Seismic Refraction and Resistivity Studies of part of Igbogbo Township, South-West Nigeria

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Journal Sci. Res. Dev., 2008 / 2009, Vol. 11, 42 – 61

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ABSTRACT

Seismic refraction shooting and Electrical resistivity depth sounding have been carried out at Igbogbo (Ikorodu area, Southwest Nigeria) to determine the structural setting of the subsurface materials and groundwater potential.

A total of eighteen vertical electrical sounding using the schlumberger array of 500m maximum spread and twenty-seven seismic refraction data using forward and reverse shooting methods of lateral distance 42m along each profile were acquired within the study area.

The results indicate the presence of three seismic refraction layers with the first layer having velocity 150-366m/s and thickness 1.0-3.3m, representing topsoil. The second refraction layer is composed of lateritic clay with thickness 4.5-10.5m and velocity 578-878m/s. The third refraction layer consists of sandy clay with velocity 1000-2500m/s. The delineated refraction layers are characterized by increase in velocity with depth. The geoelectric sounding clearly show that the subsurface layers are characterized by topsoil, laterite, sandy clay, clayey sand, sand and clay with sand acting as aquifer units. The two thick aquifer units mapped are capable of sustainable industrial development in the area.

The seismic refraction shooting was able to delineate three layers because of the energy source used which is consistent with the first three layers in geoelectric sounding. To attain deeper depths of penetration using seismic refraction method, a stronger energy source is recommended.

Keywords: *Resistivity, seismic refraction, aquifer units, groundwater, geoelectric sounding, topsoil*

1.0 INTRODUCTION

Igbogbo is one of the major towns in Ikorodu Local Government Area of Lagos State, Nigeria and is located within latitudes $6^{0}\ 34'$N and $6^{0}35'$N and longitudes $3^{0}34'$E and $3^{0}32.5'$E. The area is accessible from Ikorodu to the north and has easy access to the

Lagoon through its immediate neighbouring towns of Ibese, Ososun and Offin to the west, Ijede to the east and Oreta, Igbopa and Ason to the south (Fig 1a). The area is located within equatorial rain forest belt with a large undeveloped landmass. The recent pronouncement by the Lagos State Government on the construction of the fourth mainland bridge across the lagoon to link Ikorodu to Lagos Island is expected to bring social, economic, industrial and infrastructural development coupled with population expansion to the area will place a greater demand on the land use and groundwater abstraction. As there is no known geological, geophysical and hydrogeological data available for the area, there is need to develop a geophysical and hydrogeological database that will help in site and groundwater development in this area. Hence, the need for this study.

