Evaluation of Water Drilling Problems in a Transition Aquifer, a Case Study of Ogwashi Asaba Formation And Benin Formational Boundaries Within Orlu Area, Imo Sedimentary Basin Se Nigeria

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***Abstract*- Aquifer identification problems in a transition environment have been studied with the aim of evaluating the major causes of water borehole drilling failures of transition environment. Vertical electrical sounding principles were employed in probing the vertical lithology of the areas lying within the transition Environment of Ogwashi Asaba and Benin Formation. The major equipment used in this operation is Scintex R Sp- 6 and signal average system SAS 300 Terrameter. The result shows that the lithological arrangement is chaotic and cannot be correlated. The borehole drill log and electrical resistivity survey of the underlying lithology doesn't correspond because of the inter fingers of sediments which could not be detected by VES survey. This leads to error in total drill depth estimation. Most of the aquifers at the deep levels have no shale base making the total drill depth estimation a guess. A water bore hole in a single location may have aquifer at different levels of the well, therefore, multiple screens are ideal. Hand dug well is possible in some areas. No bore hole in the area should terminate before 90m (270ft). It was discovered that trilinear VES survey should be employed in the area. Where water bore hole drilling is difficult, hand dug well should be installed if possible. The VES report of one area should not be used for another, because the well cutting of any borehole does not match its vertical electrical resistivity results.**

***Index Terms*— Transition aquifer. Imo Sedimentary basin, Orlu SE Nigeria, underground water bore hole.**

I. INTRODUCTION

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The area together with their geological formations is found on a coordinate between 5°34N to 5°55N and Longitude 7°00E to 7° 25E, and involves all zones at the transition between Ogwashi Asaba and Benin Formations within Orlu area. These areas among others are Owerri Ebiri, Nkwerre, Umudi, Nsu, Amokpara, Owerri Nkwoji, etc Fig 1.

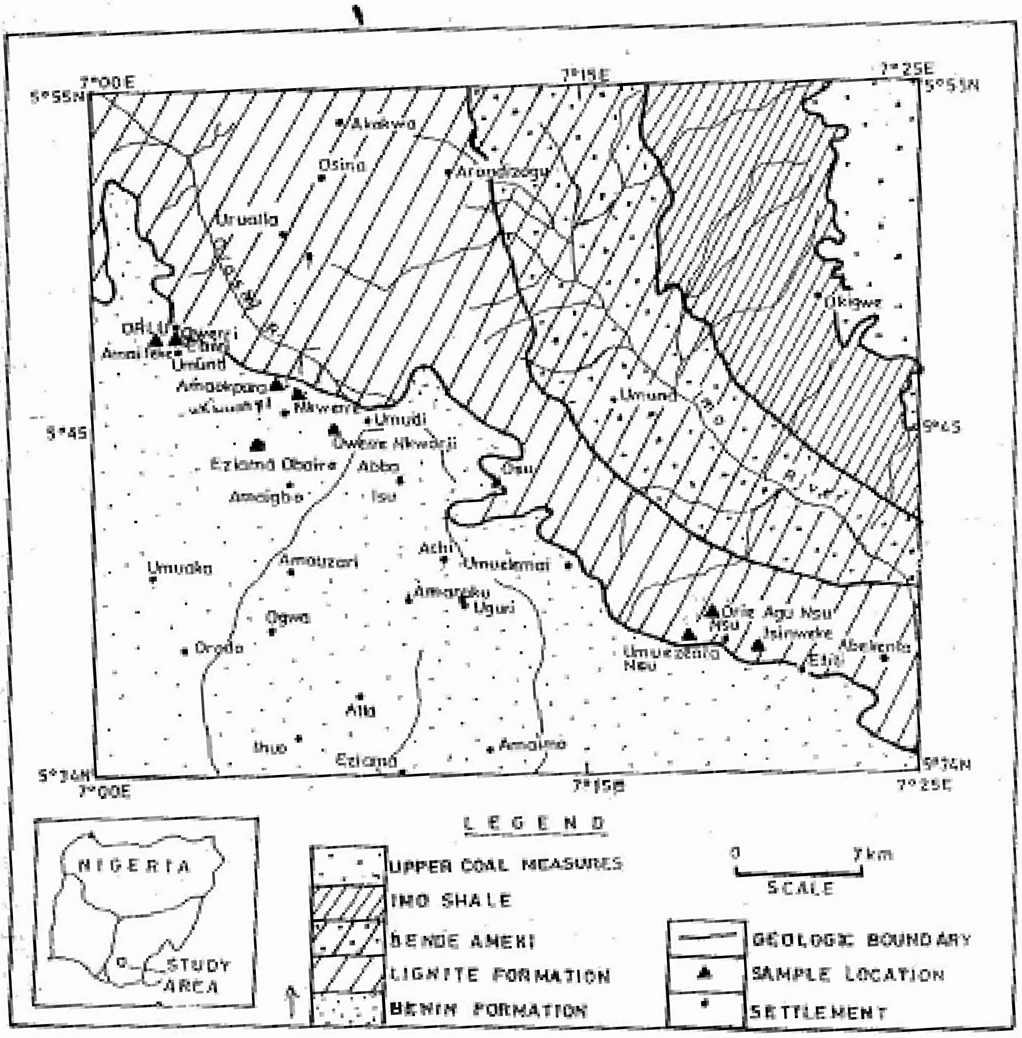


Fig. 1.0 Geologic Map of the Study Area (Reyment, 1965)

Nkwerre is used as a reference area. According to (Uma, 1989), identifying aquifers in a transition environment has become a source of problem to water resources development. Cases of unsuccessful underground water exploitation difficulties abound in transitional areas between two formations especially when two aquicludes or an aquiclude and aquiferous formations share boundaries (Kollert, 1981).

This study therefore tries to discover the natural causes of this anomaly with a view to finding solutions.

