Journal of the Nigerian Association of Mathematical Physics
Volume 62, (October – Dec., 2021 Issue), **pp97 – 106**

THE USE OF GEOPHYSICAL PROSPECTING METHOD IN GROUNDWATER EXPLORATION: A CASE STUDY OF SAPELE, DELTA STATE, NIGER DELTA BASIN, NIGERIA

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Abstract

The electrical resistivity method as a tool for geophysical exploration is based on the fact that the underlying rock material can impose resistance to the flow of current and as such ohm's law could be applied. Electrical resistivity surveys are very useful for groundwater search and for mineral exploration. Information about the subsurface formations can also be gotten when potential measurements are taken at the surface. In this study, five VES soundings were made. The results gave six hydrogeophical curves from which lithologic characters were determined. The lithologic sections created graphically depicted suitable acquifer zones for water exploitation.

Keywords*: Geophysical, Groundwater, Sapele, Aquifer, Electrical Resistivity Survey*

1. INTRODUCTION

The electrical resistivity method as a tool for geophysical exploration is based on the fact that the underlying rock material can impose resistance to the flow of current and as such ohm's law could be applied. If the earth is homogenous, the resistivity measured is called true resistivity, otherwise, the term apparent resistivity is used and this is a weighted average of the resistivity of the various formations [1]
Electrical resistivity surveys are very useful for groundwater search and for mineral exploration. Information about the subsurface formations can also be gotten when potential measurements are taken at the surface. Vertical Electrical Sounding and Dipole-Dipole Array are examples of Electrical Resistivity Survey. Vertical Electrical Sounding (VES) was the dominant geophysical resistivity method. It has been used all over the world for three primary purposes: geotechnical investigation, groundwater exploration and mineral exploration [2]

GENERAL GEOLOGY OF THE STUDY AREA

The Niger Delta Formation is made up of three diachronous formations, which are the Benin, the Agbada and the Akata Formations [3]. The Benin Formation is the youngest, and it is the prolific aquifer. However, the formation is masked in the Sombrero–Deltaic plain by a sequence of silts, medium to coarse grained sands, sandy clays, and clay bands. This sequence is indistinguishable from the underlying Benin Formation in borehole section. Sand is indeed the present-day expression of this formation. The problem though is that the clay bands are not uniform in thickness, and many boreholes have been abandoned because the entire clay sequence could not be penetrated in order to access the underlying water bearing sandy layers or aquifer.

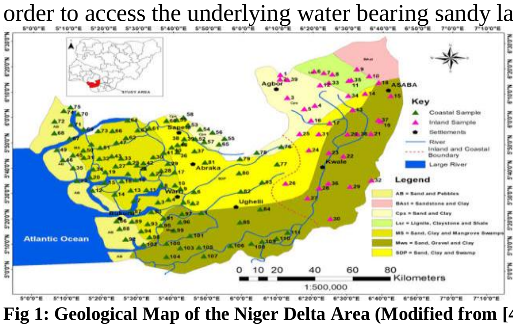

Fig 1: Geological Map of the Niger Delta Area (Modified from [4]

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LOCATION OF STUDY

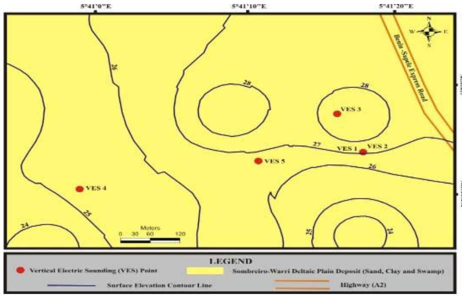

Fig.2: Study location map showing points of investigation

MATERIALS AND METHODS

Materials

The basic field equipment for this study is the PETROZENITH **TERRAMETER** which display resistance values in ohms digitally as computed from Ohm's law, and the resistance is computed with their geometric factors to give the apparent resistivity. It is powered by a 12.5 D.C power source and later Terrameter has internal power source. Other accessories attached to Terrameter includes; battery booster, several metal electrodes, cables for current and potential electrodes, hammers, measuring tapes, and walkie-talkie for communicating during very long spread.