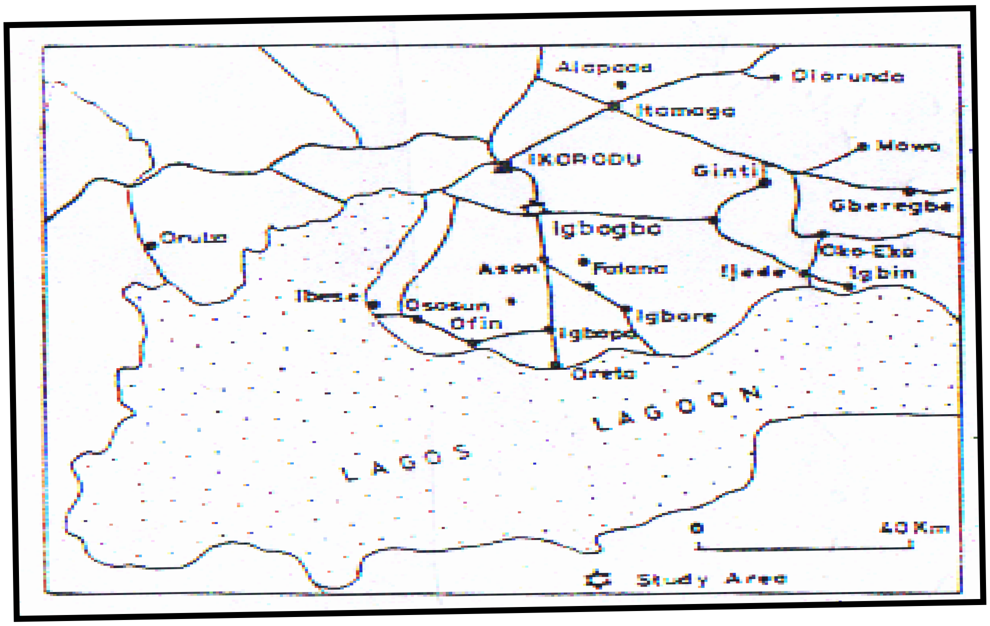


Fig 1a: Map of the study area.

Geophysical methods are often used in site investigation to determine the overburden thickness and map subsurface conditions prior to excavation and construction. Electrical resistivity and seismic exploration methods are the most common techniques for this purpose (Kurthenecker 1934; Drake 1962; Early and Dyer 1964; Burton 1976; Nun 1979; Keary and Brooks 1984; Olorunfemi and Meshida 1987).

Also both seismic refraction method and resistivity depth sounding enjoy a varied reputation with engineers, geologists and geophysicists in foundation and groundwater investigations. Both methods can be used in geotechnics to assess the rock strength, determine rippability and potential fluid content (Ayolabi, 2004).

In this study, both seismic refraction and electrical resistivity methods were carried out with a view to determining the structural setting of the subsurface materials and groundwater potentials.

2.0 MATERIAL AND METHODS

2.1 Climate and Geology of the Study Area

The study area is located in the equatorial rain forest belt of Southwest Nigeria. The area is characterized by a mixture of green plants, shrubs, grasses and trees. The diurnal temperature ranges from 32-36^{0}C during the dry season. The mean annual rainfall is over 1800 mm (Jeje,1983). Peaking twice in the year between March – July and September – October. The bedrock has been intensely weathered to great depths and is highly leached, predominantly clayey in texture and almost uniform throughout their profiles. The soil is very porous, does not shrink or swell and is relatively resistant to erosion (Odemerho and Onokerhoraye, 1994). Geologically, the area is underlain by Post-Cretaceous sediments (Fig1b) of Southwestern Nigeria. The Quarternary geology of the study area composes the Benin formation (Miocene to Recent), Recent littorial alluvium and lagoon/coastal plain sand deposits (Longe et al,. 1987). The alluvium deposits consist mainly of sands, littorial and lagoon sediments formed between two barrier beaches (Adeyemi, 1972) and coastal plain sands.

