AQUIFER COMPARIBILITY AND FORMATION STRATA IN OROGUN AND OSUBI (UGOLO) AREA OF DELTA STATE USING ELECTRICAL RESISTIVITY METHOD

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ABSTRACT
Vertical electrical sounding (VES) using Schlumberger electrode configuration was carried out at Osubi (Ugolo) and Orogun areas of Delta State. A total of ten VES were carried out in the two communities with 6 VES at Osubi and 4 VES at Orogun with maximum current electrode separation of 500m. The equipment used for acquiring data is the ABEM SAS 1000 Terrameter with an inbuilt booster. The data obtained were interpreted using computer software WINRESIST. The interpretation processes were carried out firstly by curve matching and computer iteration where the geological model parameters and curves were obtained. Five geological layers were observed within the two communities. These ranges from topsoil, coarse grained soil, clayey sand, clay and fine grained soil. For Osubi, the water bearing zone depth ranges from 29.7 to 42.2m and resistivity ranges from 366.1Ωm. to 3304.5Ωm, but good portable water is observed at a depth of 30 to 39m while for Orogun location, the depth ranges from 13.6 to 54.6m, and resistivity ranges from to 101.3Ωm to 6224.0Ωm but for VES 2 of Orogun location, water bearing zone is at the range of 20m to 42m. For this location, good portable water is observed at the depth of 38.0 to 49.0m. The study shows that locations 3 and 6 of Osubi and locations 1 and 4 of Orogun are the best for sitting boreholes since they have higher resistivity indicating low corrossivity and salinity with higher transmissivity.

Keyword: *Transmissivity, aquifer, resistivity, Osubi, Orogun, Corrosivity.*

1. INTRODUCTION
Geophysical resistivity methods are based on the effective response of the earth to the flow of subsurface electrical current. The method involves passing electrical current into the ground by means of two current electrodes AB and two potential electrodes MN used to record the resultant potential difference between them thereby resulting in the measurement of electrical impedance.
The resistivity method is designed to yield information or bodies having electrical anomalous electrical conductivity. It is mainly employed in geophysics to map bedrock in ground water studies and to determine salinity Egbai and Asokhia [1].
Vertical electrical techniques was chosen for this study because the equipment is simple, field logistics are easy and straight forward and the analysis of data is economical and less tedious than other methods Zhody et al [2]. The method has been very useful in the mapping of salt water interface in many different hydrogeologic settings Olorunfemi [3] and Zhody and Martin [4].
There have been some drilling operations in Osubi, Okpe Local Government Area of Delta State and Orogun, Ughelli North Local Government Area of Delta State without geophysical investigations despite the availability of information from the Delta State Water Board indicating difficulties which might be encountered in these areas.
These two communities are fast growing in population due to the closeness of oil producing towns of Warri and Ughelli. This has resulted in continuous influx of people thereby increasing the population leading to high demand for portable water for commercial and industrial purposes. Hence, there arises the need to carry out geophysical and hydrogeological surveys of Osubi and Orogun communities to provide information on the possible sites for sitting boreholes for portable and sustainable water supply to take care of the teaming population Egbai [5]. The survey will help provide basic technical guidelines regarding the drilling operations that might take place in these areas so as to prevent unnecessary wastage of funds for abortive boreholes. The survey will also provide information for effective determination of the depths of aquifers and to make comparison of these two areas in terms of subsurface lithology.
Further references in this study could be seen from the work of the following geophysicists: Ali et al [6], Egwuebe et al [7], Ako and Olunrenmi [8], Ekine and Osobonye, [9] and Emenike [10].

2. LOCATION OF OROGUN AND OSUBI (Ugolo).
Orogun is located in Ughelli North Local Government Area of Delta State. It lies between Latitude 5^0 30^1 N and 5^0 40^1N and Longitude of 5^0 56^1 E and 6^0 04^1E. The major road in the town serves as a linked road from which a

number of lined roads branch out, linking to various places as streams, foot path, farms, market, settlement etc. It is bounded in the north by Ogunu Abraka, east by Emonu Orogun and West by Amai.
Secondly, Osubi lies within Latitude 05^0 35^1 N and $5^0 38^1$ N and Longitude 05^0 50^1 E and 05^0 53^1E. It is located in Okpe Local Government Area of Delta State. The area is accessible mainly through Warri-Eku express way. It has a population of about 7,000 people. It is bounded in the north by Orerokpe and south by Efuru and Warri towns. An airstrip is located in this community.

GEOLOGY OF OROGUN AND OSUBI

The geology of Niger Delta comprises of the Benin, Agbada and Akata formations. Osubi and Orogun are found to be within the Benin formation. Benin formation is predominantly loose fresh water bearing sand with occasional lignite and clay, with depth of about 2,786m with no overpressures. The top most unit of the formations is the Benin formation. It is over 90% sandstone with shale intercalations.
Akata and Agbada formations are usually over pressured, with the later associated with hydrocarbon accumulation, Aigedion and Egbai [11]. The Osubi and Orogun formations are aquiferous because low percentage of shally layers and the lithology consists of an alteration of lignite, sand and clays. Figure 1 shows the schematic dip of Niger Delta.
The two communities are of typical rainforest and receive rainfall of about seven months a year. The existence of this rainfall, closeness to delta region and sea give the characteristic of its swampy nature which suggests the possibility of obtaining enough groundwater in these two communities. The influence of salt water from the sea within these communities has serious impact on the subsurface water resulting in the high corrosiveness of water.

