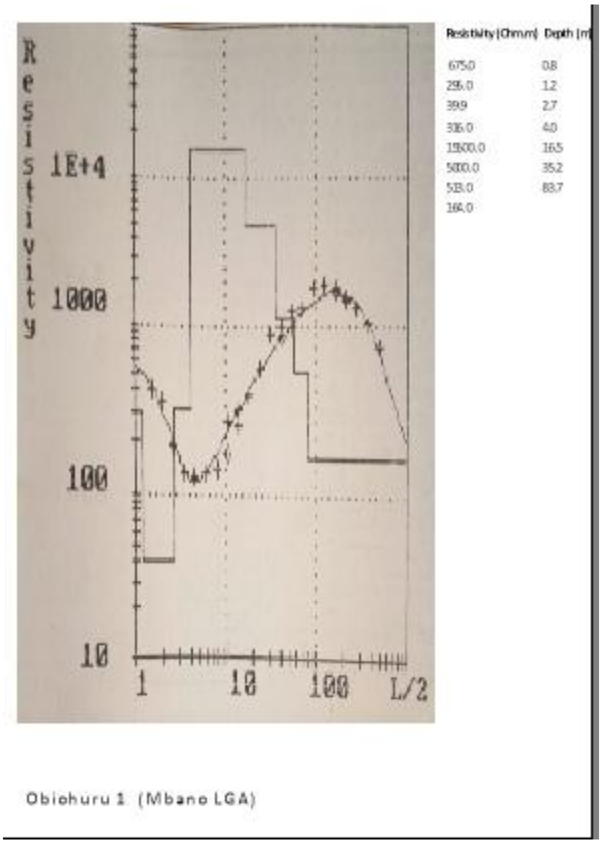


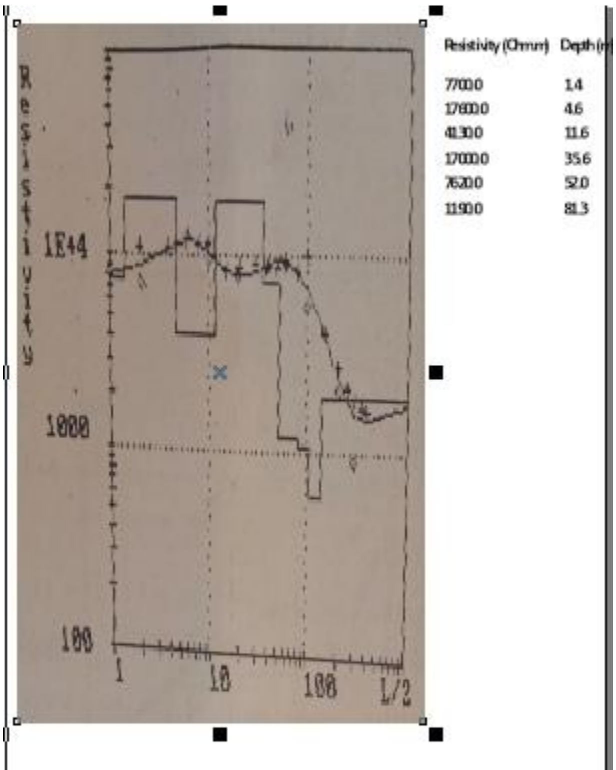
Fig. 4: VES for Obiohuru.