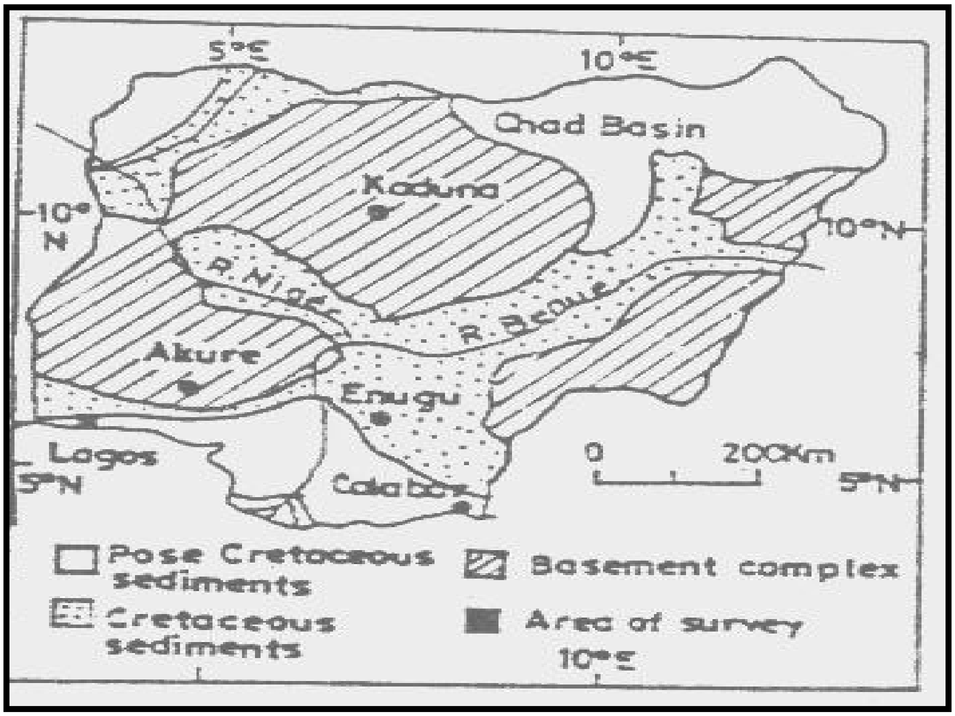


Fig 1b: Generalized Geological Map of Nigeria showing the study area

2.2 Seismic Refraction Method

Seismic refraction method is widely used in site investigation to determine the elastic properties of the subsurface materials. The seismic refraction method can be used to obtain a very clear picture of variations in rock horizons (Stewart *et al*., 1997). The method depends upon Seismic waves travel through different material at different velocities and measuring the time taken for a seismic wave to travel from one point to another, underground layers of hard materials can be located for depths below the surface to be calculated. A total of twenty-seven (27) seismic refraction profiles were run (Fig. 1c) along seven traverses. Both forward and reverse shooting were carried out along each profile over a lateral distance of 42 m. Detail of the refraction shooting procedure has been reported by Ayolabi (2004).

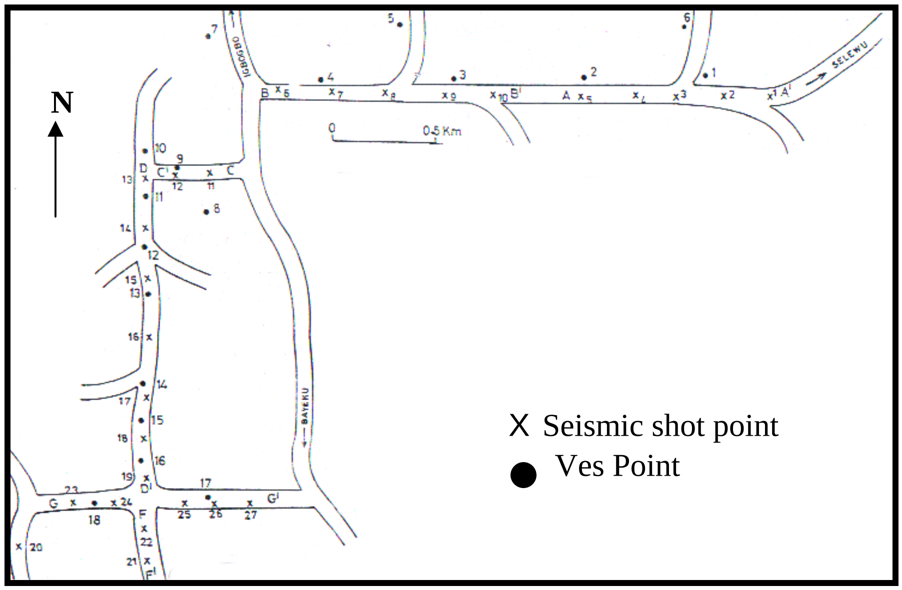


Fig 1c: Data acquisition map

MCSEIS-160 VI.32 12-Channel Model Seismograph with a weight drop mechanism as energy source was used to obtain the seismic refraction data. The geophone layout reflecting geophone spacing is shown in Figure 2. The first arrivals of the seismic wave were recorded from the seismograph.