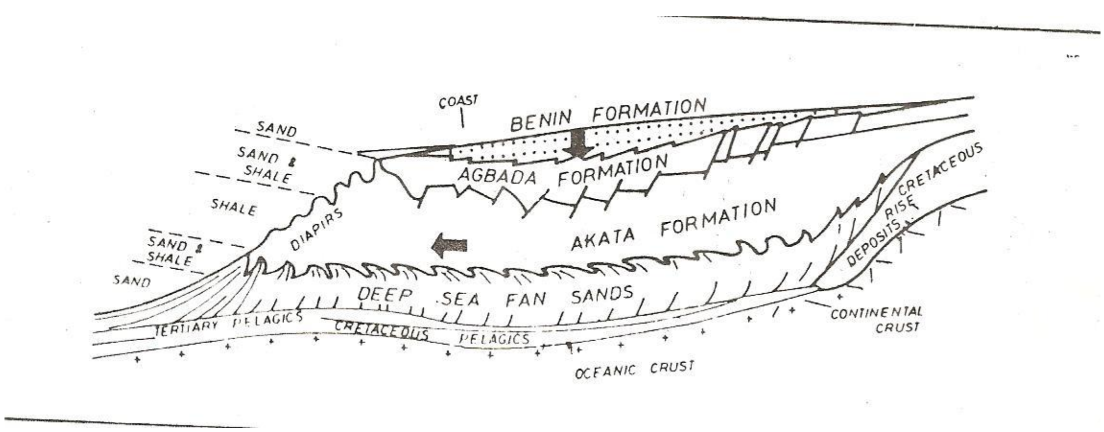

Figure 1: Schematic dip of Niger Delta.

THEORY

The electrode configuration for the Schlumberger resistivity survey is as shown in figure 2. The recordings necessary in resistivity methods are surface measurements of the potential field distribution due to the current passing through the groundwater Egbai and Aigbogun [12]. This potential is a solution to Poisson's equation

$$\nabla^2 V = 0 \quad (1)$$

where ∇^2 is a second derivative operator and V is the potential. The potential, V at a distance r due to current source I on surface of the earth is given by the solution

$$V = I\rho/2\pi r \quad (2)$$

where ρ is the resistivity of the subsurface,
The resulting potential difference is given by

$$\Delta V = \frac{I\rho}{2\pi}\left\{\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)\right\} \quad (3)$$

Solving equation 3 above, the resistivity ρ of the surface could be determined. The equation above is possible if we assume a homogeneous and isotropic half-space. Since the earth is neither homogeneous nor isotropic, a measured voltage difference yields a resistivity value that is an average over the path the current follows. (Egbai and Aigbogun [12]. This apparent resistivity is given by

$$\rho_a = \frac{2\pi\Delta V}{I}\left[\frac{1}{\left(\frac{1}{r_1} - \frac{1}{r_2}\right) - \left(\frac{1}{r_3} - \frac{1}{r_4}\right)}\right] \quad (4)$$

$$\rho_a = \frac{\Delta V K}{I}$$

K is the geometric factor. It is dependent upon the spatial arrangement of electrodes for specific arrays.