Benin Formation is dominantly sandy with a few clay lenses (Oteze, 1976). The sands and sandstones are coarse to fine grained and commonly of granular texture. The Benin Formation sands and sandstones are mainly deposits of the continental upper deltaic plane environment (Short and Stauble, 1967). Reyment, 1965, branded it coastal plain sand. Benin Formation comformably overlies the Ogwashi /Asaba Formation. The Formation starts as a thin edge at its contact with Ogwashi-Asaba Formations and thickens seawards (Avbovbo, 1978). Ogwashi Asaba Formation (Lignite series) consists of alternation of lignite seams and clay. Presence of coal seams in the Formation makes it suitable for the existence of acidic water. (Uma, 1989). The lignite series is a variable succession of clays, sands with grits or minor clay units. Ogwashi Asaba Formation stratigraphically is Oligocene and Miocene in age. It is predominantly sandy, alternating with lignite and few beds of clay (Reyment, 1965). This makes transition environment a very difficult area to locate prolific aquifer (Uma, 1989). Ogwashi Asaba Formation is overlain by Benin Formation of possible Miocene to recent (Uma, 1989). The stratigraphic succession of this area is shown in table I

Table 1: Stratigraphic Succession of the area (SE Nigeria) (Reyment, 1965)

Age	Age	Formation	Lithology
Tertiary	Miocene-Recent	Benin Fm.	Medium to coarse grained poorly consolidated sands with clay lenses and stringers.
	Oligocene-Miocene	Ogwashi Asaba FM	Unconsolidated sands with lignite seams.
	Eocene	Ameki FM Nanka Sands	Grey clayey sandstone and sandy clay stone.
	Paleocene	Imo Shale	Laminated clay shale.
Cretaceous	Maestrichtian (Upper)	Nsukka FM.	Sand stones intercalating with shales.
		Ajali Sandstone	Poorly consolidated sand stone, typically cross bedded with minor clay layers.
	Maestrichian (Lower)	Mamu FM.	Shales, sandstone, mud stones and coal seams.
	Campanian	Nkporo/Enugu Shale	Dark grey shale, clayey shale with clay lenses
	Santonian	Awgu FM.	Bluish grey shale with clay lenses.
	Turonian	Ezeaku FM.	Balck shale with clay and limestone lenses

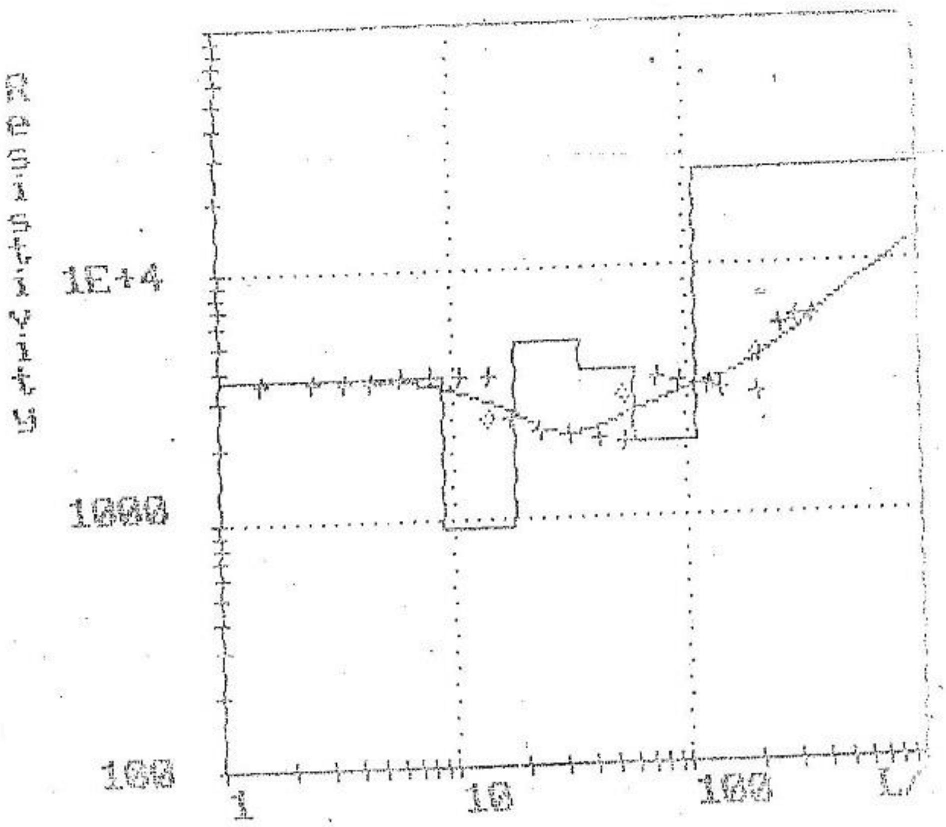
Study Method:

The vertical electrical sounding principles was employed to probe the vertical lithology of the areas lying within the transition zone. These ares are Owerri Ebiri, Amifeke, Ukwuinyi (Nkwerre), Amaokpara, Owerri Nkworji, Eziama Obire and Nsu. The aim is to record their resistivities with the view of identifying their lithological forms and hence aquifer nature, by passing electrical current through the earth and noting their potential drops or increase. The major equipment used for this operation is Sc intex R SP-6 and signal average system SAS 300 Terrameter. The information gathered from the field measurements are shown in tables 2, 3, 4 5, 6 7, and 8 with their corresponding computer modeled curves figs 2, 3, 4, 5, 6, 7, 8.

Results: The results are shown in table 2, 3, 4, 5, 6, 7, 8 and figures 2-8.