Methods

In this configuration, the four electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. To change the depth range of the measurements, the current electrodes are displaced outwards while the potential electrodes in general are left at the same position. The resistance readings were used for computing the apparent resistivity using Schlumberger electrode configuration based on the following relationship:

$$\rho = \frac{2\pi}{\left[\frac{1}{AM} - \frac{1}{BN} - \frac{1}{AM} + \frac{1}{BN}\right]}\left[\frac{\Delta V}{I}\right] = K\left[\frac{\Delta V_{MN}}{I}\right] \tag{1}$$

Where, ρ is the apparent resistivity, ΔV is the potential difference (volt, V) and *I* is the electric current (ampere, A), where *K*, is the geometrical coefficient/factor that depends on the arrangement of the four electrodes A, B, M and N. The geometrical factor was calculated as:

$$K = \pi \frac{\left[\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2\right]}{2\left(\frac{MN}{2}\right)} \tag{2}$$

The above relationships (equations 1 and 2) hold provided that the current electrode spread AB/2 is equal to or greater than five times the potential electrode spread MN/2 with the depth of investigation as a function of electrode spacing. Based on the prevailing geologic condition during the survey, the maximum outer electrode spacing of 200m or 300m was made at the sounding station. When the ratio of the distance between the current electrodes to that between the potential electrodes becomes too large, the potential electrodes must also be displaced outwards otherwise the potential difference becomes too small to be measured with sufficient accuracy. Measurements of current and potential electrode positions are marked such that $AB/2 \geq MN/2$ [5]

Where; AB/2 = current electrode spacing

MN/2 = potential electrode spacing

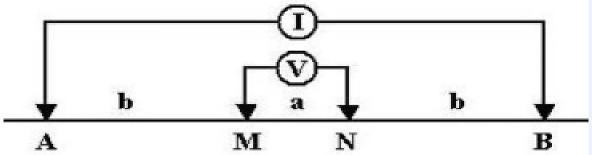

Fig 3: Schlumberger array profiling [5]

RESULTS AND INTERPRETATION

Results

Table 1: VES 1 Data and Geoelectric parameters at Sapele with Lat.: 5°54′2.334″N and Long.: 5°40′18.16″E.

VES 1 DATA				RESISTIVITY MODEL		
S/N	AB/2(m)	MN/2	Adjected Resistivity (Ωm)	Resistivity (Ωm)	Thickness (m)	Depth (m)
1	1.00	0.20	84.56	86.588	1.3628	1.3628
2	1.47	0.20	77.65	29.149	1.3424	2.7052
3	2.16	0.20	74.89	209.41	1.3891	4.0942
4	3.16	0.20	68.09	602.31	11.456	15.550
5	4.68	0.50	69.14	463.62	25.624	41.175
6	6.80	0.50	89.12	2112.4	Undetermined	Undetermined
7	10.00	1.00	130.52			
8	14.70	1.00	159.25			
9	21.00	1.00	211.27			
10	31.60	1.00	287.16			
11	48.70	1.00	366.22			
12	68.60	2.00	445.70			
13	100.00	2.00	583.00			

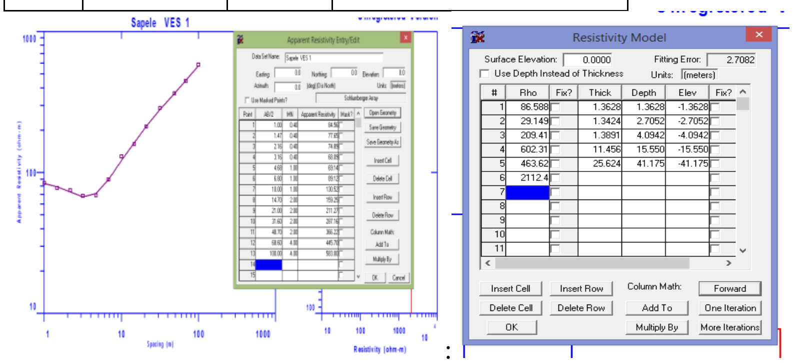

Fig 4: Typical Hydrogeophysical Sounding Curve; Apparent Resistivity Data and Resistivity Model