Table 3: APPARENT REISTIVITY VALUES FOR SOME SELECTION AB/2 SPREAD SELECTED STATION IN MBAISE L.G.A

S/N	VES STATION	NORTHINGS	EASTINGS	AB/2 (m) P/Ωm	AB/2 (m) P/Ωm)	AB/2 (m) PΩm	AB/2 (M) P/Ωm	AB/2 (m) P/Ωm	AB/2 (m) P/Ωm	AB/2 (m) P/Ωm	AB/2 (m) P/Ωm	AB/2 (m) P/Ωm	AB/2 (m) P/Ωm
1	Umuagba Onicha (EziniletteMbano)	168741	540113	2.00 7197	4.00 10742	10.00 1154	40.00 8867	60.00 9546	100 10049	150 4332	200 2165	250 2248	300 92 3
2	Umumbiri Oparanadim (Ahiazu Mbaise)	173902	534823	2.00 829	4.00 1069	10.00 1250	40.00 2380	60.00 3044	100 3870	150 3662	200 4115	250 2286	300 3065
3	Nkwo Obohia (Ahiaza Mbano)	172246	530001	2.00 386	4.00 529	10.00 1554	40.00 7140	60.00 29270	100 30610	150 35840	200 47500	250 50500	300 46860
4	Umughara Onicha (Ezinilille Mbano)	167088	540071	2.00 408	4.00 728	10.00 1335	40.00 2811	60.00 3568	100 4791	150 5676	200 5782	25 5270	300 4192

Table 4: APPARENT REISTIVITY VALUES FOR SOME SELECTION AB/2 SPREAD SELECTED STATION IN MBAISE L.G.A

S/ N	VES STATION	LAYER 1 DEPTH (m) P(Ωm)	LAYER 2 DEPTH (m) P(Ωm)	LAYER 3 DEPTH (m) P(Ωm)	LAYER 4 DEPTH (m) P(Ωm)	LAYER 5 DEPTH (m) P(Ωm)	LAYER 6 DEPTH (m) P(Ωm)	LAYER 7 DEPTH (m) P(Ωm)	LAYER 8 DEPTH (m) P(Ωm)
1	Umuagba Onicha	Top Soil 1.4 7700	Dry sand 11.6 17600	Sand 11.6 4130	Gravel / sandstone 35.6 17000	Sand 52.6 7620	Sandy clay/ silt 81.3 1190		
2	Umumbiri Oparanadim	Top Soil 0.5 354	Clay 6.5 696	Clay 6.5 696	Sand 25.7 4010	Sand 40.7 6740	Sand 69.7 1140	Sand 92.9 3830	Shale 790.9 87
3	Nkwo Obohia (Ahiaza Mbano)	Top Soil 0.8 225	Sand 2.0 4528	Sand 2.5 12585	Sand 150 98525	Sand 150 45228			
4	Umughara Onicha	Top soil 0.6 137	Sand 3.3 2460	Clayey sand 9.8 1140	Sand 23.7 6290	Sandstone 67.2 14200	Sand 106.0 5000	Sand 147.0 3670	Sand 191.0 3150



UMUAGBA-ONICHA (EZINIHITTE MABAISE LGA)

