

**INVESTIGATION OF THE DEPTH OF GROUNDWATER USING SEISMIC
REFRACTION AND ELECTRICAL RESISTIVITY METHODS IN IBUSA
AND OGWASHI UKU, DELTA STATE**

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ABSTRACT

The Resistivity and the seismic investigations of the study areas have provided valuable information on the nature of the sub-surface layers. The geo-electrical section of the study areas shows five to six layered earths and the water bearing formation, Aquifer. From the VES in Ibusa and Ogwashi-uku, it was observed that the first layer ranges from $59.8\Omega\text{m} - 100.5\Omega\text{m}$ with depth $0.6\text{m} - 1.2\text{m}$, this is the Topsoil (laterite soil). The second layer ranges from $140.1\Omega\text{m} - 714.5\Omega\text{m}$ with depth $1.3\text{m} - 2.5\text{m}$, this is Brownish sand. The third layer ranges from $125.5\Omega\text{m} - 92.87\Omega\text{m}$ with depth $5.7\text{m} - 5.5\text{m}$, this is sand/medium sand. The fourth layer ranges from $405.7\Omega\text{m} - 865.5\Omega\text{m}$ with depth $23.0\text{m} - 24.5\text{m}$, this is fine sand to medium sand. The five layer ranges from $307.2\Omega\text{m} - 428.3\Omega\text{m}$ with depth $51.97\text{m} - 50.17\text{m}$. This is a clayey sand. From the seismic refraction method in Ibusa and Ogwashi-uku, it was found that the velocity of the first layer for forward and reverse is from $175\text{m/s} - 273\text{m/s}$, and the second layer for the forward and reverse is from $478\text{m/s} - 577\text{m/s}$ with an average thickness of 1.5m in Ibusa and for Ogwashi uku, the velocity of the first layer for forward and reverse is from $172\text{m/s} - 273\text{m/s}$ and the second layer for the forward and reverse is $492\text{m/s} - 645\text{m/s}$ with an average thickness of 2.275m . The total average thickness for both Ibusa and Ogwashi-uku is 1.89m . Since the average thickness is 1.89m , it shows shot-geophone spread and as a result, can be used to determine the nature of the weathered layer from the layer velocities. The aquifer can be located at depth beyond 50m but most prolific aquifer of the study areas can be related beyond the depth of 104.7m with the resistivity values ranging between $728.8\Omega\text{m}$ to $428.3\Omega\text{m}$.

KEYWORDS: Aquifer, Depth, Groundwater, VES, Ibusa, Ogwashi-Uku, Delta State

INTRODUCTION

Groundwater is characterized by some measurable parameters which are determined by geophysical methods such as Electrical methods, seismic methods, magnetic methods, gravity methods, etc. (Dobrin, *et al.*, 1976).

Electrical resistivity method is one of the most useful techniques in underground water geophysical exploration because the resistivity of rock is very sensitive to its ionic content (Alile *et al.*, 2011). While the seismic methods have been used to delineate

bedrock aquifer and fractured rock systems. Electrical resistivity methods in geophysical exploration for groundwater in a sedimentary environment have proven reliable (Emenike, 2001). Records show that depth of aquifers differ from place to place because of variational geo-thermal and geo-structural occurrence (Ekine, *et al.* 1996), (Akinbiyi and Abudulawal, 2012) and (Okwueze, 1996).

Ahmed *et al.* (2012) used 2-D seismic refraction method to investigate a sewage treatment site located at Ahmadu Bello University Zaria, Nigeria. By using this method, they were able to determine the overburden thickness and velocity of the subsurface layers in the area, and delineating any geological structures, such as fracture zone, that may pose a threat to the safe running of the Sewage lagoon system in the area.

In the study areas, Ibusa and Ogwashi-uku, boreholes drilled in some areas could not yield plausible results as a result of not drilling to the aquifer zone. Consequently, For Ibusa area, it will be encouraging to drill to a depth

beyond 104.7m, and for Ogwashi-uku area, it will be encouraging to drill to a depth beyond 50.17m.