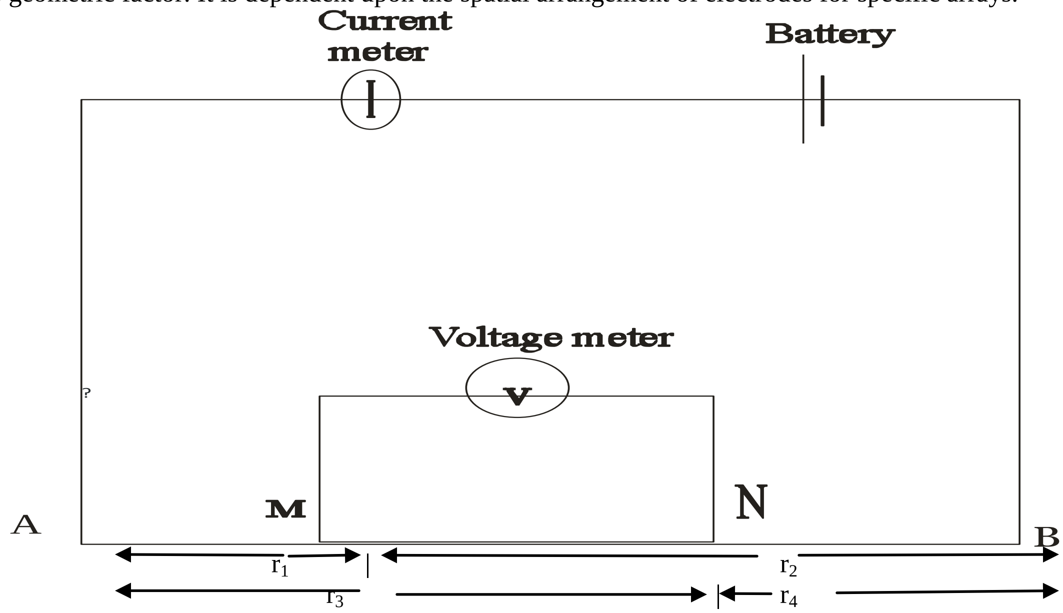

Figure 2: Schlumberger Electrode Configuration

METHODLGY AND DATA ACQUISITION

The visibility survey of the area of the study was carried out from which Vertical Electrical Sounding (VES) location points were decided. At each sounding point, a reference point (called the STATION) was chosen from which measurements of current and potential electrodes positions were marked and pinned with the aid of 100m tape reels. The Abem SAS 1000 Terrameter was used to acquire the field data. A total of six VES locations were carried out at Osubi while four were taken at Orogun. The maximum current electrode spacing for Osubi is 200m while for Orogun is 500m and each location sounding points is approximately 2000m from each other. The potential electrode spacing ranges from 0.2m to 30m respectively for all sounding points. For each reading, the current electrodes were pinned down to the ground effectively by means of a hammer on either side of the station and equidistance from AB such that AB/2 ≥ 5MN/2.

Finally, the end result of the field measurement is the computation of an apparent resistivity. These data were plotted as curves of apparent resistivity in ohm-metre against electrode separation (AB/2) in metre using log-log sheet. This was carried out quantitatively by curve matching. The initial values of the resistivity and thickness of the subsurface layers were obtained from the partial curve matching which were used as starting model for the computer iterative techniques with the aid of the Resist Software based on the work of Vander Velpen [13] to obtain the true resistivity and thickness delineated. The values obtained are shown in Tables 1-2 while some of the curves are shown in Figures 3-7.

Further work was carried out by computing the aquifer characteristic in terms of the transmissivity. Transmissivity of aquifer expresses the ability of the aquifer material to transmit water Egbai, [5]. Niwas and Singhai [14] established the relationship between transmissivity of aquifer and longitudinal conductance as

$$Tr = K\delta R = \frac{KS}{\delta}$$

where Tr= transmissivity, K= hydraulic conductivity, δ= electrical conductivity, R= transverse resistance of aquifer and S= longitudinal conductance of aquifer.

An average hydraulic conductivity of 10m/day MWT [15] is assumed for existing boreholes in the two communities. Table 3 and 4 shows the model parameters, curve type and lithology of Osubi and Orogun respectively. Table 5 shows a summary of aquifer electrical properties for all VES locations.

TABLE 1: SCHLUMBERGER RESISTIVITY SOUNDING DATA
LOCATION: OSUBI
L.G.A: Okpe
STATE: Delta state

S/N	Electrode Separation AB/2(m)	Potential Electrode Separation MN/2 (m)	Geometric Factor $K=\frac{\pi L}{2a}$	Resistivity $\rho(\Omega m)$ VES1	Resistivity $\rho(\Omega m)$ VES2	Resistivity $\rho(\Omega m)$ VES3	Resistivity $\rho(\Omega m)$ VES4	Resistivity $\rho(\Omega m)$ VES5	Resistivity $\rho(\Omega m)$ VES6
1	1	0.5	6.20	198	696	2256	314	1855	1392
2	2	0.5	25.12	350	883	3008	491	2232	1774
3	3	0.5	56.54	443	986	2762	868	2567	1867
4	4	0.5	100.54	511	964	2560	967	2756	1997
5	6	0.5	226.20	642	993	1953	1283	2144	1823
6	6	1.0	113.10	703	999	1864	1338	2616	1903
7	8	1.0	254.47	717	1086	1821	1433	1420	1623
8	12	1.0	452.40	813	1326	1791	2206	1759	2711
9	15	1.0	706.86	816	1224	1550	3199	2357	2423
10	15	2.0	353.45	939	1163	1640	3121	2573	4530
11	20	2.0	268.32	950	1136	1423	2118	2705	2112
12	25	2.0	981.75	955	1498	1452	2082	2866	4185
13	32	2.0	1608.50	1050	1436	1500	2404	4561	3900
14	40	2.0	2513.28	1081	1900	1599	2667	2751	4535
15	40	5.0	1005.13	1115	1744	1603	2398	2516	4603
16	50	5.0	1570.80	1212	1314	1909	3030	3603	3645
17	65	5.0	2654.65	1519	3390	1713	2025	3368	3749
18	80	5.0	4021.24	2515	4050	2740	2082	2929	3368
19	100	5.0	6283.20	4040	5082	6864	1543	4369	2756
20	100	10.0	3141.60		3315		1700	2961	2230

TABLE 2: SCHLUMBERGER RESISTIVITY SOUNDING DATA
LOCATION: OROGUN
L.G.A: Ughelli-North
DELTA: Delta State