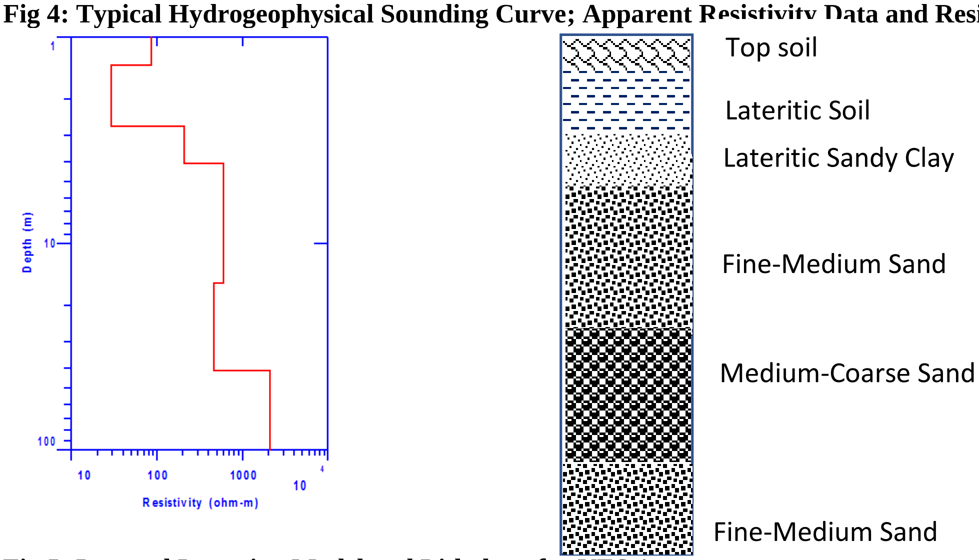

Fig 5: Layered Inversion Model and Lithology for VES 1

Table 2: VES 2 Data and Geoelectric parameters at Sapele with Lat.: 5°52′47.45″N and Long.: 5°41′8.46″E.

VES 2 DATA				RESISTIVITY MODEL		
S/N	AB/2(m)	MN/2	Adjected Resistivity (Ωm)	Resistivity (Ωm)	Thickness (m)	Depth (m)
1	1.00	0.20	375.77	371.17	1.1391	1.1391
2	1.47	0.20	374.95	403.05	2.6683	3.8074
3	2.16	0.20	375.10	252.44	3.4165	7.2239
4	3.16	0.20	378.75	875.36	7.9718	15.196
5	4.68	0.20	384.28	237.33	30.316	45.512
6	6.80	0.50	378.34	1110.1	Undetermined	Undetermined
7	10.00	0.50	373.00			
8	14.70	1.00	405.32			
9	21.00	1.00	438.20			
10	31.60	1.00	441.73			
11	48.70	1.00	414.73			
12	68.64	2.00	418.38			
13	100.00	2.00	460.05			

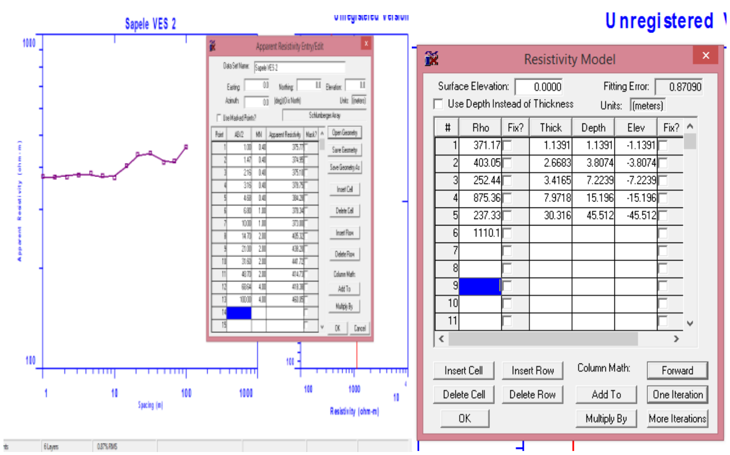

Fig 6: Typical Hydrogeophysical Sounding Curve; Apparent Resistivity Data and Resistivity Model