Geology of the Study Area

The study areas are located within the vegetational area of the Niger Delta. The areas are Ibusa and Ogwashi-uku, which are in Oshimili North and Aniocha South Local Government Areas of Delta State, Nigeria. They lie between Latitude 6.10'E and 6.11'E, in figure 1. Ibusa is bounded at the East by Asaba Town, West by Ogwashi-uku town, North by Okpanam and South by Achala-Ibusa as the boundary towns. Ogwashi-uku is also bounded at the East by Ibusa town, West by Ani-Emegwai Town, North by Edo-Ogwashi and South by Ogwashi-olor as the Boundary Towns.

The study areas are parts of the Niger Delta. The ground over there is usually hard and mostly filled with laterite. Borehole has been drilled there before and now in the area but most were successful while some were unsuccessful due to lack of pre-knowledge of the hydrogeologic problems.

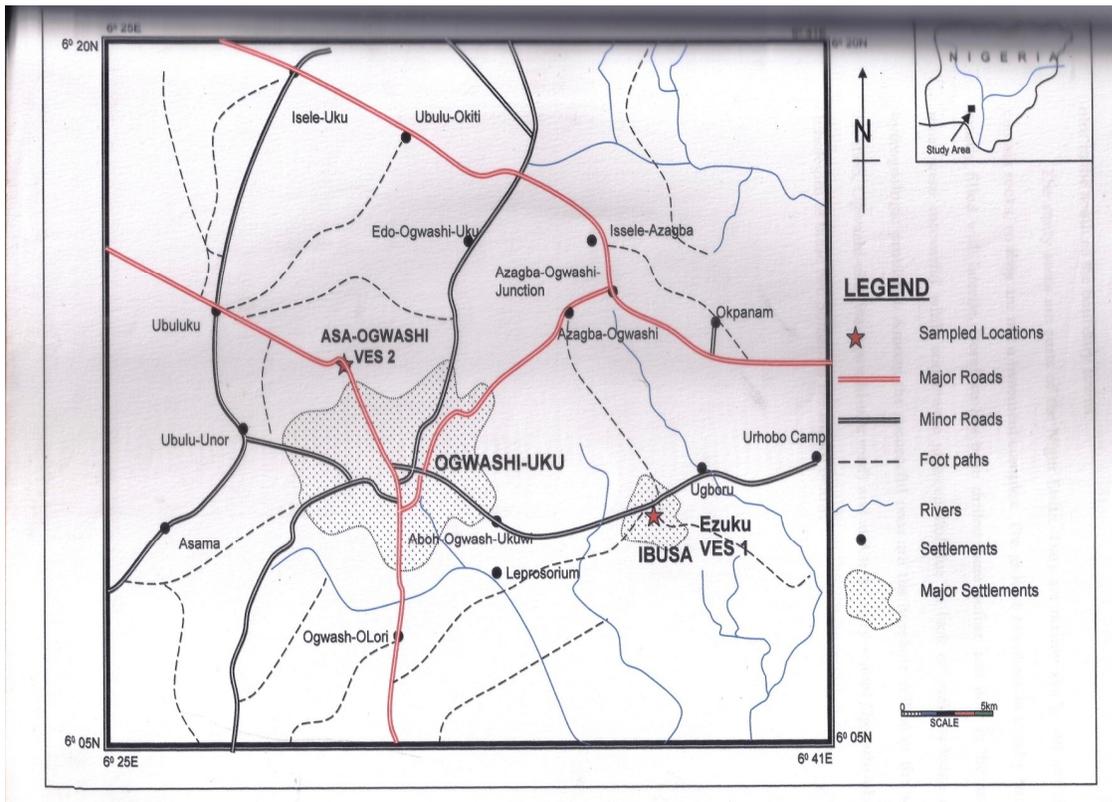


Fig. 1: Map of Ogwashi-Uku, Ibusa and environs showing sampled Locations

METHODOLOGY

Resistivity Method

Theory of Resistivity

The fundamental physical law used in resistivity surveys is Ohm's Law that governs the flow of current in the ground. The equation for Ohm's Law in vector form for current flow in a continuous medium is given by;