Table 2: Vertical Electrical Sounding (VES) for Owerri Ebiri

Resistivity (ohm-m)	Depth (m)	Lithological thickness (m)	Lithology	Aquifer Type
3660	0-9.2 (30.2ft)	9(29ft)	Laterite	Unconfined
940	9.2-18.2 (60ft)	9(29ft)HDW	Clay	
5000	18.2-35.1 (115ft)	17(56ft)	Sand	
3780	35.1-60.9 (200ft)	25(82ft)	Sand Sand	
2010	60.9-109(358ft)	49(161ft)	Sand Silt	
25100	109> (358ft)	>49(161ft)	Sand Sandstone	
	Below		Shale shale	



Data (File) name	SATEC	Date	21-02-2001
Project name	SURVEY	Direction lay out	NDIOKWU,OWERRIEBIRI
Code name	GEOPHYSICS	Remarks	COMMUNITY BOREHOLE
Coordinates	OYLM	Schlumberger	O'Neill

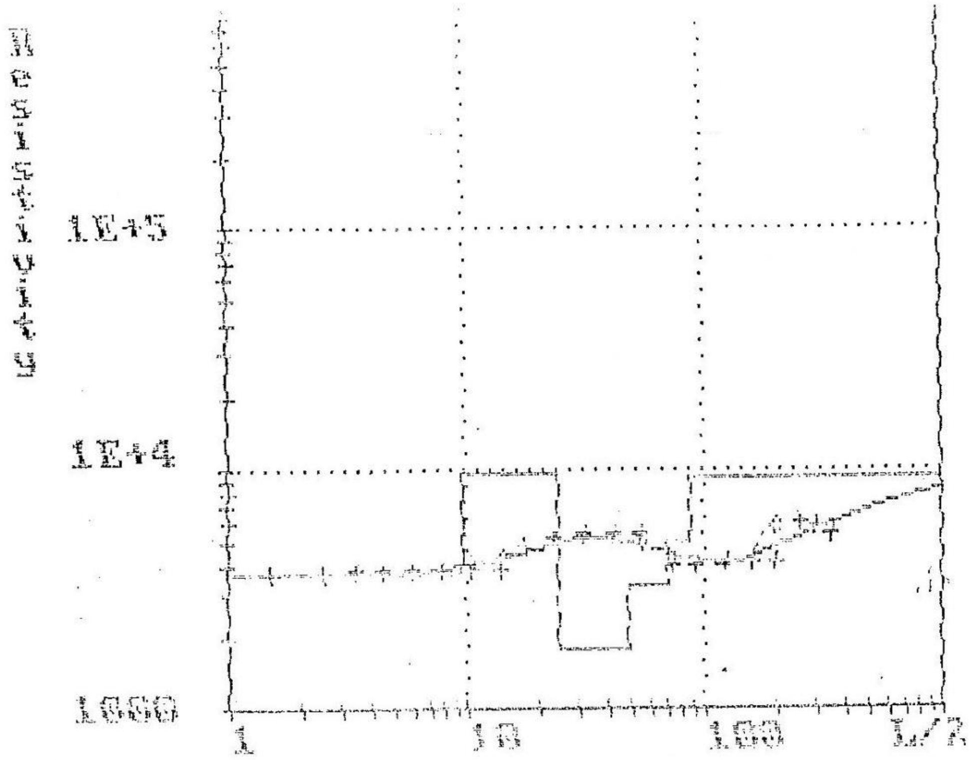
L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.5	3500.0	15.0	2450.0	95.0	3400.0
2.5	3500.0	18.0	2450.0	125.0	3250.0
3.5	3520.0	24.0	2230.0	150.0	3150.0
4.5	3520.0	32.0	2170.0	200.0	3090.0
6.0	3600.0	42.0	2060.0	200.0	4250.0
8.0	3600.0	55.0	2000.0	250.0	5600.0
10.5	3600.0	55.0	3000.0	300.0	6100.0
14.0	3600.0	75.0	3550.0	350.0	5900.0

Resistivity (Ohm.m)	Depth (m)
3660.0	9.2
940.0	18.2
5060.0	35.1
7780.0	60.9
2010.0	109.6
25500.0	

Fig 2: Computer Modelled Curve for Owerri Ebiri with total drill depth of 110m-(360ft TDP)

Table 3: Vertical Electrical Sounding (VES) For Amifeke

Resistivity (ohm-m)	Depth (m)	Lithological thickness (m)	Lithology	Aquifer Type
3640	0-9.7(29.5ft)	9(30ft)	Laterite	Unconfined
9700	9.7-24.5(80ft)	15(49’)	Sand	
1770	24.5-47.6(150ft)	23(75’) No HDW	Silt	
3340	47.6-70.2 (230ft)	23(25’)	Sand	
5060	70.2-89.4(293ft)	19(62’)	Sand	
9100	89.4-119(390)	30(98’)	Sand	
	Below?		Shale??	



Data (File) name OELU Date 20-05-2001
Project name SURVEY Direction lay out
ERIOHA RD. AMAIFEKE OELU
Code name GEOPHYSICS Remarks
IVATE WATER BOREHOLE
Coordinates AMAIFEKE ORLU Schlumberger O'Neill

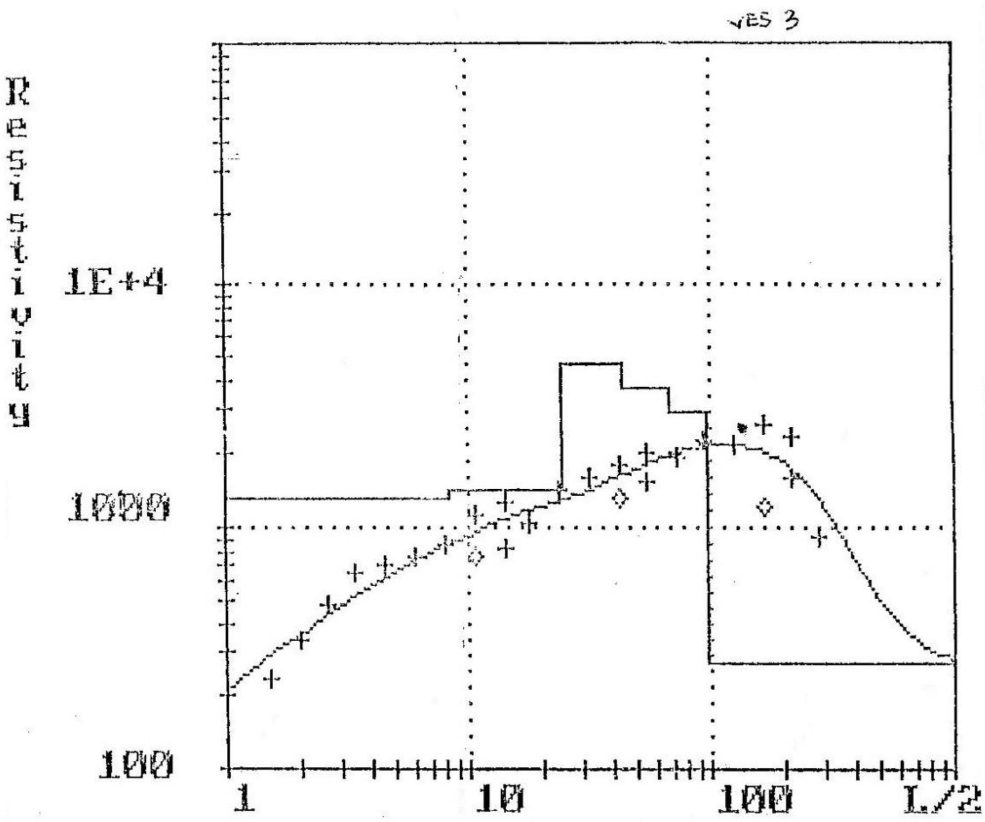
L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.5	3700.0	14.0	4110.0	[illegible]	[illegible]
2.5	3730.0	18.0	4730.0	[illegible]	[illegible]
3.5	3740.0	24.0	5140.0	[illegible]	4100.0
4.5	3740.0	32.0	5290.0	[illegible]	4150.0
6.0	3770.0	42.0	5360.0	[illegible]	5700.0
8.0	3770.0	55.0	5440.0	[illegible]	[illegible]
10.5	3770.0	55.0	4920.0	300.0	5850.0
14.0	3770.0	75.0	3950.0	[illegible]	5350.0