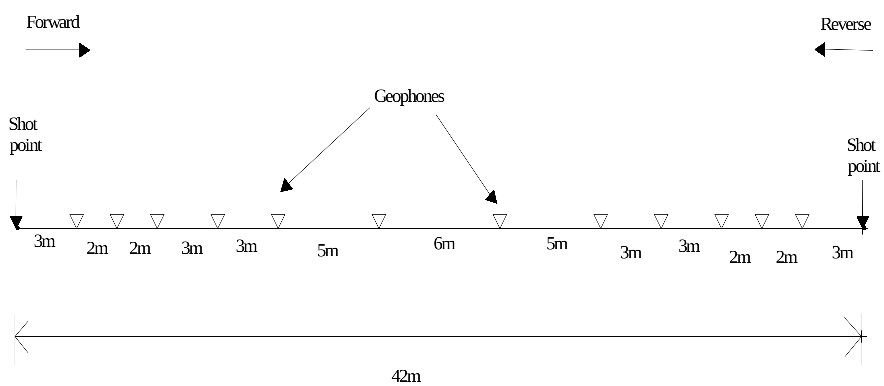


Fig 2: Geophone layout for the seismic refraction data acquisition

2.3 Electrical Resistivity

Electrical depth soundings are effective in horizontally stratified media, since the spatial distribution of the electrical current in the ground and, hence, the depth of investigation depends on the configuration of the array and spacing of the electrodes (McCann *et al.,* 1997). When using
a standard Wenner or Schlumberger array, the depth of investigation increases with the current electrode spacing and this gives rise to an electrical resistivity depth section which can be related to the geological structure beneath the survey line (McCann *et al.,* 1997).
A total of eighteen (18) vertical electrical soundings using the Schlumberger array were carried out at the study site (Fig. 1c). The maximum current electrode separation AB/2 of 500 m was used for VES 1-8 to provide hydrogeological information at depth, while the maximum current electrode separation AB/2 of 240m was used for VES 9-18 to provide near surface information for site development. ABEM SAS 300C Terrameter was used to obtain the ground resistance at each VES point.

3.0 RESULTS

Time-distance (T-X) graph for each profile was plotted using the arrival time, and from the T-X graphs, layer velocities and thicknesses were calculated using the intercept time method. The true velocities of the first and second refraction layers were obtained using arithmetic mean, since the dip is very small (Sharma, 1997), while the harmonic mean of the forward and reversed velocities was used to determine the velocity of the third refraction layer (Table 1). Samples of the time-distance graph (T-X) generally indicated three layer structures except beneath shot points 7, 11, 13, 16 and 20 where two layer structures were obtained (Figures 3a-d). Table 2 gives a summary of electrical depth sounding results.
The interpretation software, WingLink was used for the interpretation of VES data. Thecurves generated from the data indicated four to six geoelectric layers. Samples of the curves are shown in Figure 4. The results are presented as electrical resistivity geoelectric sections and seismic refraction sections (Figs. 5-10).