$$J = \sigma E \quad (1.1)$$

$$E = -\nabla\Phi \quad (1.2)$$

$$J = -\sigma \nabla\Phi \quad (1.3)$$

In almost all surveys, the current sources are in the form of point sources. In this case, over an elemental volume ΔV surrounding the current source I , located at $(X_S Y_S Z_S)$ the relationship between the current density and the current (Dey and Morrison 1979a) is given by;

$$\nabla \cdot J = \left(\frac{I}{\Delta V} \right) \delta(x - x_s) \delta(y - y_s) \delta(z - z_s) \quad (1.4)$$

Where δ is the Dirac delta function

$$-\nabla \cdot [\sigma(x, y, z) \nabla \phi(x, y, z)] = \left(\frac{I}{\Delta V} \right) \delta(x - x_s) \delta(y - y_s) \delta(z - z_s) \quad (1.5)$$

Where V and J are the potential difference and the current density

This is the basic equation that gives the potential distribution in the ground due to a point current source.

The electrode arrangement used in this research is the schlumberger arrangement. The ABEM SAS 300B electrical resistivity equipment was employed to observe resistivity responses of the subsurface layers which are recorded in resistance measured in ohm meter. The two current and potential electrodes were hammered into the ground in accordance with the standard schlumberger recording sheet. Furthermore, the current electrodes were spread further apart with corresponding potential electrodes spacing and terrameter, was used to take the readings at each of the stations.

Seismic Refraction Method

OYO McSeiS – 160 equipment was used for the recording of the seismic refraction pulses with a chosen field configuration, Twelve (12) geophones, with a multicore cable were connected to the 12-channel seismic recorder port of the equipment. An off-set distance of 3m was set from the extreme geophone position for both the forward and reverse shot points. The distances within the geophones 1-12, were in the configuration 2m, 2m, 3m, 3m, 5m, 6m, 5m, 3m, 3m, 2m, 2m.

The sledge hammer was used as the source of energy or provides sufficient energy to transverse the short recording range. (Philip and brooks.1991). With the trigger metal and base metal plate well placed and every other connection intact, a measured offset distance of 100m between multicore cable and the geophone positioning (firmly stacked vertically with their spikes to the ground) were established. Besides forward shots were made and seismic refraction pulses were recorded and printed out a hardcopy. The entire operation was replaced for the reverse shot as well. The forward and reverse shots were repeated four (4) other along different specified transverse.

RESULTS

The data in tables (1 – 6) were collected during a geophysical mapping using seismic and Resistivity Method from Ibusa and Ogwashi-uku.

Resistivity Method

The field data obtained was interpreted by using computer iteration method. This was done by inputting the data into a computer containing the resistivity software, which in turn, gives us the depth and the graph of the data. The data below were obtained from the resistivity (VES) method carried out in Ibusa and Ogwashi-Uku.

Resistivity Field Record

Table 1: VES for Ibusa and Ogwashi-Uku

VES 1 (Ibusa)			VES 2 (Ogwashi-Uku)		
Station Number	Electrode AB/2	Apparent Resistivity (Ωm)	Station Number	Electrode AB/2	Apparent Resistivity (Ωm)
1	1.00	71.0	1	1.00	110
2	1.47	85.0	2	1.47	125
3	2.15	96.0	3	2.15	150
4	3.00	110.0	4	3.00	180
5	4.60	121	5	4.60	220
6	6.80	130	6	6.80	240
7	10.00	165	7	10.00	250
8	14.70	181	8	14.70	282
9	21.50	235	9	21.50	210
10	31.60	300	10	31.60	425
11	46.00	315	11	46.00	500
12	68.00	323	12	68.00	550
13	100.00	390	13	100.00	650
14	147.00	500	14	147.00	800
15	213.00	553	15	213.00	950
16	326.00	600			
17	464.00	700			

The characteristics Geo-electrical section for the study areas mapped, is shown in fig 1.10. The Geo-electrical section was taken along NW-NE profile, showing a maximum of five to six layered lithology in the study areas.