Resistivity (Ohm.m)	Depth (m)
3640.0	9.7
9700.0	24.5
1770.0	47.6
3340.0	70.2
5060.0	89.4
9100.0	

Fig.3: Computer Modeled Curve for Amifeke with total drill depth of 110m (360ft TDD)

Table 4: Vertical Electrical Sounding (VES) For Ukwuinyi

Resistivity (ohm-m)	Depth (m)	Lithological thickness (m)	Lithology	Aquifer Type
126	0-0.6 (2ft)	0.6 (2ft)	Laterite	Semi-confined
1300	0.6-8.3 (27.2ft)	7(23ft) No HDW	Silt	
1420	8.3-24.1 (79ft)	16 (52’)	Silt	
4710	24.1-43.4(142ft)	19(62’)	Sand	
3730	43.4-67.6(221ft)	24(79’)	Sand	
2930	67.6-96(315ft)	29(95’)	Silty sand	
268	96.2 below shale		Shale	



Data (File) name	NKRR	Date	30-03-2000
Project name	WATER BOREHOLE	Direction lay out	Dir:N-S
Code name	VES 1	Remarks	
erre L.G.A. Imo	State		
Coordinates	UKWUINYI-VILLAGE	NKWERRE	
		Schlumberger	O'Neill

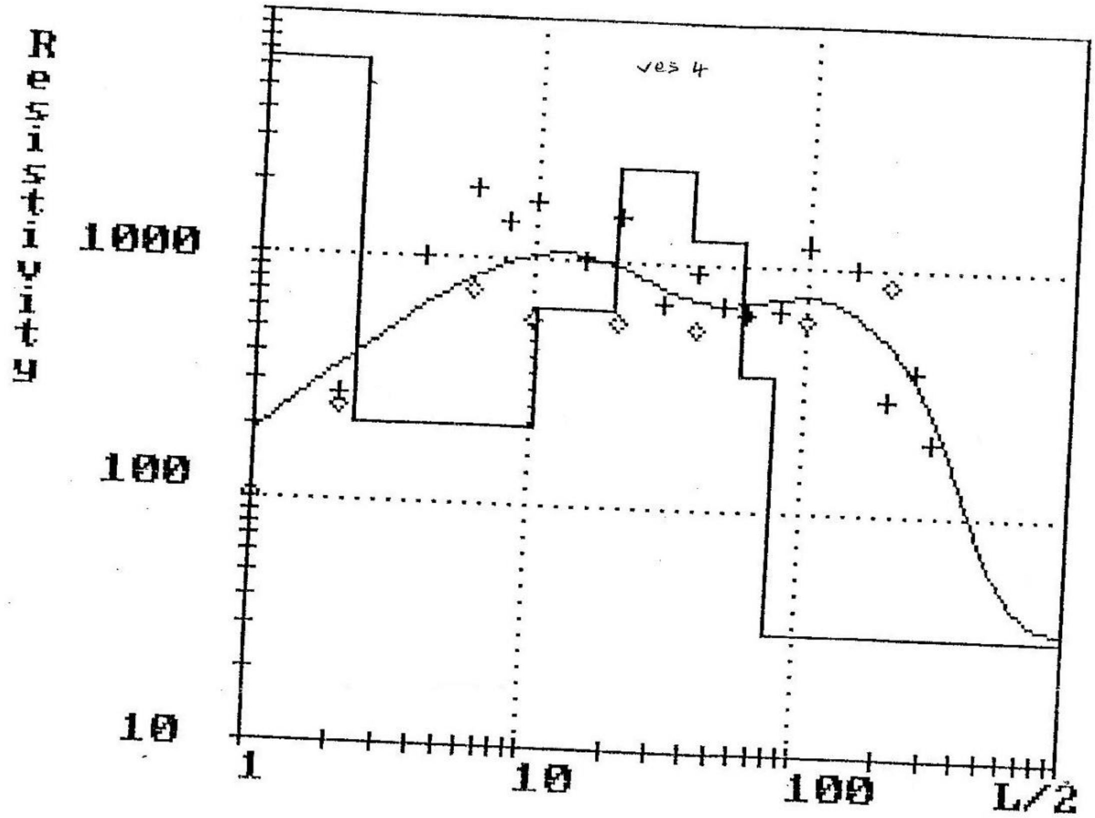
L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.5	229.2	10.5	761.6	72.5	1936.9
2.0	339.3	14.0	806.0	95.0	2180.2
2.6	476.5	18.0	1045.8	125.0	2150.4
3.4	646.8	24.0	1419.3	165.0	2617.9
4.5	709.6	32.0	1589.0	215.0	2311.7
6.0	759.1	42.0	1784.0	165.0	1216.9
8.0	860.0	55.0	2009.1	215.0	1564.7
10.5	1096.8	42.0	1290.1	280.0	920.2
14.0	1260.8	55.0	1527.9		