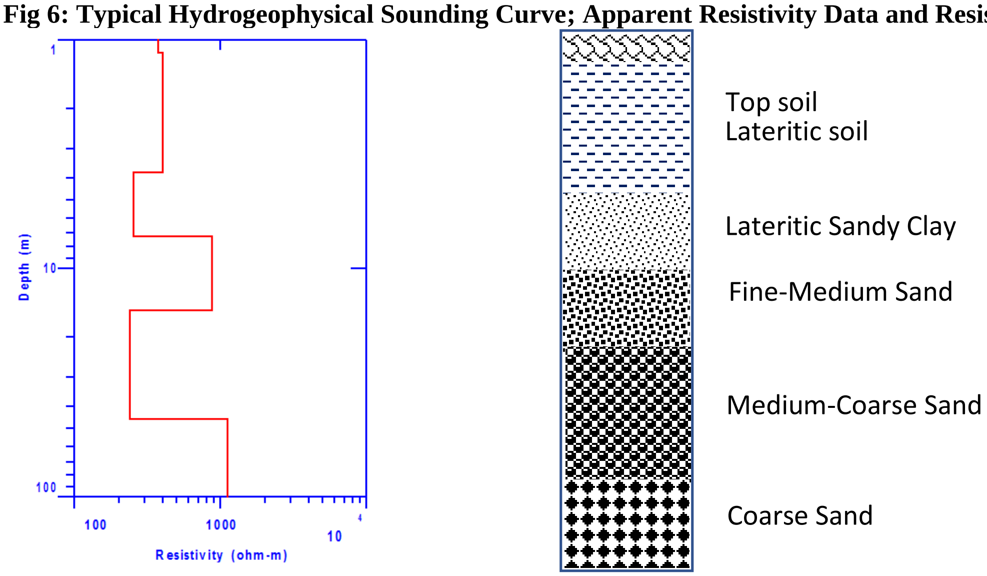

Fig 7: Layered Inversion Model and Lithology for VES 2

Table 3: VES 3 Data and Geoelectric parameters at Sapele with Lat.: 5˚53′50.742″N and Long.: 5˚40′11.232″E.

VES 3 DATA				RESISTIVITY MODEL		
S/N	AB/2(m)	MN/2	Adjected Resistivity (Ωm)	Resistivity (Ωm)	Thickness (m)	Depth (m)
1	1.00	0.2	467.48	51.793	1.7010	1.7010
2	1.47	0.20	608.92	60.624	2.0965	3.7975
3	2.15	0.20	649.01	19.169	3.4594	7.2569
4	3.16	0.20	696.85	826.57	13.171	20.427
5	4.64	1.00	799.00	76.660	15.411	35.838
6	6.81	1.00	850.88	13.227	Undetermi	Undetermined
7	10.00	1.00	1240.78			
8	14.70	2.00	2275.79			
9	21.50	2.00	3179.01			
10	31.60	3.00	101.00			
11	46.40	3.00	127.91			
12	68.10	3.00	142.77			
14	100.00	5.00	134.79			
15	120.00	5.00	123.27			

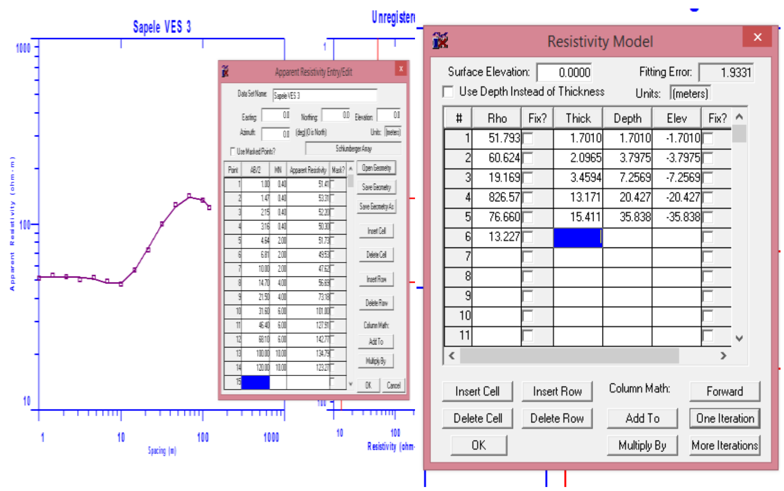

Fig. 8: Typical Hydrogeophysical Sounding Curve; Apparent Resistivity Data and Resistivity Model