S/N	Electrode Separation AB/2(m)	Potential Electrode Separation MN/2 (m)	Geometric Factor $K=\frac{\pi L}{2a}$	Resistivity VES1 ρ (Ωm)	Resistivity VES2 ρ (Ωm)	Resistivity VES3 ρ (Ωm)	Resistivity VES4 ρ (Ωm)
1	1	0.5	6.20	1011	89	72	922
2	2	0.5	25.12	906	112	100	1570
3	3	0.5	56.54	731	118	118	1767
4	4	0.5	100.54		92	127	1432
5	6	0.5	226.20	253	93	131	1358
6	8	1.0	113.10	1255	104	152	1197
7	12	1.0	254.47	1364	103	159	1405
8	15	1.0	452.40	1561	140	140	1396
9	15	1.0	706.86	1745	152	224	1197
10	15	2.5	353.45	1836	104	224	1124
11	20	2.5	268.32	1556	235	442	1219
12	25	2.5	981.75	2915	117	241	1456
13	32	2.5	1608.50	1626	185	502	2383
14	40	2.5	2513.28	1407	609	204	2216
15	40	5.0	1005.13	1392	288		1937
16	50	5.0	1570.80	1454	101	135	
17	65	5.0	2654.65	2067	267		3227
18	80	5.0	4021.24	4849	257	547	
19	100	5.0	6283.20	933	235	646	2478
20	100	10.0	3141.60	1126	184	317	3196
21	120	10.0	4523.89	1256			
22	150	10.0	8042.42	1013	689	1005	2048
23	200	10.0	12566.38	1396	299		8936
24	200	20.4	8975.98		869		
25	250	20.4	14024.97				2402

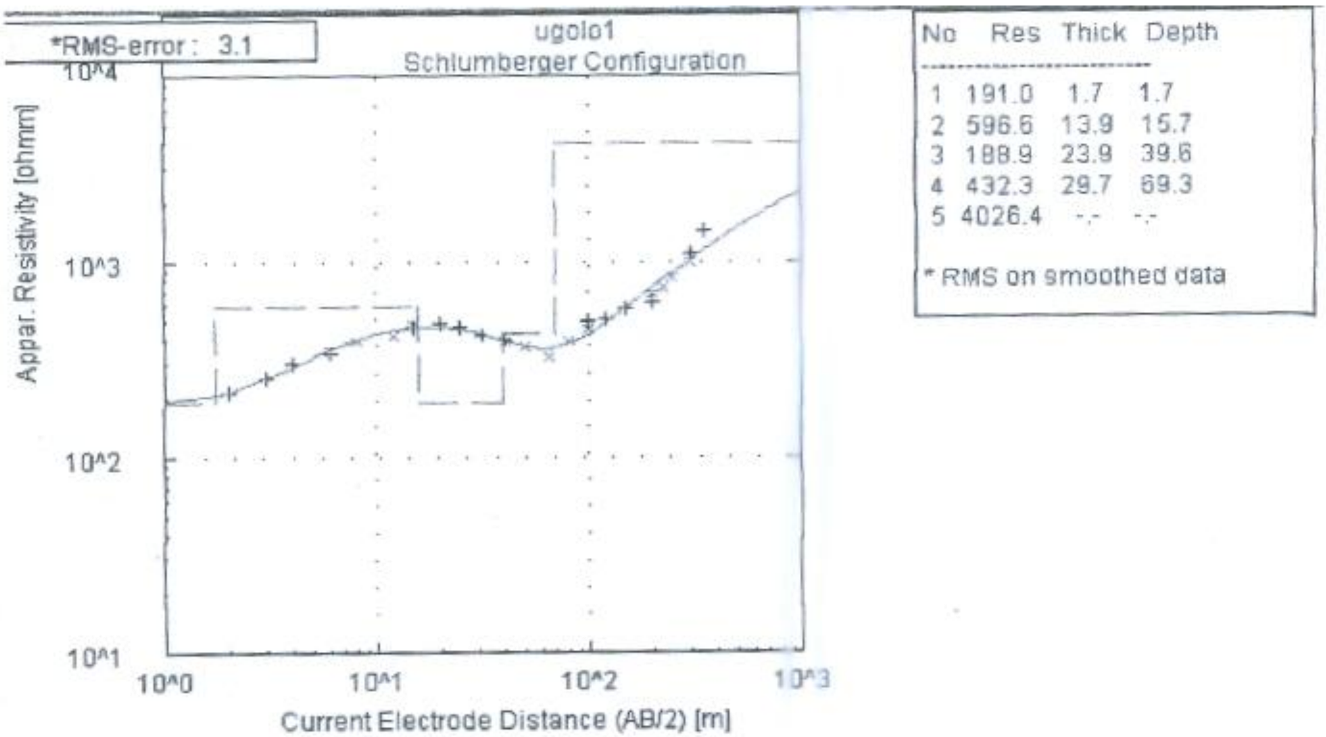

Fig 3: Sounding Curves for Osubi (VES 1)