Resistivity (Ohm.m)	Depth (m)
126.0	0.6
1300.0	8.3
1420.0	24.1
4710.0	43.4
3730.0	67.6
2930.0	96.2
268.0	

Fig. 4: Computer modeled Curve for Ukwuinyi with total drill depth of 110.6m(330ft)

Table 5: Vertical Electrical Sounding (VES) For Amokpara

Resistivity (ohm-m)	Depth (m)	Lithological thickness (m)	Lithology	Aquifer Type
57.5	0-0.3 (1ft)	Laterite	0.3(1ft)	Confined
6480.0	0.3-2.3(7.5ft)	Sand Stone	2(7ft)	
207	2.3-10.2 (33.5ft) HDW	Shale	8(26ft)	
621	10.2-19.3 (63ft)	Clay	9(30ft)	
2450	19.3-37.7 (123.7ft)	Sand	18(59ft)	
1240	37.7-57.8 (189.6ft)	Silt	20(66ft)	
354	57.8-78.16 (255.9ft)	Shale	20(66ft)	
32	>78m (255.9ft)	Shale		



Data (File) name	KRR	Date	15-09-2001
Project name	WATER BOREHOLE	Direction lay out	Dir: N-S
Code name	VES 1	Remarks	Imo State
Coordinates	UMUEGBE AMAOKPARA (Nkwerre L.G.A.)	Schlumberger	O Neill

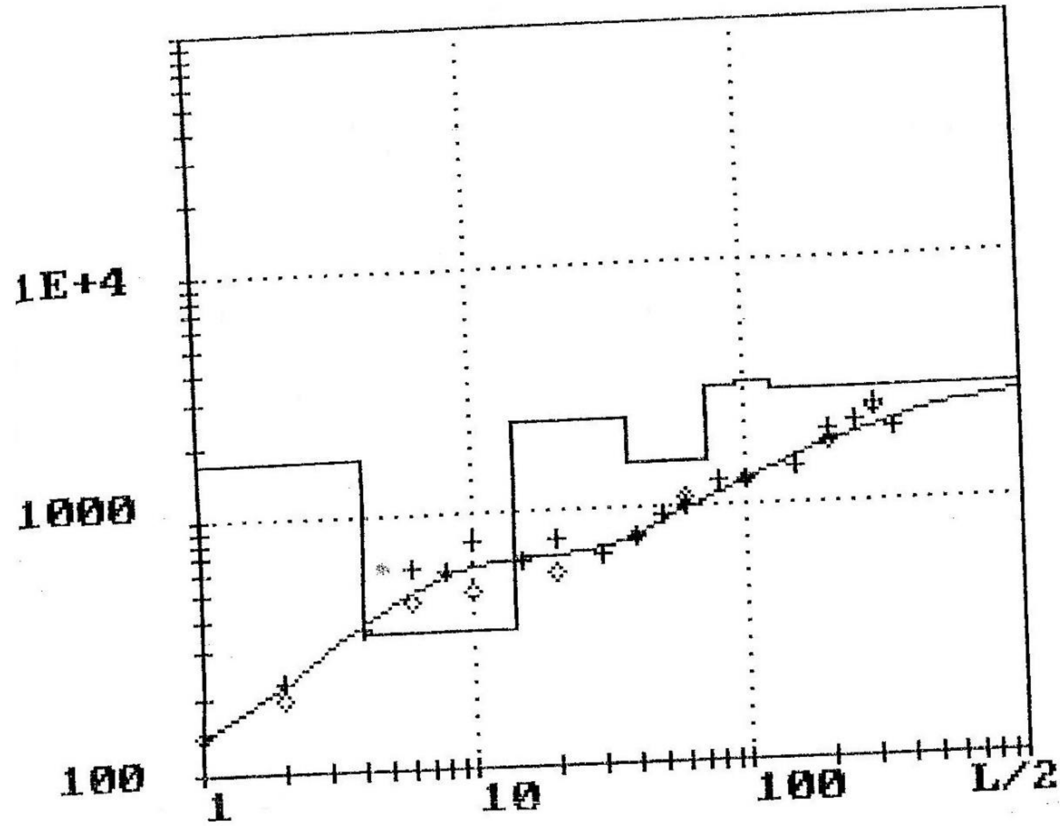
L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.0	103.4	15.0	997.0	[illegible]	[illegible]
2.0	267.0	20.0	1492.8	100.0	1212.7
2.0	243.9	20.0	568.5	100.0	603.2
4.0	994.9	30.0	676.9	150.0	980.7
6.0	1901.8	40.0	906.3	200.0	287.7
6.0	722.2	40.0	542.9	200.0	859.8
8.0	1426.6	50.0	677.8	250.0	387.0
10.0	1700.4	60.0	621.4	300.0	198.3
10.0	558.0	60.0	626.6		

Resistivity (Ohm.m)	Depth (m)
57.5	0.3
6480.0	2.3
207.0	10.2
621.0	19.3
2450.0	37.7
1240.0	57.8
354.0	78.1
[illegible]	

Fig. 5: Computer Modeled Curve for Amokpara with total drill depth of 82m (270ft)

Table 6: Vertical Electrical Sounding (VES) For Owerre Nkworji

Resistivity (ohm-m)	Depth (m)	Lithological thickness (m)	Lithology	Aquifer Type
114	0-9 (29.5ft)	Laterite	9(25ft)	Semi-confined
1730	9-14.1 (46.2ft) HDW	Silty Sand	5(16ft)	
337	14.1-37.4 (122ft)	Clay	23(75')	
2320	37.4 -72.2 (236)	Sand	35(114')	
1550	72.2-95(311.6)	Silty Sand	23(75')	
3001	95-125(410ft)	Sand	30(98') TDD=125(410)	
3112	125-155(508ft)	Sand	60(197')	
2891	155(508ft) below	Sand	>60(197)	



ta (File) name	KWJ	Date	12-09-2001
oject name	WATER BOREHOLE	Direction lay out	Dir: NE - SW
de name	VES 1	Remarks	Imo State
ordinates	OWERRE-NKWOJI (Nkwerre L.G.A.)	Schlumberger	O'Neill