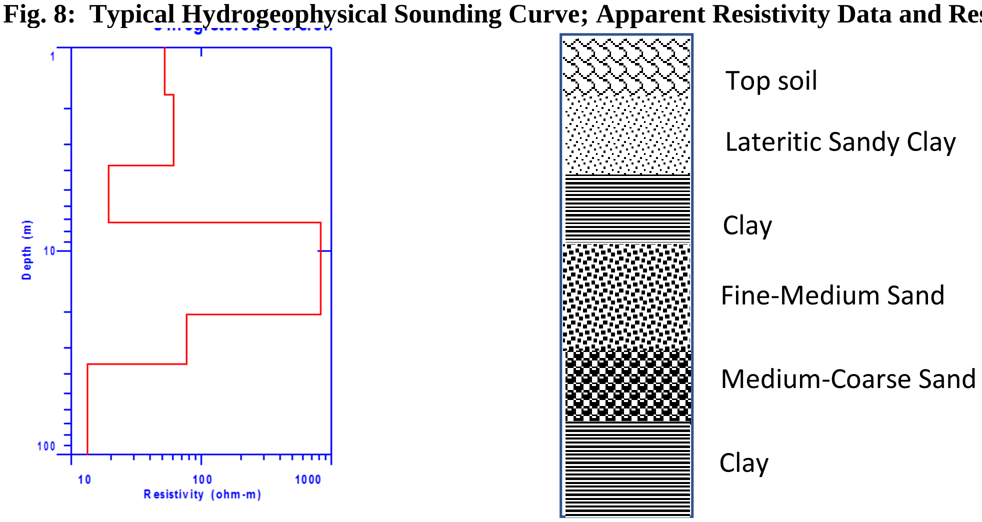

Fig 9: Layered Inversion Model and Lithology for VES 3

Table 4: VES 4 Data and Geoelectric parameters at with Lat.: 5°54′2.334″N and Long.: 5°40′18.162″E.

VES 4 DATA				RESISTIVITY MODEL		
S/N	AB/2(m)	MN/2	Adjected Resistivity (Ωm)	Resistivity (Ωm)	Thickness (m)	Depth (m)
1	1.00	0.20	5.67	74.806	0.39060	0.29611
2	1.47	0.20	43.32	35.065	2.3062	3.0311
3	2.15	0.20	36.00	14.886	5.8961	10.798
4	3.16	0.20	34.21	780.66	21.696	33.900
5	4.64	0.20	30.87	151.68	28.755	50.452
6	6.81	0.20	29.40	82.292	Undetermine	Undetermined
7	10.00	0.20	35.68			
8	14.70	0.5	47.60			
9	21.50	0.5	66.57			
10	31.60	0.5	93.52			
11	46.40	3.00	120.91			
12	68.10	3.00	142.66			
13	100.00	5.00	171.15			
14	120.00	5.00	168.09			

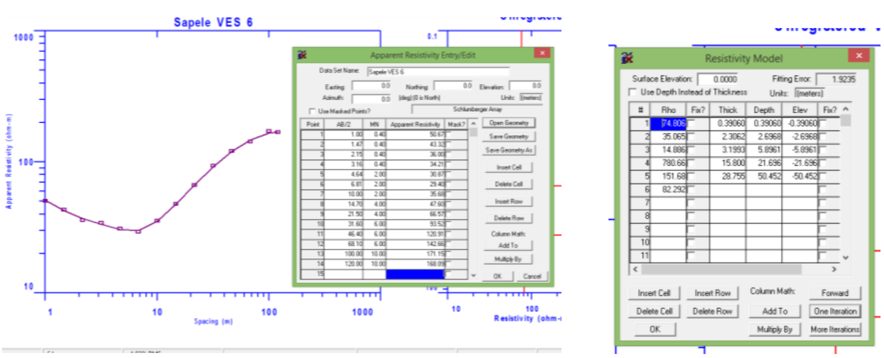

Fig 10: Typical Hydrogeophysical Sounding Curve, Apparent Resistivity Data and Resistivity Model