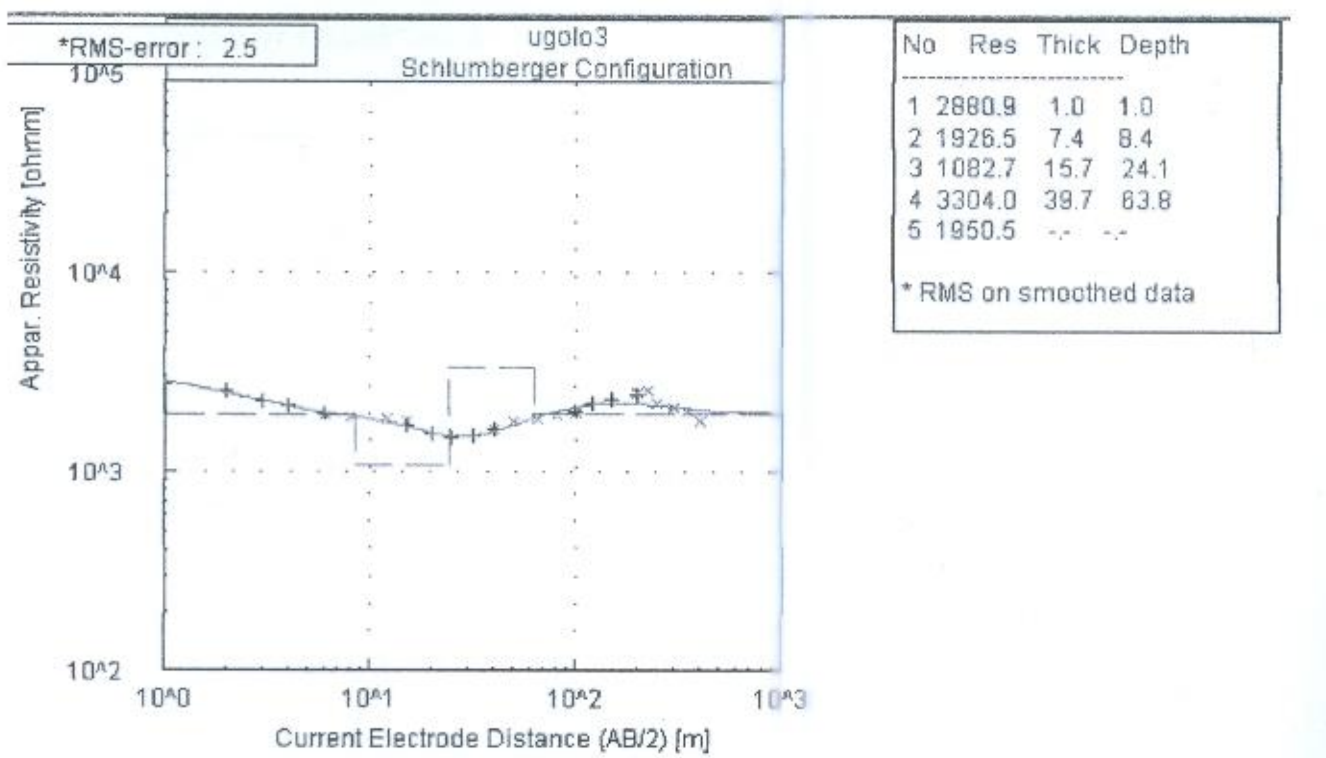

Fig 4: Sounding Curves for Osubi (VES3)

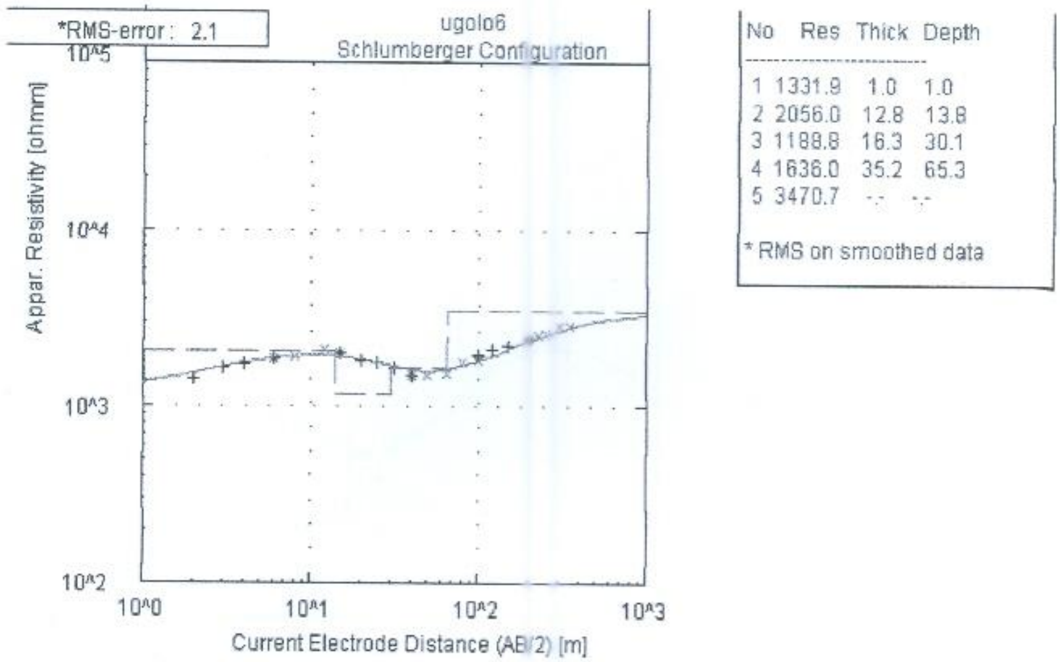

Fig 5: Sounding Curves for Osubi (VES6)