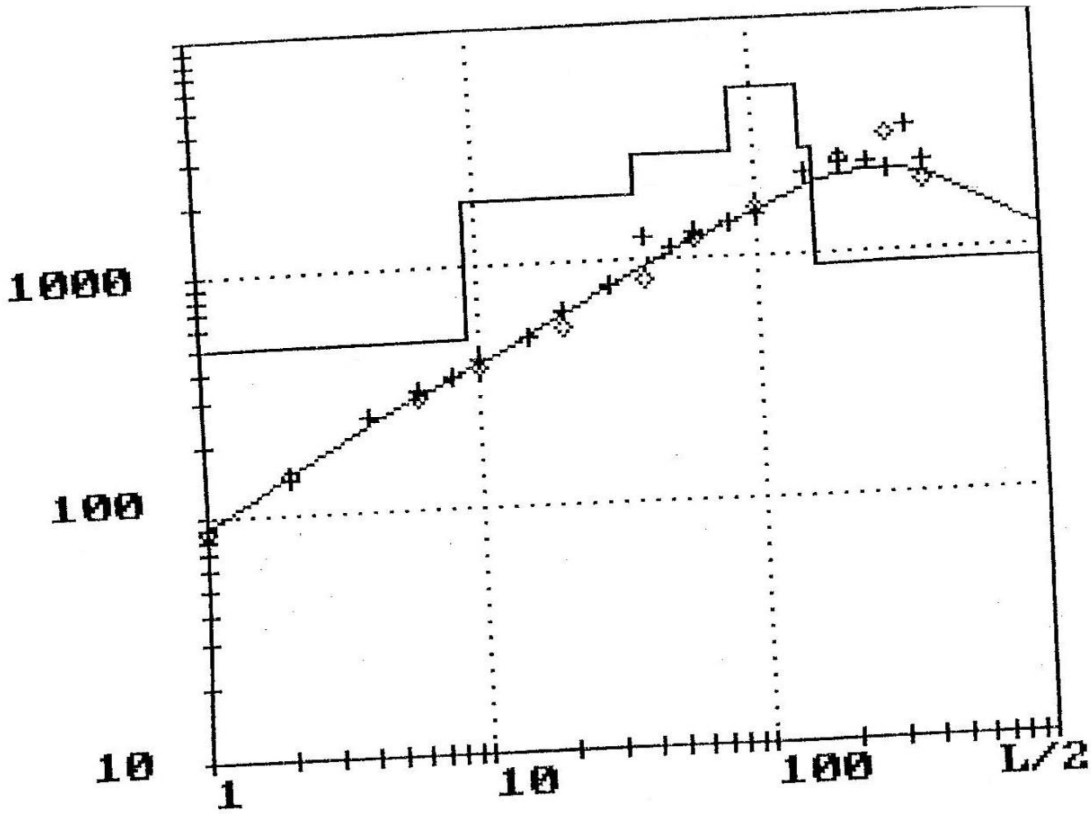
/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.0	141.0	20.0	752.6	100.0	1244.1
2.0	223.9	20.0	561.0	150.0	1419.8
2.0	193.7	30.0	642.8	200.0	2012.2
4.0	346.5	40.0	773.1	200.0	1797.4
6.0	602.6	40.0	763.0	250.0	2131.9
6.0	442.8	50.0	901.6	300.0	2509.0
8.0	587.1	60.0	1006.7	300.0	2415.0
10.0	762.8	60.0	1058.6	350.0	1954.0
10.0	476.1	80.0	1226.7		
15.0	622.9	100.0	1257.8		

esistivity (Ohm.m)	Depth (m)
114.0	0.9
1730.0	4.0
337.0	14.1
2320.0	37.4
1550.0	72.2
3001.0	95.0
3112.0	125.0
2891.0	

Fig. 6: Computer modeled Curve for Owerri Nkworji with total drill depth of 125m(410ft)

Table 7: Vertical Electrical Sounding (VES) For Eziama Obire

Resistivity (ohm-m)	**Depth (m)**	**Lithological thickness (m)**	**Lithology**	**Aquifer Type**
59.0	0-0.6 (1.97ft)	Top Soil	0.6 (2ft)	Semi-confined
510.0	0.6-9.0(29.5ft) No HDW	Clay	8(26)	
1910.0	9.0-36.8 (120.7ft)	Silt	27(88ft)	
2866.0	36.8-83.7 (274ft) x 47	Silt	47(154)	
5290.0	83.7-120(393.6ft) x 37	SandStone	37(121)	
5250	120.0 -145 (475ft)	SandStone	25(82')	
2850	145-164 (537)	Sand	19)62)	
897	164 below	Shale	19(62) below	



Data (File) name	ZMM	Date	15-09-2001
Project name	WATER BOREHOLE	Direction lay out	Dir: N-S
Code name	VES 1	Remarks	Imo State
Coordinates	EZIAMA-OBAIRE (Nkwerre L.G.A.)	Schlumberger	O'Neill