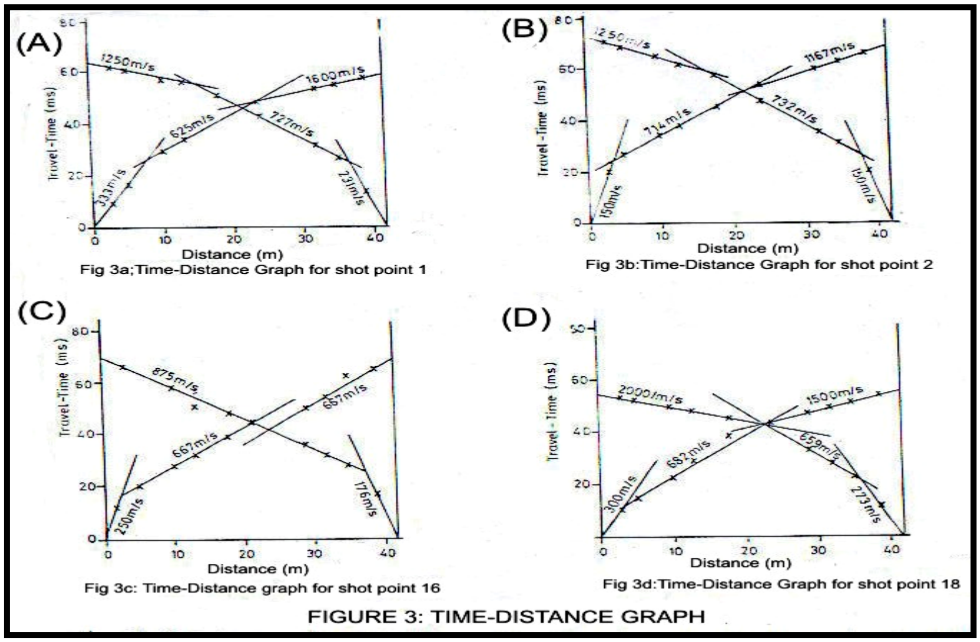
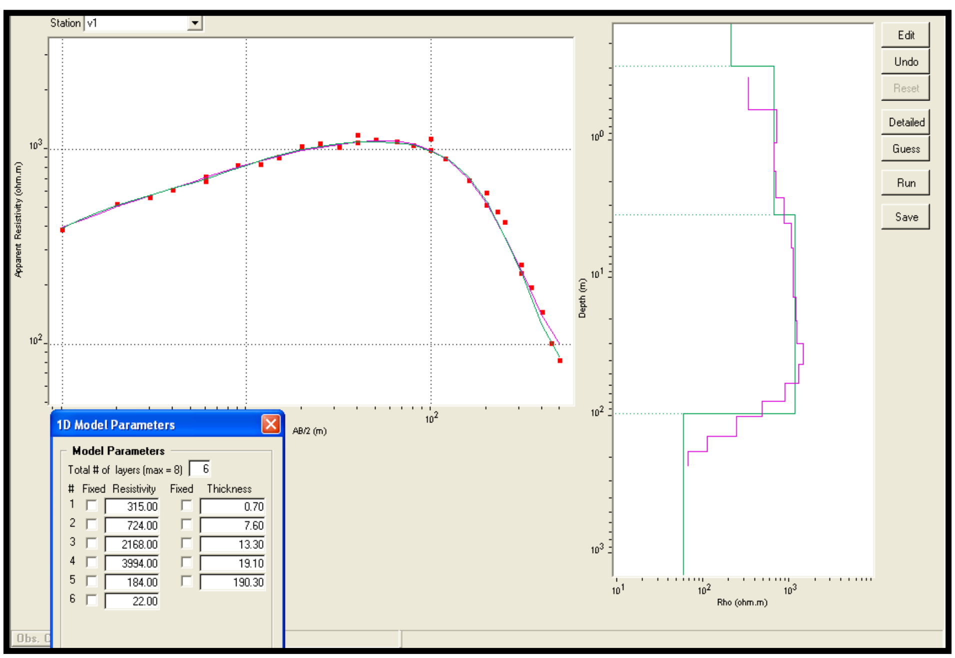
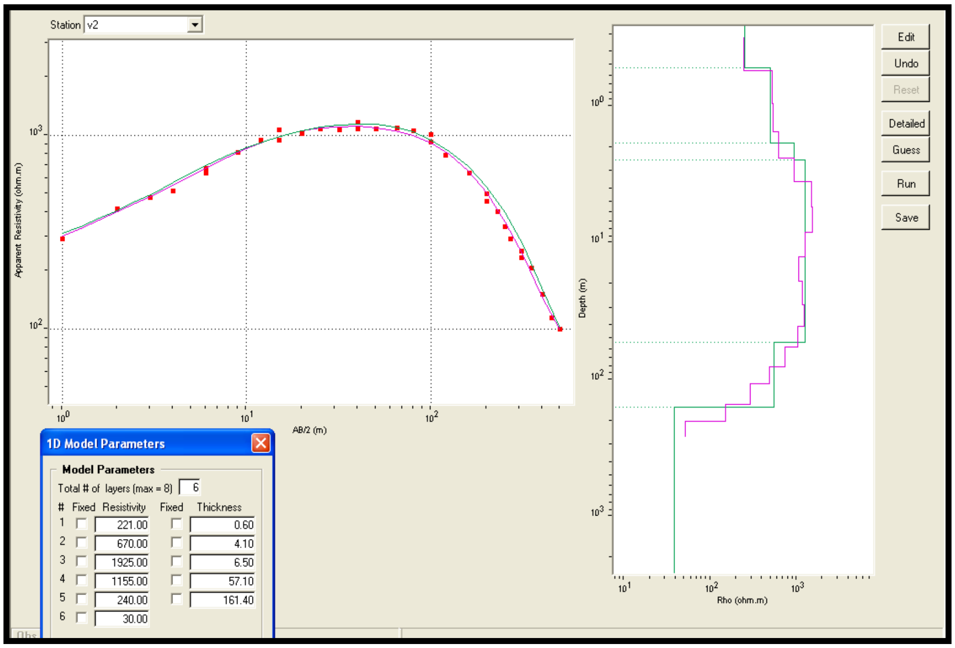