ITERATION RESULT FOR OSUBI LOCATION

Table 3: Model Parameter for Osubi (Ugolo)

VES	LAYER	RESISTIVTY Ωm	THICKNESS (m)	DEPTH (m)	LITHOLOGY	CURVE TYPE
1	1	191.0	1.7	1.7	Top soil	
	2	596.6	13.9	15.6	Medium coarse grained sand	
	3	188.9	23.9	39.5	Clayey sand	HKA
	4	432.3	29.7	69.2	Coarse grained sand	
	5	4026.4	-	-	Fine sand	
2	1	677.9	2.1	2.1	Top soil	
	2	1362.0	17.7	19.8	Medium coarse grained sand	HKA
	3	667.0	19.8	39.6	Clayey sand	
	4	458.2	42.2	81.8	Coarse grained sand	
	5	3214.5	-	-	Fine sand	
3	1	2880.9	1.0	1.0	Top soil	
	2	1923.5	7.4	8.4	Medium coarse grained sand	QKH
	3	1082.7	15.7	24.1	Clayey sand	
	4	3304.0	39.7	63.8	Coarse grained sand	
	5	1950.5	-	-	Fine sand	
4	1	334.3	2.4	2.4	Top soil	
	2	1535.0	4.9	7.3	Medium coarse grained sand	AHK
	3	3093.6	12.6	19.9	Coarse sand	
	4	366.1	41.8	61.7	Coarse grained sand	
	5	7550.7			Fine sand	
5	1	1859.6	1.0	1.0	Top soil	
	2	3140.1	12.4	13.4	Medium coarse grained sand	
	3	1461.5	23.5	36.9	Clayey sand	HQK
	4	1302.5	40.6	77.5	Coarse sand	
	5	3949.0			Fine sand	
6	1	1331.9	1.0	1.0	Top soil	
	2	2056.0	12.8	13.8	Medium coarse grained sand	HQK
	3	1188.0	16.3	30.1	Clayey sand	
	4	1636.0	35.2	65.3	Coarse grained sand	
	5	3470.7			Fine sand	

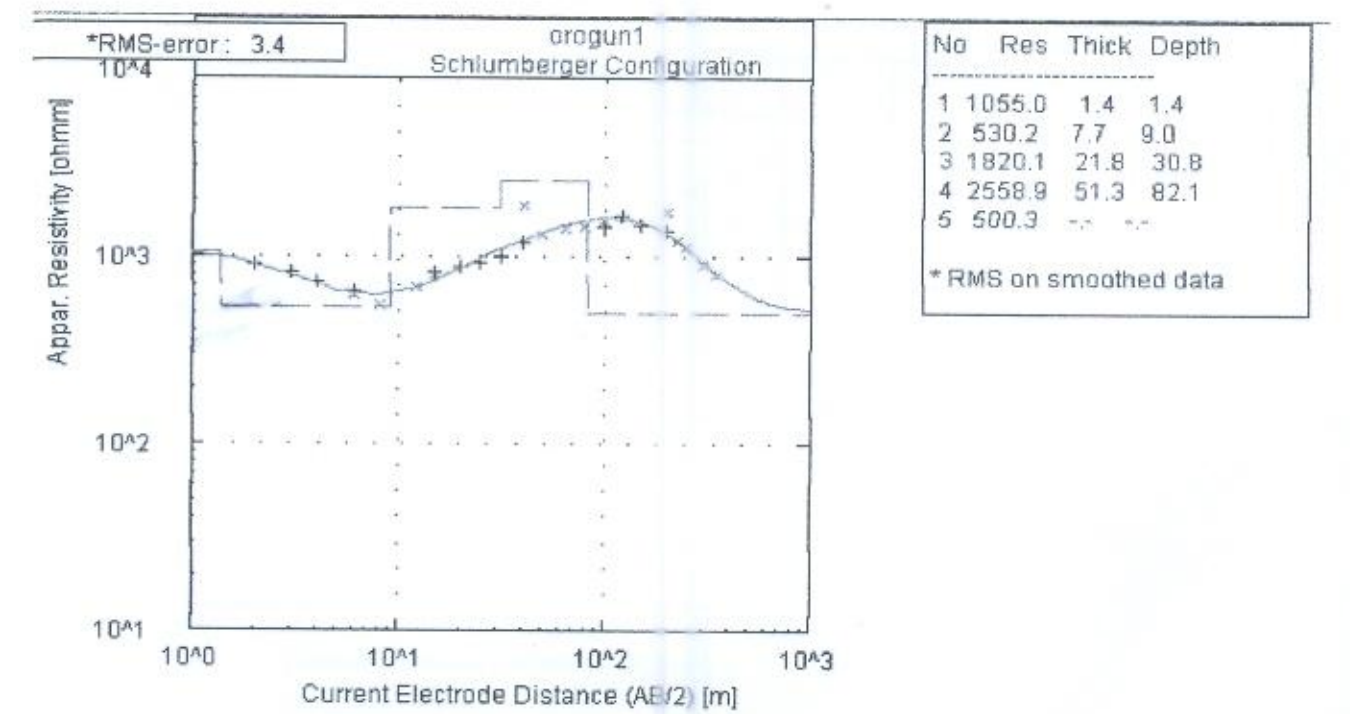

Fig 6: Sounding Curves for Orogun (VES1)