The first layer, which is the weathered zone (Topsoil), has a resistivity values ranging between 59.8 Ωm in Ves1 and 100.5 Ωm in VES 2 with a depth of 0.6m and 1.2m respectfully. This is the Topsoil (laterite soil).

The second layer has a resistivity values ranging between 140.1 Ωm VES 1 and 714.5 Ωm in VES 2 with a depth of 1.3 m and 2.5m. This layer is brownish weathered rock sand.

The third layer has a resistivity values ranging between 125.5 Ωm in VES1 and 92.87 Ωm in VES 2 with a

depth of 5.7m and 5.5m. This layer is fine sand to medium sand.

The fourth layer has a resistivity values ranging between 405.7 Ωm in VES 1 and 865.5 Ωm in VES 2 with a depth of 23.0m and 24.5m. This layer is fine sand to medium sand.

The Fifth layer has a resistivity values ranging between 307.2 Ωm in VES 1 and 428.3 Ωm in VES 2 with a depth of 51.97m and 50.17m. This layer is coarse sand with clay.

The sixth layer has a resistivity value of 728.8 Ωm in VES 1 with a depth of 104.7m. This layer is clayey sand.

A correlation of the lithologic log around the study areas with the geo electric section in fig 1.10 shows that the sediments of the various layers (1,2,3,4,5 and 6) of the study areas reveal essentially laterite soil (Topsoil), brownish sand, fine sand/medium sand

and fine sand medium sand, coarse sand with clay and clayey sand.

Seismic Method

In seismic refraction interpretation, the time – distance (t-x) graphs were plotted using the seismic data obtained from the field. These seismic data are shown in Table 3 – 5. From the graph, the slopes were obtained which are the inverse of the velocities, and the intercept time was also determined. The

variables, wave velocity and intercept time, were used to calculate the thickness (Z) of each layer using the equation:

$$Z = Ti V_1 V_2 / 2(v_2^2 - v_1^2) \dots\dots\dots (1.1)$$

$$Ti = 2Z (v_2^2 - v_1^2) / v_1 v_2 \dots\dots\dots (1.2)$$

Where Ti = Intercept Time

Z = Thickness of the layer

V₁ and V₂ = Velocities in layer 1 and 2

Table 2: Ibusa Forward and Reverse (Ezuku)

GEOPHONE NO	1	2	3	4	5	6	7	8	9	10	11	12
GEOPHONE DIST	3	2	2	3	3	5	6	5	3	3	2	2
ON GEOPHONE SEP	3	5	7	10	13	18	24	29	32	35	37	39
REV GEOPHONE SEP	39	37	35	32	29	24	18	13	10	7	5	3
ON TIME (ms)	12	17	-	35	43	49	60	68	73	78	-	85
REV TIME (ms)	85	78	-	72	68	55	48	38	32	23	-	18

Table 3: Ibusa Forward and Reverse (Ezuku)

GEOPHONE NO	1	2	3	4	5	6	7	8	9	10	11	12
GEOPHONE DISTANCE	3	2	2	3	3	5	6	5	3	3	2	2
ON GEOPHONE SEP	3	5	7	10	13	18	24	29	32	35	37	39
REV GEOPHONE SEP	39	37	35	32	29	24	18	13	10	7	5	3
ON TIME (ms)	13	18	-	27	35	42	54	63	72	77	-	84
REV TIME (ms)	85	78	-	72	67	56	44	37	32	23	-	10