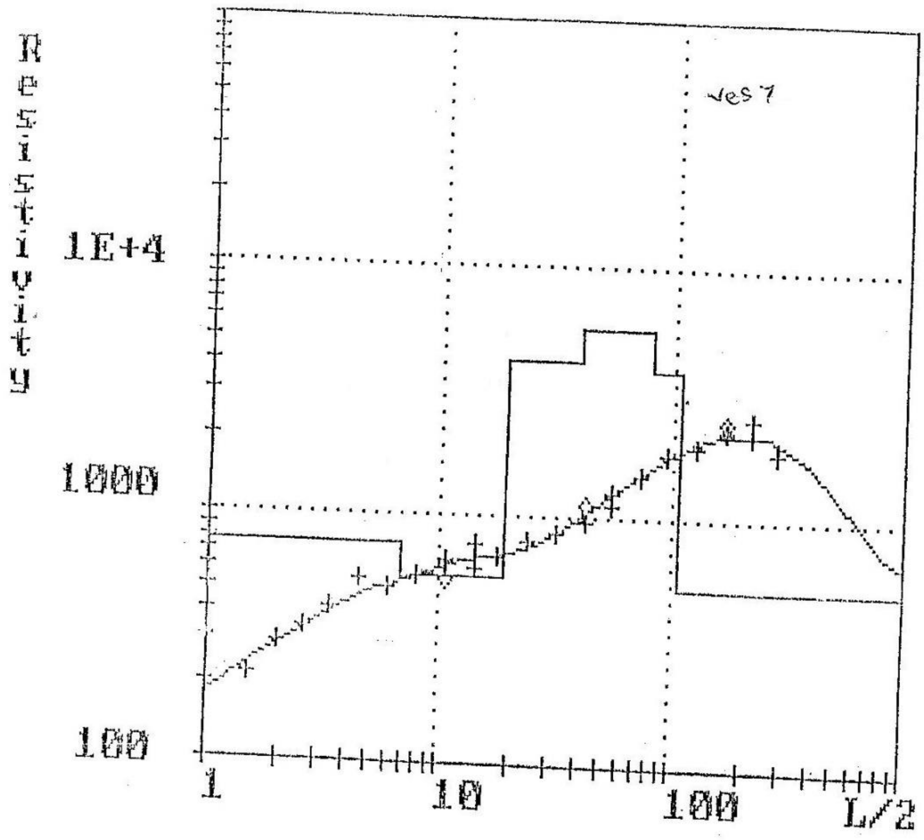
L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.0	85.7	20.0	634.4	100.0	1613.6
2.0	138.0	20.0	532.3	150.0	2190.0
2.0	148.1	30.0	784.4	200.0	2410.3
4.0	253.9	40.0	1256.4	200.0	2499.6
6.0	318.1	40.0	817.3	250.0	2370.6
6.0	293.2	50.0	1095.3	300.0	2201.9
8.0	349.5	60.0	1275.4	300.0	3096.1
10.0	410.3	60.0	1194.3	350.0	3346.0
10.0	374.0	80.0	1375.8	400.0	2414.0
15.0	497.6	100.0	1528.8	400.0	2012.0

Resistivity (Ohm.m)	Depth (m)
59.5	0.6
510.0	9.0
1910.0	36.8
2860.0	83.7
5290.0	120.0
5250.0	145.0
2850.0	164.0
897.0	

Fig. 7: Computer Modeled Curve for Eziama Obire with total drill depth (TDD) 164m(540ft)

Table 8: Vertical Electrical Sounding (VES) For Nsu

Resistivity (ohm-m)	Depth (m)	Lithological thickness (m)	Lithology	Aquifer Type
115	0.0.6 (1.97ft)	Laterite	0.6(2ft)	Confined
766	0.6-6.9(22.6ft)	Clay	6’(20)	
570	6.9-18.9(62ft)	Clay	12(39’)	
4110	18.9-39(130ft)	Sand	20(66’)	
5710	39-81(265ft)	Sand Stone	42(138’)	
3840	81-107 (351ft)	Sand	26(85’)	
529	>107 351	Shale	26(85) >	



Data (File) name NS
Project name WATER BOREHOLE
Code name VES 1
Coordinates ORIE AGU NSU (Ehime Mbano L.G.A.)
Date 25-03-2000
Direction lay out Dir: NW-SE
Remarks IMO STATE
Schlumberger O'Neill

L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)	L/2 (m)	Rho (Ohm.m)
1.5	212.9	10.5	529.3	72.5	1465.4
2.0	292.1	14.0	600.6	95.0	1755.1
2.6	336.2	18.0	688.8	125.0	1916.8
3.4	415.0	24.0	794.4	165.0	2187.7
4.5	530.0	32.0	864.0	215.0	2136.2
6.0	493.0	42.0	970.9	165.0	2397.8
8.0	562.[illegible]	55.0	1112.7	215.0	2459.4
10.5	650.5	42.0	1096.5	280.0	1808.2
14.0	750.3	55.0	1258.5		

Resistivity (Ohm.m)	Depth (m)
115.0	0.6
766.0	6.9
570.0	18.9
4110.0	39.9
5710.0	81.0
3840.0	107.0
529.0	

Fig. 8: Computer Modeled Curve for Nsu with total drill depth of 350m (106.7ft)

The tables and figures above (Tables 2,3,4,5,6,7,8 and Figures 2,3,4,5,6,7 and 8) explain the mode of aquifer emplacement in a transition zone. Fig 9.