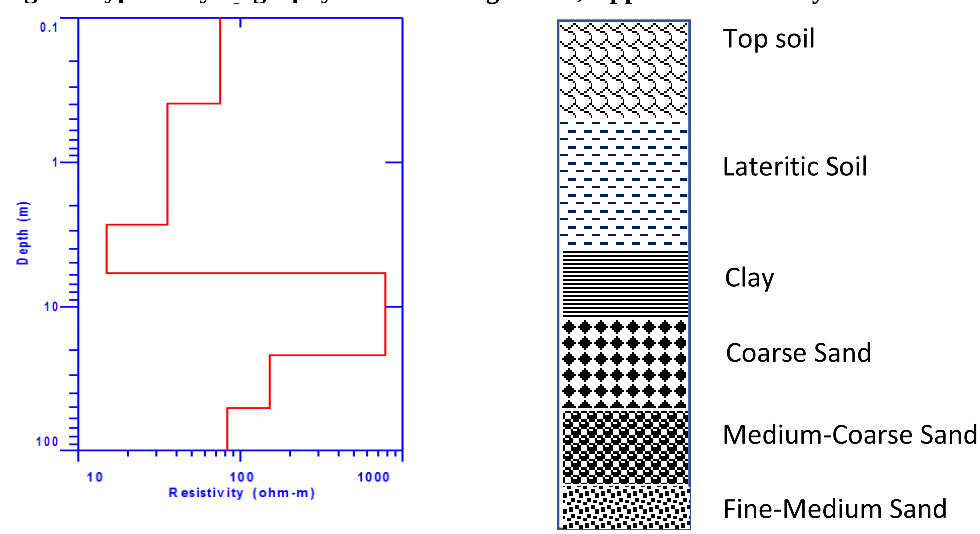

Fig 11: Layered Inversion Model and Lithology for VES 4

Table 5: VES 5 Data and Geoelectric parameters at with Lat.: 5°52′49.626″N and Long.: 5°41′4.254″E.

VES 5 DATA				RESISTIVITY MODEL		
S/N	AB/2(m)	MN/2	Adjected Resistivity (Ωm)	Resistivity (Ωm)	Thickness (m)	Depth (m)
1	1.00	0.20	74.73	51.840	0.9860	1.9860
2	1.50	0.20	75.00	65.314	1.7932	3.7792
3	2.16	0.20	73.52	16.530	3.0430	6.8222
4	3.16	0.20	71.39	961.02	11.845	18.667
5	4.64	1.00	64.86	73.356	13.071	31.738
6	6.81	1.00	53.15	8.9497	Undetermin	Undetermined
7	10.00	2.00	51.31			
8	14.70	2.00	58.76			
9	21.50	2.00	80.20			
10	31.60	3.00	109.77			
11	46.40	3.00	142.62			
12	68.10	5.00	192.68			
13	100.00	5.00	250.96			
14	150.00	5.00	301.11			

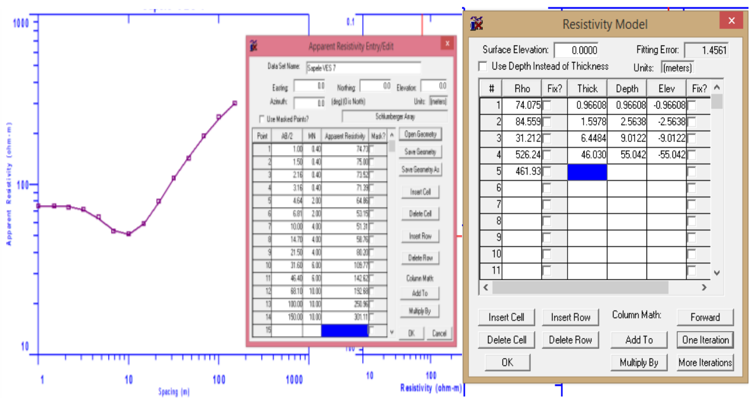

Fig 12: Typical Hydrogeophysical Sounding Curve, Apparent Resistivity Data and Resistivity Model