Fig. 5: VES for Umoagba Onicha

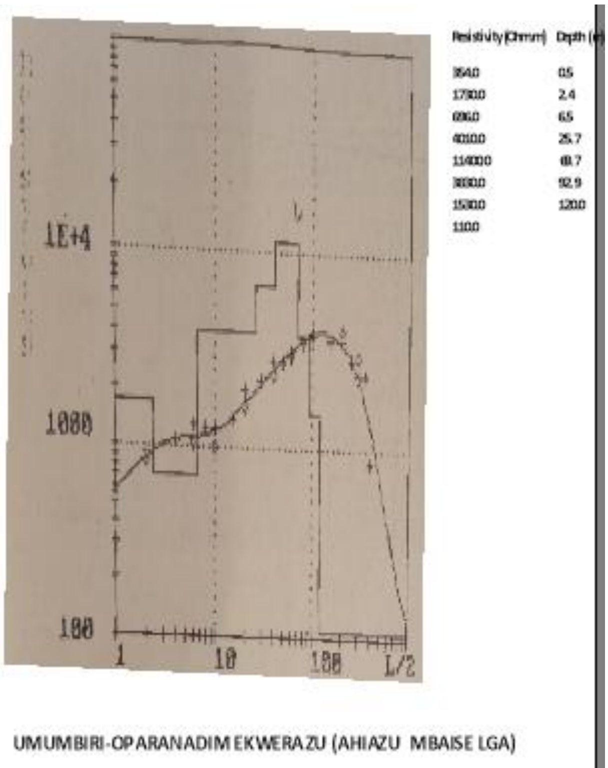


Fig. 6: UMUMBIRI-OPARANADUM

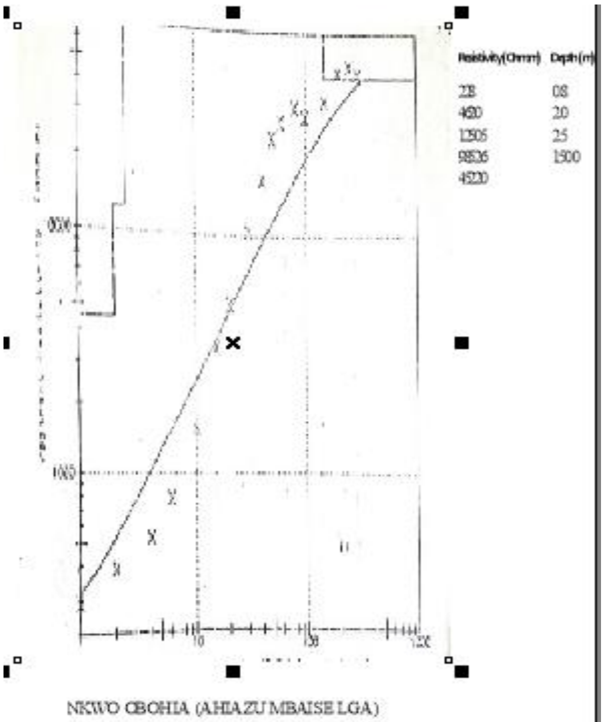


Fig. 7: VES for NKWO OBOHIA

Table 5: SUMMARY OF LITHO-GEOPHYSICAL AND HYDRO-GEOPHYSICAL CHARACTERIZATION RESULT (COORDINATES) FOR ONUIMO LGA.

S/N	VES STATION	NORTHINGS	EASTINGS	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm	AB/2 (m) ρ/Ωm
1	Okwe I	194011	528398	2.00 240	4.00 58	10.00 37	40.00 103	60.00 136	100 150	150 128	200 101	250 81	300 53
2	Okwelle II	192101	525385	2.00 1377	4.00 870	10.00 1093	40.00 963	60.00 891	100 673	150 322	200 180	250 134	300 93
3	Okwelli I	192328	524631	2.00 1018	4.00 1069	10.00 450	40.00 699	60.00 967	100 1316	150 1668	200 1960	250 1979	300 1904
4	Amuro I	196535	533894	2.00 31	4.00 10	10.00 16	40.00 47	60.00 55	100 57	150 48	200 26	250 20	300 12
5	Amuro 2	197628	535422	2.00 19	4.00 11	10.00 7	40.00 15	60.00 19	100 33	150 39	200 49	250 61	300 70

Table 6: SUMMARY OF LITHO-GEOPHYSICAL AND HYDRO-GEOPHSI CAL CHARACTERIZATION RESULT OF VES STATION IN ONUIMO L.G.A (COORDINATES REMAINED THE SAME)

S/N	VES STATION	LAYER 1 DEPTH DEPTH (m) P(Ωm)	LAYER 2 DEPTH (m) P(Ωm)	LAYER 3 DEPTH (m) P(Ωm)	LAYER 4 DEPTH (m) P(Ωm)	LAYER 5 DEPTH (m) P(Ωm)	LAYER 6 DEPTH (m) P(Ωm)	LAYER 7 DEPTH (m) P(Ωm)	LAYER 8 DEPTH (m) P(Ωm)
1	Okwe I	Clay 0.6 m 930	Shale 1.8m 22.6	Sand 11.6 4130	Sandy shale 9.6m 318	Sandy shale 38.5m 594	Shale 292m 88	Shale 292m 21	
2	Okwelle II	Top Soil 1.0m 1770	Sandy clay 2.5m 735	Sand 41.1m 1140	Sandy shale 59.1m 450	Shale 215m 118	Shale 215m 29.6		
3	Okwelli I	Top Soil 0.9m 890	Sand 3.3m 1550	Shale 8.6m 149	Shale 16.2m 422	Dry sand Shale 61.7m	Sand 104m 2150	Sand 162m 1120	Shale 162m 324
						8500			
5	Amuro 2	Top soil 0.7m 45.7	Shale 4.0m 10.1	Shale 10.6m 3.5	Shale 20.9m 25.5	Shale 61.6m 85	Shale 102m 130	Shale 102m 170	