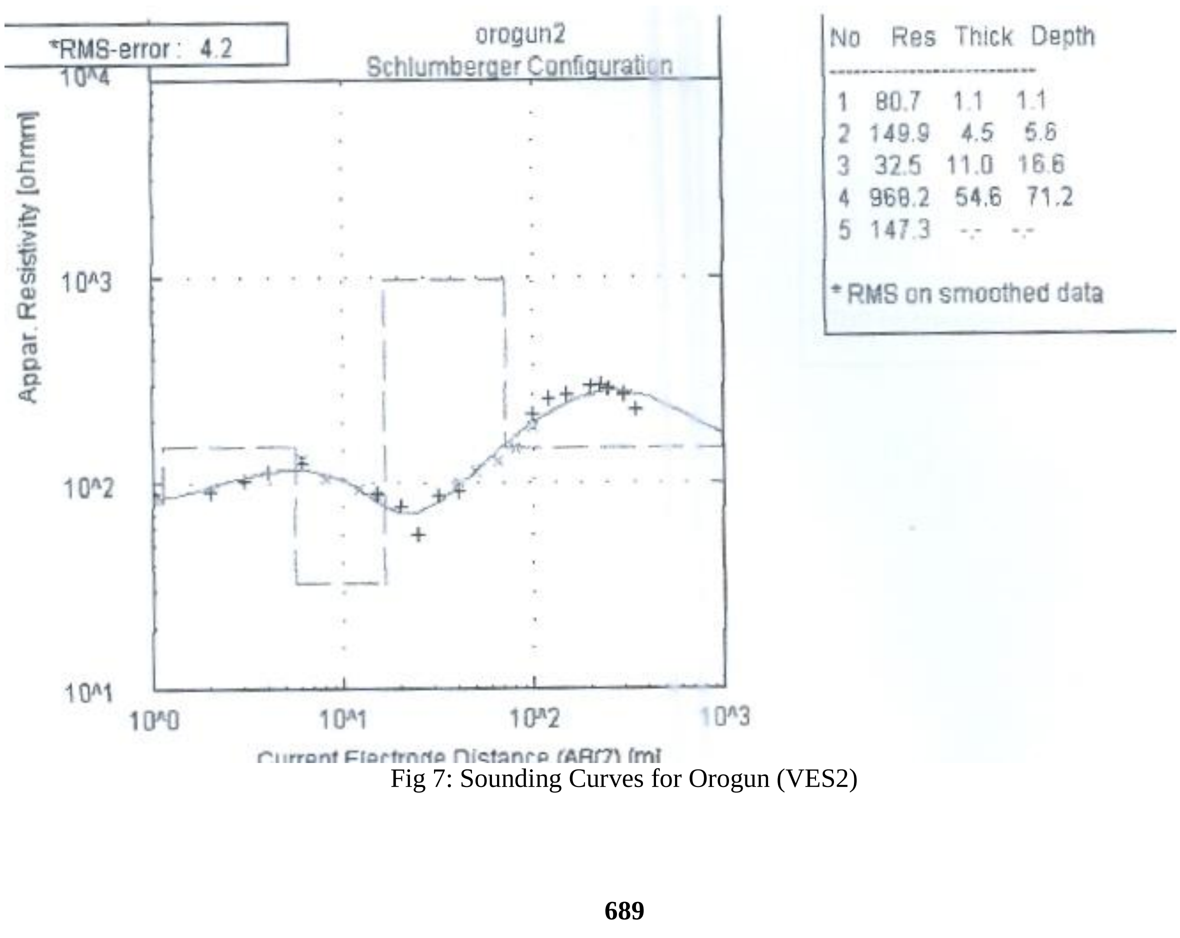

Fig 7: Sounding Curves for Orogun (VES2)

TABLE 4: ITERATION RESULT FOR OROGUN (MODEL PARAMETER)

VES	LAYER	RESISTIVITY Ωm	THICKNESS	DEPTH	LITHOLOGY	CURVE TYPE
1	1	1055.0	1.4	1.4	Top soil	
	2	530.2	7.7	9.1	Medium coarse grained sand	KAH
	3	1820.1	21.8	30.9	Coarse sand	
	4	2558.9	51.3	82.2	Fine sand	
	5	500.3			Clay	
2	1	80.7	1.1	1.1	Top soil	
	2	149.9	4.5	5.6	Fine grained sand	
	3	32.5	11.0	16.6	Clay sand	HKH
	4	968.2	54.6	71.2	Coarse grained sand	
	5	147.3			Fine sand	
3	1	58.9	1.2	1.2	Top soil	
	2	156.7	4.3	5.5	Fine smooth sand	
	3	23.1	10.0	15.5	Clayey sand	HKA
	4	101.3	13.6	29.2	Fine smooth sand	
	5	616.1			Fine sand	
4	1	858.8	0.6	0.6	Top soil	
	2	1290.8	38.5	39.0	Clayey sand	
	3	2087.4	24.2	63.2	Medium coarse grained sand	HQK
	4	6224.3	48.2	111.8	Coarse grained sand	
	5	1169.2			Fine sand	