Table 4: Ogwashi-Uku Forward and Reverse

GEOPHONE NO	1	2	3	4	5	6	7	8	9	10	11	12
GEOPHONE DIST	3	2	2	3	3	5	6	5	3	3	2	2
ON GEOPHONE SEP	3	5	7	10	13	18	24	29	32	35	37	39
REV GEOPHONE SEP	39	37	35	32	29	24	18	13	10	7	5	3
ON TIME (ms)	13	18	-	37	45	56	62	73	79	84	-	90
REV TIME (ms)	91	90	-	83	77	73	58	44	36	26	-	15

Table 5: Ogwashi-Uku Forward and Reverse

GEOPHONE NO	1	2	3	4	5	6	7	8	9	10	11	12
GEOPHONE DIST	3	2	2	3	3	5	6	5	3	3	2	2
ON GEOPHONE SEP	3	5	7	10	13	18	24	29	32	35	37	39
REV GEOPHONE SEP	39	37	35	32	29	24	18	13	10	7	5	3
ON TIME (ms)	13	18	-	27	35	42	54	63	72	77	-	84
REV TIME (ms)	85	78	-	72	67	56	44	37	32	23	-	10

Comparing the velocities in Tables 1.3-1.6 with the appropriate velocities of the longitudinal wave for representative material, for the first transverse, IBUSA (0057, 0058), the forward and reverse seismic sections were sections recorded and had a velocity range of the first layer as 175m/s – 273m/s and the second layer as 478m/s – 577m/s with an average thickness of 1.5m. This corresponds to Topsoil (laterite with clay). While the second transverse, OGWASHI-UKU (0060, 0061), the velocities of the first layer for forward and reverse ranges from 172m/s-273m/s and the second layer for forward and reverse ranges from 492m/s-645m/s with an average thickness of 2.275m. This also corresponds to Topsoil (laterite with clay).

CONCLUSION

The Vertical Electrical Sounding (VES) and the seismic investigation of the study areas have provided valuable information on the nature of the sub-surface layers. The geo-electrical section of the study areas shows five to six layered earths and the water bearing formation, (Aquifer).

The prolific aquifer can be located at depth beyond 50m but most prolific aquifer of the study areas can be related beyond the depth of 104.7m with the resistivity values ranging between

728.8 Ω m to 428.3 Ω m. From the geophysical investigation for the search of groundwater using VES in Ibusa and Ogwashi-uku, it has been found or observed that the first layer is the Topsoil (laterite soil), the second layer is the Brownish sand, the third layer is the sand/medium sand, the fourth layer is fine sand to medium sand and the five layer clayey sand Portable groundwater would be available at a depth beyond 104.7m in the study areas.

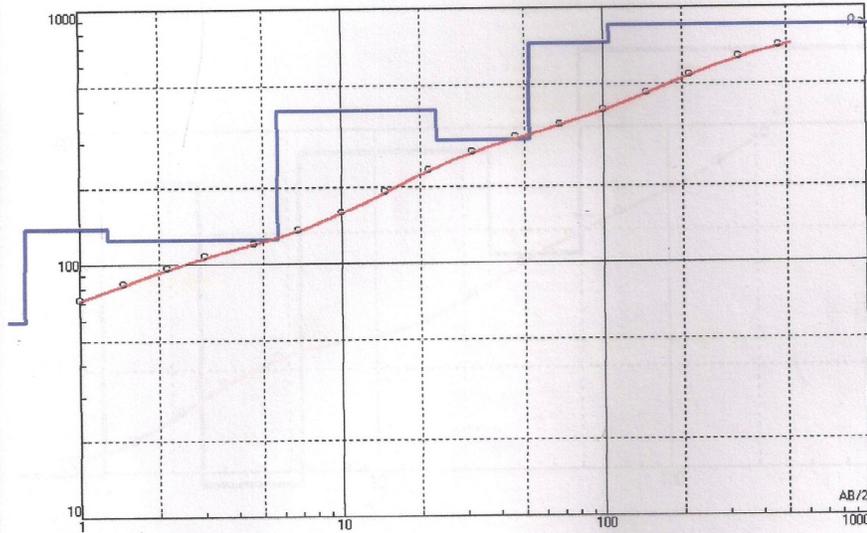
Besides, from the geophysical investigation for the search of groundwater using seismic refraction method in Ibusa and Ogwashi-uku, it was found that the velocities of the first layer for forward and reverse is 175m/s -273m/s, and the second layer for the forward and reverse is 478m/s-577m/s with an average thickness of 1.5m in Ibusa. While the velocities of the first layer for forward and reverse is 172m/s-273m/s and the forward and reverse is 492m/s-645m/s with an total average thickness of the layer for both Ibusa and Ogwashi-uku was 1.81m due to the short-geophone spread, the seismic method was used to determine the nature of the weathered layer from layers velocities which fall under laterite with clay and is regarded as the Topsoil (weathered layer). It was observed from the Resistivity and Seismic methods interpretation, that the aquifer zone is beyond 104.75m.