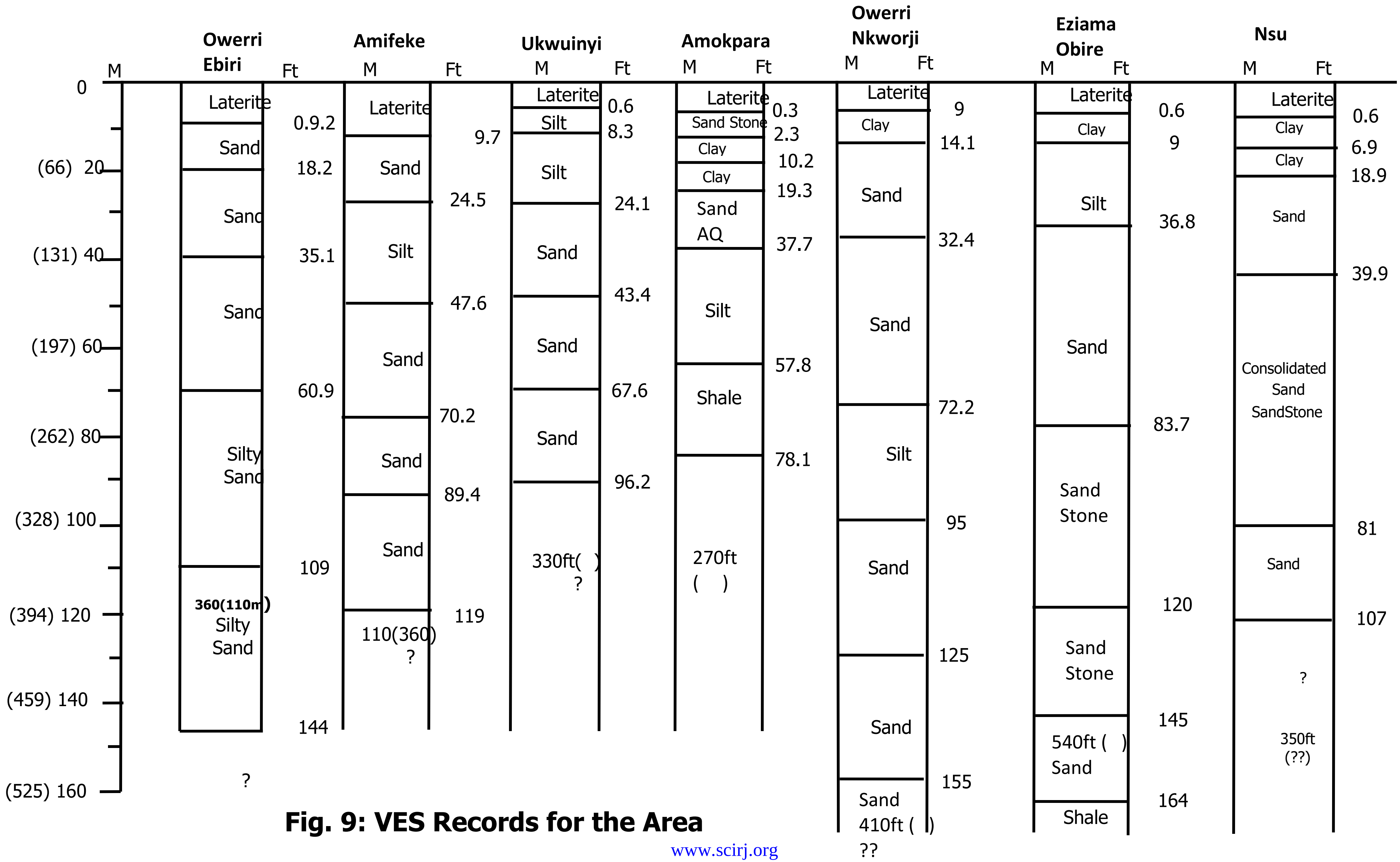


Fig. 9: VES Records for the Area

In Owerri Ebiri (Table 2), Aquifer thickness is beyond the scope of Resistivity graph and therefore the drill depth is indeterminate and this has to be estimated as 110m (360ft). The aquifer thickness is approximately 23m (74ft). The aquifer is unconfined. Hand dug well is predictable in this zone. Lithological thickness varied from 25-49m(82ft-162ft).

In Amifeke Table 3, this zone was used as a reference guide, and it shows a semi confined aquifer, though the shale base is unpredictable as the Resistivity plot could not establish the base, this in essence means that the aquifer base could not be reached, however, this has to be extrapolated and the total drill depth was established at 110m(360ft) (Geovinda, 2009). It is not possible to drill a hand dug well in this area due to the absence of shale base. Aquifer thickness ranged from 23-30m (74-98). In Ukwuinyi, the base of aquifer is reached (92m) the aquifer is semiconfined. Hand dug well is not possible due to the absence of shale base at the shallow level. At Amokpara, Hand dug well is not possible. The aquifer is confined between (10-37m). Hand dug well is not possible.

At Owerre Nkworji, the aquifer is likely confined though the shale base could not be accommodated by the VES graph indicating that the shale base is indeterminable, total drill depth was established at 125 (410ft). Hand dug well is possible . At Eziama Obire, the aquifer is semi confined by silty base. At Nsu the aquifer is confined between 40-107m (131-350ft).

II. Discussion

Lithologic logs in the area of transition vary in each location. There is wrong estimation of lithological thickness due to discontinuities (Kollert, 1981). Therefore none of the areas can employ an electrical sounding results of another. The sandy unit of Benin formations inter finger with the silty, shaley and Sand Stone formations of Ogwashi Asaba Formation in different configurations making it impossible for accurate thickness estimation. In some cases the sandy unit is in alternation with silt and shale/clay on either the shallow, middle, or deep horizon. Some areas have thick deposits of sand at the lower depth making the aquifer depth indeterminable. In some quarters the shale /clay base appears at the upper and lower horizon, making it possible to produce hand dug well at the shallow levels and also water borehole exploitation at the deep level. The chaotic arrangement of particles of the lithology indicates that underground water can be tapped at different horizons in one bore hole. It is clear that in many bore holes at deeper levels, the position of aquifer/shale base is too deep since it cannot be accommodated in the resistivity graph.

Total drill depth location in these wells is only a guess work. From the reports given by Mano Consulting Geologists (water drilling enterprise) 2011, the borehole drilling logs never corresponded with electrical resistivity survey reports. These also contribute to problems of transition aquifer. The suggestions that the lithological units may not be laterally continuous is possible, this is because a shift of some distance from abortive borehole proves successful since lithological correlation is not practicable (Mano, 2011). Borehole caving and pipe stocking is also dominant.

It was discovered from the actual borehole drilling logs that in most of the areas, the electrical resistivity results could not conform to the drilling logs.

This causes more problems in transition aquifer location. It was discovered in the area that bore hole depth must terminate from 90m(270ft) and stop at shale layer from here.

III. Recommendation

The authors recommended as follows:

Trilinear VES Survey is predicted since the aquifer is likely to be discontinuous.

No one VES should be used for different water bore hole irrespective of the distance.

Multiple screen is suggested since aquifers occur in different horizon. The multiple screens taps all the aquifers.

Where hand dug well is possible, this should be tapped especially where the aquifer depth was not accommodated by the VES graph due to the large thickness of sand members.

The borehole of transition zone must be logged as to confirm the sediments.

The total drill depth must not be less than 90m (270ft).

IV. Conclusion

Care should be exercised when drilling in a transition aquifer environment. Water drilling in a transition environment is problematic due to difficulties in aquifer locations, non conformity of actual bore hole log with the electrical resistivity measurements. There may be problems of uncomformity. Preparation should be made against incessant caving and probable pipe stock.

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