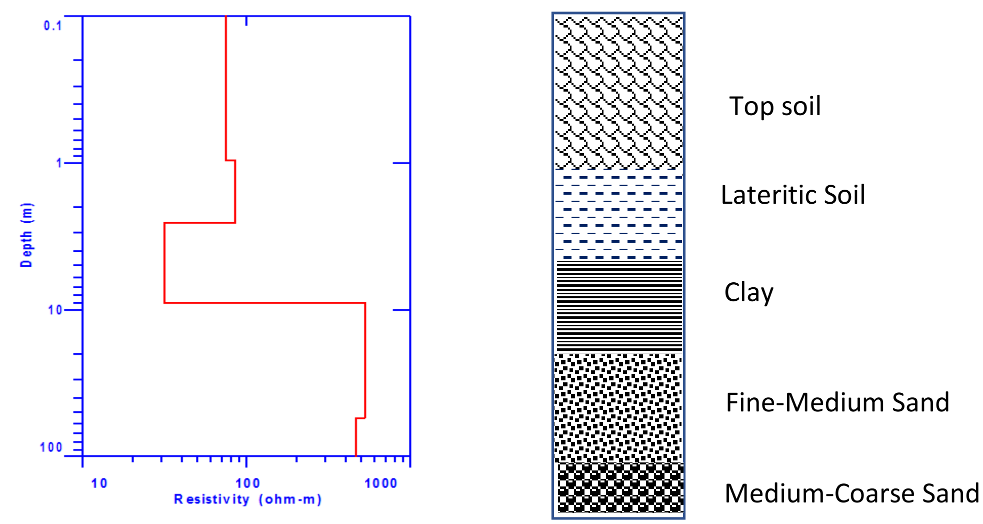

Fig 13: Layered Inversion Model and Lithology for VES 5

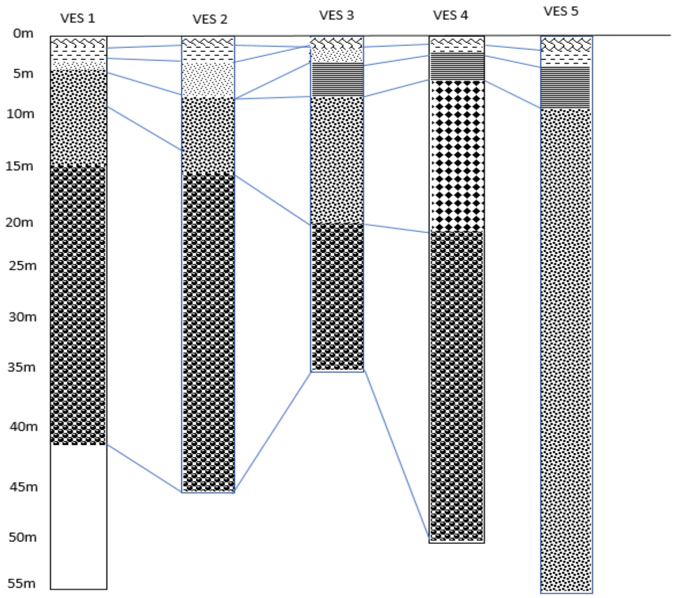

Fig 14: Correlation of the VES 1-5 around the study the area

Interpretation of VES 1-5 cite

The Modelling of VES 1 (Tab 1, Figs 4 and 5) reveals six (6) Geoelectric layers. The Resistivity ranges from 86.60Ωm to 2112.4Ωm, overburden has a thickness ranges from 1.3628m to 1.3891m and depth ranges from 1.3628m to 4.0942m. The VES 1 reveal that the SAND has a thickness ranges from 11.456m to 25.624m and the depth ranges from 15.550m to 41.175m. The Modelling of VES 2 (Tab 2, Figs 6 and 7) reveals six (6) Geoelectric layers. The Resistivity ranges from 252.44Ωm to 1110.1Ωm, overburden has a thickness ranges from 1.1391m to 3.4165m and depth ranges from 1.1391m to 7.2239m. VES 2 reveal that the SAND has a thickness ranges from 7.9718m to 30.316m and the depth ranges from 15.196m to 45.512m. The Modelling of VES 3 (Tab 3, Figs 8 and 9) reveals six (6) Geoelectric layers. The Resistivity ranges from 13.169Ωm to 826.57Ωm, overburden has a thickness ranges from 1.7010m to 3.4594m and depth ranges from 1.7010m to 7.2569m. VES 3 reveal that the SAND has a thickness ranges from 13.171m to 15.411m and the depth ranges from 20.427m to 35.838m. The Modelling of VES 4 (Tab 4, Figs 10 and 11) reveals six (6) Geoelectric layers. The Resistivity ranges from 14.886Ωm to 780.66Ωm, overburden has a thickness ranges from 0.39060m to 3.1993m and depth ranges from 0.39060m to 5.8961m. VES 4 reveal that the SAND has a thickness ranges from 15.800m to 28.755m and the depth ranges from 21.696m to 50.452m. The Modelling of VES 5 (Tab 5, Figs 12 and 13) reveals five (5) Geoelectric layers. The Resistivity ranges from 31.212Ωm to 526.24Ωm, overburden has a thickness ranges from 0.96608m to 6.4484m and depth ranges from 0.96608m to 9.0122m. VES 5 reveal that the SAND has a thickness ranges from 6.4484m to 46.030m and the depth ranges from 9.0122m to 55.042m.