COMPUTER ITERATION

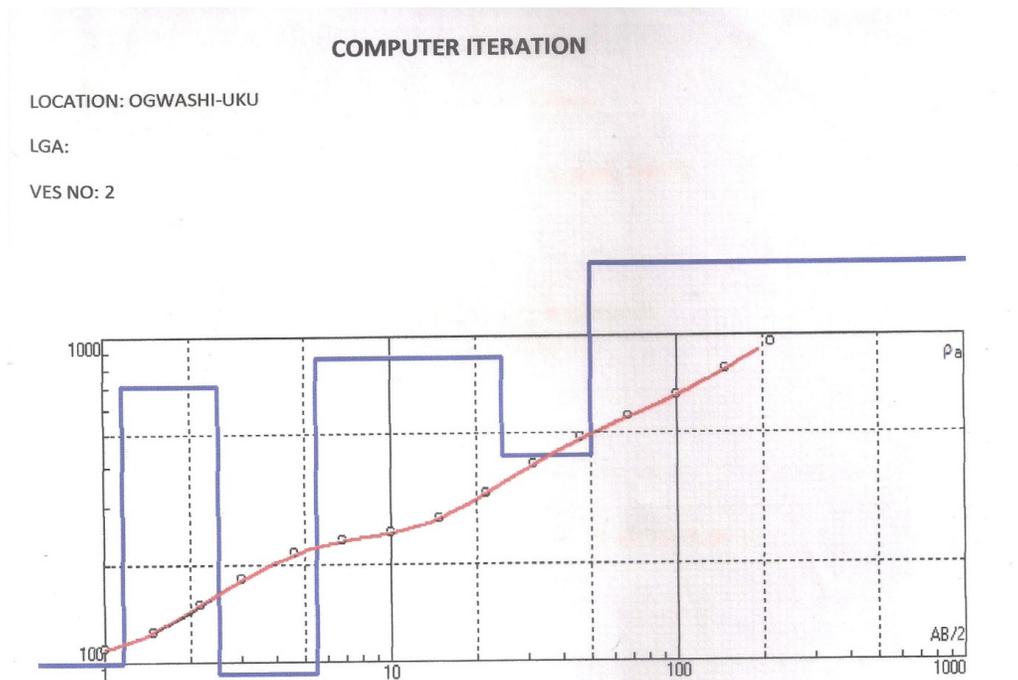
Location: IBUSA

L.G.A:

VES NO: 1



N	ρ	h	d	Alt
1	59.76	0.6169	0.6169	0.6168
2	140.1	0.6522	1.269	-1.269
3	125.5	4.443	5.712	-5.7117
4	405.7	17.33	23.04	-23.042
5	307.2	28.93	51.97	-51.968
6	728.8	52.75	104.7	-104.72
7	860.7			



N	ρ	h	d	Alt
1	100.5	1.165	1.165	-1.1648
2	714.5	1.339	2.504	-2.5041
3	92.87	3.028	5.532	-5.5324
4	865.5	18.98	24.51	-24.512
5	428.3	25.66	50.17	-50.175
6	1683			

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