TABLE 5: A SURVEY OF AQUIFER ELECTRICAL PROPERTIES FOR ALL VES LOCATIONS OSUBI (Ugolo)

VES Locations	Resistivity Ωm ρ	Thickness	Conductivity $(\Omega m)^{-1}$ Δ	Longitudinal Conductance S	Transmissivity Tr
1	432.3	29.7	2.3×10^{-3}	6.83×10^{-2}	296.95
2	458.2	42.2	2.2×10^{-3}	9.30×10^{-2}	422.73
3	3304.0	39.7	3.0×10^{-4}	1.20×10^{-2}	400.00
4	366.1	41.8	2.98×10^{-3}	12.45×10^{-2}	417.78
5	1302.5	40.6	7.7×10^{-4}	3.12×10^{-2}	405.19
6	1636.0	35.2	6.1×10^{-4}	2.15×10^{-2}	352.46
OROGUN					
1	25589.9	51.0	3.9×10^{-4}	1.99×10^{-2}	510.26
2	968.2	54.6	1.03×10^{-3}	5.60×10^{-2}	543.69
3	101.3	13.6	9.9×10^{-3}	13.5×10^{-2}	136.36
4	6224.3	48.6	1.6×10^{-4}	0.78×10^{-2}	487.50

RESULTS AND DISCUSSION

The studied areas, Osubi and Orogun have five distinct layers namely top soil, medium grained sand, clayey sand, coarse sand and finally fine sand. The geoelectric section shows different layers with top soil in Osubi varying in thickness from 1.0m to 2.4m and resistivity value ranging from 191.0 to 28809Ωm. The top soil for Orogun has thickness varying from about 0.6m to 1.4m while its resistivity values vary from 58.9 to 1055.0Ωm.

The second layer for Osubi is medium coarse grained sand with resistivity values ranging from 596.6 to 3140.1 Ωm with thickness varying from 4.9 to 17.7m while Orogun is made up of sand of different types such as smooth, coarse and clayey sand for different locations with thickness varying from 4.3 to 38.5m with resistivity values ranging from 149.9 to 1290.8Ωm.

The third layer for Osubi is of clayey sand. The layer resistivity values vary from 188.9 to 3093.6Ωm with thickness ranging from 12.6 to 23.9m while for Orogun, the resistivity values vary from 23.1 to 2087.4Ωm with thickness varying from 10.0 to 24.2m.

The fourth layer is of coarse grained sand with resistivity values ranging from 366.1 to 3304.0Ωm with thickness varying from 29.7 to 42.2m for Osubi. For Orogun, the resistivity values vary from 101.3 to 6224.3Ωm with thickness ranging from 13.6m to 54.6m. This layer for both communities is the most prolific aquifer or water bearing zone. The aquifer is unconfined for both zones.

The fifth layer in Osubi is of fine sand with resistivity ranging from 3214.5Ωm to 7550.7Ωm and above while Orogun in its infinite layer is of fine sand with resistivity values ranging from 147.3Ωm to 1169.2Ωm.

Locations 3 and 6 at Osubi have high resistivities of 3304.0Ωm and 1636.0Ωm indicating low corrosivity. Locations 2 and 4 have very low resistivities of 458.2Ωm and 366.1Ωm with transmissivity of 422.73m^2/day and 417.78m^2/day respectively. These areas show high corrosivity which requires that water from these areas need high treatment before consumption. Therefore, the best area for sitting boreholes in Osubi should be located in locations 3 and 6. The transmissivity of 400.00m^2/day and 352.46m^2/day for these locations are very good in a sedimentary area of Osubi.

In Orogun, locations 1 and 4 have higher resistivity of 2558.9Ωm and 6224.3Ωm indicating low corrosivity. Locations 2 and 3 at Orogun have low resistivity of 968.2Ωm and 101.3Ωm indicating areas of high corrosivity and salinity. Locations 1 and 2 are very good for sitting boreholes due to low corrosivity, low salinity and having high transmissivity of 510.26 and 487.50m^2/day respectively.

CONCLUSION

The results of the lithology of Osubi and Orogun show five distinct layers with different strata. The two locations have water bearing formations in the fourth layers (coarse grained sand). The fourth layer is the best environment for sustainable water supply. The thickness of this layer for Osubi varies from 30 to 42m while for Orogun; the thickness varies from 49m to 54m except location 3 which have a low thickness of 13.6m.

The study shows that locations 3 and 6 are the best locations for sitting boreholes in Osubi since they have low corrosivity and high transmissivity of 422.73m^2/day and 417.78m^2/day respectively. The best locations for sitting boreholes in Orogun are locations 1 and 4 with higher resistivity indicating low corrosivity and salinity with high transmissivity. The aquifers in these two communities show unconfined aquifer.

The research will definitely pave way for hydrogeological structure in Osubi and Orogun area of Delta State. It will create awareness to individuals and government in the location, design and construction of boreholes in the two communities in terms of thickness and depth of aquifer for sitting boreholes for sustainable water supply.

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