CONCLUSION

The conclusion is summarized in the following tables:

Table 6: Summary of Geoelectric parameter and Lithology for VES 1-5

VES 1				
S/NO	**Specific Layer Resistivity (Ωm)**	**Thickness(m)**	**Depth(m)**	**Inferred Lithology**
1	86.588	1.3628	1.3628	Topsoil
2	29.149	1.3424	2.7052	Lateritic Soil
3	209.41	1.3891	4.0942	Lateritic Sandy Clay
4	602.31	11.456	15.550	Fine-Medium Sand
5	463.62	25.624	41.175	Medium-Coarse Sand
6	2112.4	Undetermined	Undetermined	Coarse Sand

VES 2				
S/NO	**Specific Layer Resistivity (Ωm)**	**Thickness(m)**	**Depth(m)**	**Inferred Lithology**
1	371.17	1.1391	1.1391	Topsoil
2	403.05	2.6683	3.8074	Lateritic soil
3	252.44	3.4165	7.2239	Lateritic Sandy Clay
4	875.36	7.9718	15.196	Fine-Medium Sand
5	237.33	30.316	45.512	Medium-Coarse Sand
6	1110.1	Undetermined	Undetermined	Coarse Sand
VES 3				
S/NO	**Specific Layer Resistivity (Ωm)**	**Thickness(m)**	**Depth(m)**	**Inferred Lithology**
1	51.793	1.7010	1.7010	Topsoil
2	60.624	2.0965	3.7975	Lateritic Sandy Clay
3	19.169	3.4594	7.2569	Clay
4	826.57	13.171	20.427	Medium-Coarse Sand
5	76.660	15.411	35.838	Fine-Medium Sand
6	13.227	Undetermined	Undetermined	Clay
VES 4				
S/NO	**Specific Layer Resistivity (Ωm)**	**Thickness(m)**	**Depth(m)**	**Inferred Lithology**
1	74.806	0.39060	0.39060	Topsoil
2	35.065	2.3062	2.6968	Lateritic Soil
3	14.886	3.1993	5.8961	Clay
4	780.66	15.800	21.696	Fine-Medium Sand
5	151.68	28.755	50.452	Medium-Coarse Sand
6	82.292	Undetermined	Undetermined	Fine-Medium Soil
VES 5				
S/NO	**Specific Layer Resistivity (Ωm)**	**Thickness(m)**	**Depth(m)**	**Inferred Lithology**
1	74.075	0.96608	0.96608	Topsoil
2	84.559	1.5978	2.5638	Lateritic Soil
3	31.212	6.4484	9.0122	Clay
4	526.24	46.030	55.042	Fine-Medium Soil
5	461.93	Undetermined	Undetermined	Medium-Coarse Sand

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