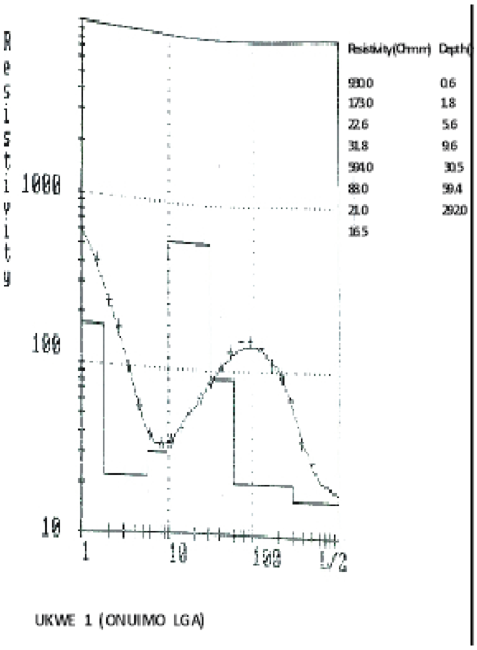


Fig. 8 : VES for UKWE 1

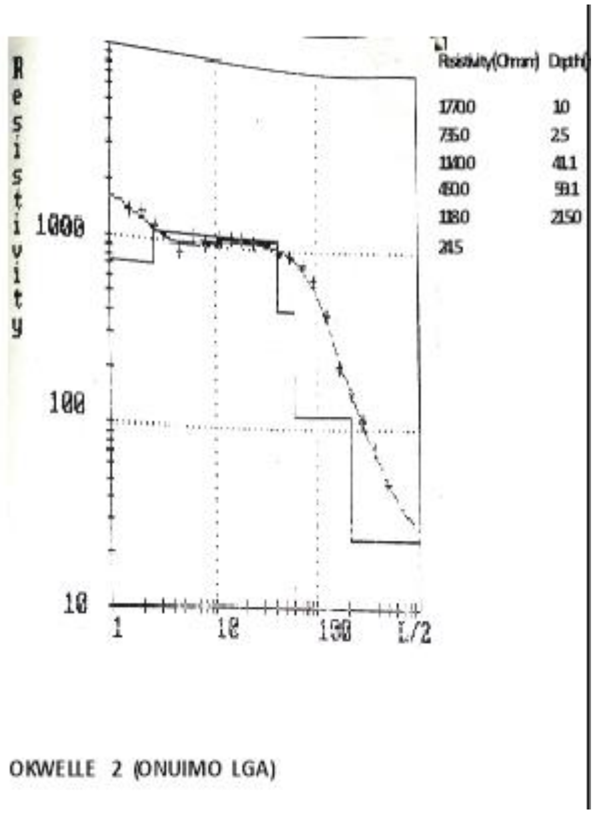


Fig.9 : VES for OKWELLE 2

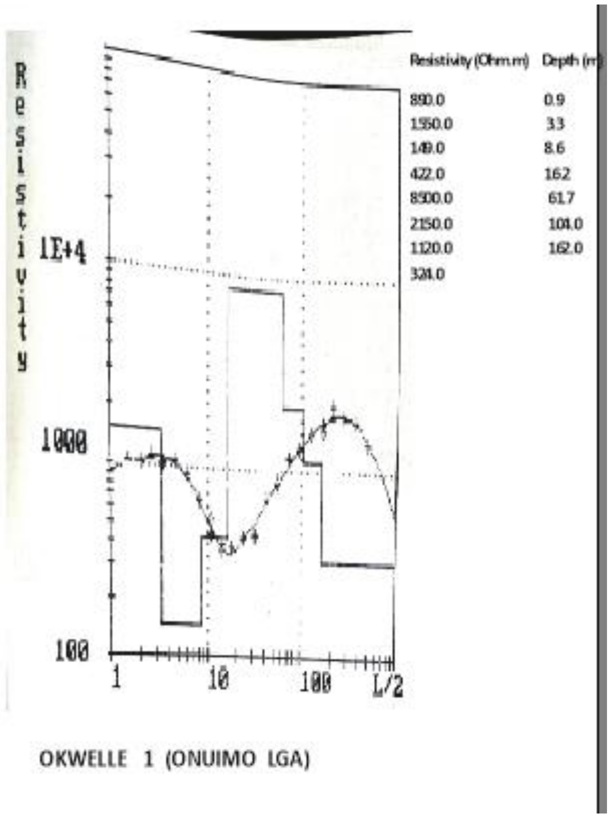
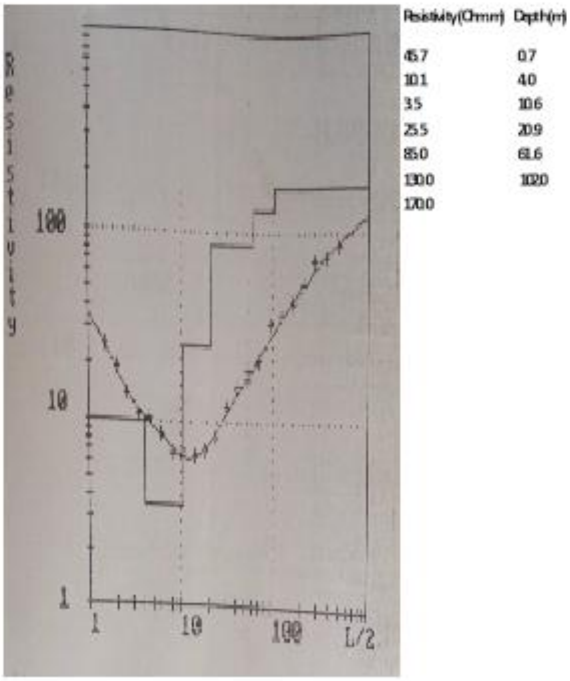


Fig.10 : VES for OKWELLE 1((ONUIMO LGA)



AMURO 11 (ONUIMO LGA)

Fig. 11 : VES for AMURO 11

II. Results and Findings

Well data from the study area were used in mapping the subsurface geology. The data collected from the well show that the area of study is mostly within the Bende Ameki and the Nanka sands and a little into the Imo shale. From the geoelectric sections it can be observed that the saturated sand layer forms the main aquifer within the study area. Throughout the study area, thin layer is underlain by clay, sand clay, clayey sand or shale.

Comparison of geologic with geoelectric section in Mbano (tables 1 and 2)

Ikpa Mbeke geoelogic and geoelectric section(

A close look at table I-2 and fig. 2 shows that while geoeletric section interprets a thickness less than 1.0m from the surface as the top soil, the geologic section interpret same to be about 2.00m thick. The underlying layer interpreted by the geo-section as sandy clay/sandstone to a depth of 17.2m is interpreted by geologic section as sandy soil to a depth of a 40m. Between the depth of 41.4m and 84.5m is interpreted as shale layer by the geoelectric section and geologic sections.

At Umuzoho Ezihe, the geoelectric section interprets a thickness of 0.4m from the surface as the top soil, the geologic section interprets same to be 2.00m. The underlying layer is interpreted by the geoelectric section as clay and sandy clay to a depth of 44.5m. Between the depth of 64.0m and 90.9m is interpreted as shale in both is geoelectric and the geologic section.

At Ugwunadim(fig. 3) , at a total of the current electrode up to 100 metres the geoelectric section could be interpreted as sandy layer to a depth of 64.6m to a depth of 150.00 metres. This might mean that the overburden layer contains a conductive effect over the underlying layer interpreted a silt by the geoelectric section.

At Obiohuru I(fig. 4), between the depth of 1.2m and 57.7m, the geologic section/interpreted about four layers, alternating sequence of shale and salty sand layers.

Comparison of geologic and geoelectric section in Mbaise (tables 3 and 4).

At Umuagba Onicha in figure 5, the geoelectric section interprets a thickness less than 2.00m from the surface as overburden, the geologic section as top soil and of nearly equal resistivities. The underlying layer interpreted by the geoelectric section as dry sand to the depth up to 52.6 metres below the surface as interpreted by the geologic section as loose sands up to a depth of 60.00m.

Umumbiri Operandim(fig. 6), the geoelectric sedim interprets a thickness less than 1.0m from the surface as top soil and between 2.4m – 92.9m as sandy, the geologic section interprets it as sand stone.

Nkwo Obohia ,Ahiazu- Mbaise (fig.7), while the geo-electric section interpret a thickness of 0.8m as top soil, the geologic sectin interprets same to be 2.00metres. The underlying layer interpreted by the geo-electric section as sand up to 10.00m is interpreted as medium and very coarse grained sand up to 250 metres.

At Umughara Onicha , at a total of the current electrode up to 40 metres the geologic section interprets sand while the geoelectric section interprets as sandstone up to a depth of 191.00 metres.

Comparison of geologic and geoelectric section in Onuimo (tables 5 and 6)

At Okwe I station(fig.8), while geoelectric section interprets a thickness of 0.6m from the top surface as clay, the geologic sectin interprets same as clayey sand. The underlying layer interpreted by the geo-electric section as shale to the depth of 30.5 metres is also interpreted as shale up to a current electron spacing of 60.0 metres by the geologic section.

At Okwelle II station(fig 9), the goelectric section interprets a thickness of less than 1.0m as top soil and sandy clay between 2.5 metres to 59.1 metres. The geologic section interprets the same range as sand and shale. Also interaction of clay and sand layers depicted by the geologic section is interpreted as clayey sand.

Table 5 and 6 have the geologic and geoelectric sections of the resistivity survey and the lithologic log at Okwelle I station (fig. 10). At a total of the current electrode up to 40 metres the geoelectric section could interpret a sandy shale situation to a depth of 16.2 metres. The overburden up to 10.00 metres is interpreted as sandy top soil. The underlying layers in both geoelectric section and the geologic section are interpreted as dry sand.

At Amuro II station(fig 11), the geologic section corresponding to a current separation of 40.00 metres with resistivity of values between 11-19 ohm metres is interpreted as shale. Similarly the underlying layer is interpreted by the geo-electric section as shale to a depth of 102 metres. The geologic section interprets about for layers with resistivity less than 70.00 ohm metre interpreted as shale. At a depth of more than 100.00 metres, the geoelectric and geologic sections are correlatable. Both indicate a possible zero for ground water occurrence.

Ground Water Resources of The Area

Obiohuru 1 (Mbano L.G.A) VES station (fig 5) which falls within Imo shale features shallow depths to the water table at an average of 12.5m along the profile. Their aquifer consists of shaly sand units with some sand stones. This aquifer are not quite productive at all with a mean thickness of 24.6m due to the sandstone and shale unit that dominate it.

In Ahiazu Mbaise within the Ogwashi-Asaba formation, in Nkwo Obohia VES station (fig) the most productive aquifer zone is observed in the investigation, with aquifer thickness of 147m. The average depth to the water table along the zone is about 60.4m. The depth to the water table at Nkwo Obohia to be specific is quite small at 2.5m which confirms the shallow system reported for the area (Uma, 1989).

Finally, the probability of locating saturated aquifer in Onuimo LGA comprising of VES stations 11 – 14 are quite rare since the formation mainly reflects shale.

III. Summary and Conclusion

The study shows that electric soundings survey could be used in mapping of the gross sub-surface geology of a given area with discrete geologic sections. The geoelectric section compared well with the lithology and gave the resistivity of the prospective aquifer, the depth to water table, the aquifer thickness as well as aquifer depth which varied across the survey area. The electric resistivity survey could also be used to determine the possible depth to load bearing rock strata for construction purposes -bridges, high rise buildings, roads and reservoirs, etc. With good well control, gross lithology over a large area could be obtained by comparing geoelectric and geologic logs. The study as a whole assessed the potential of groundwater in parts of Mbano, Mbaise and Onuimo sections of Imo state- Nigeria. It went further to delineate stations for drilling boreholes from the VES results obtained from the area.

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