Fig 3a;Time-Distance Graph for shot point 1
Fig 3b:Time-Distance Graph for shot point 2
Fig 3c: Time-Distance graph for shot point 16
Fig 3d:Time-Distance Graph for shot point 18
FIGURE 3: TIME-DISTANCE GRAPH



VES1



VES 2

Figure 4. Samples of VES curve obtained at the study area.

Table1. Summary of Seismic Refraction Results.

	Layer Velocities(m/s)			Layer Thickness (m)	
Shot Point	**V_1**	**V_2**	**V_3**	**Z_1**	**Z_2**
1	282	676	1404	2.4	6.2
2	150	732	1207	1.5	6.8
3	207	709	1945	2.0	7.9
4	167	639	1364	1.7	6.9
5	152	578	1250	1.5	5.5
6	237	690	1714	2.3	8.0
7	173	725	-	1.8	-
8	208	750	1573	2.3	7.0
9	191	635	1867	1.6	8.9
10	238	732	1220	1.4	10.3
11	366	878	-	3.3	-
12	253	766	1000	2.3	5.2
13	241	667	-	2.0	-
14	252	709	2000	2.0	10.3
15	193	643	1976	1.6	8.5
16	213	771	-	1.8	-
17	250	628	1778	1.3	6.6
18	287	659	1714	1.4	6.9
19	201	625	1936	1.4	8.3
20	295	746	-	2.2	-
21	232	620	1600	1.0	6.7
22	219	801	2500	1.5	10.5
23	219	810	1750	1.6	10.4
24	238	644	1465	1.4	7.2
25	223	667	1414	1.2	8.5
26	338	711	1211	2.1	4.5
27	225	629	1275	1.0	9.3

Table2. Summary of Electrical Resistivity Depth Sounding Results

VES No	Layer No	Resistivity (Ohm-m)	Thickness (m)	Depth (m)
1	1	315	0.6	0.0-0.6
	2	724	7.6	0.6-8.2
	3	2168	13.3	8.2-21.5
	4	3994	19.1	21.5-40.6
	5	184	190.3	40.6-230.9
	6	22		
2	1	221	0.6	0.0-0.6
	2	670	4.1	0.6-4.7
	3	1925	6.5	4.7-11.2
	4	1155	57.1	11.2-68.3
	5	240	161.4	68.3-229.7
	6	30		
3	1	188	0.9	0.0-0.9
	2	639	5.1	0.9-6.0
	3	1819	7.7	6.0-13.7
	4	1082	39.3	13.7-53.0
	5	199	284.5	53.0-337.5
	6	26		
4	1	213	0.6	0.0-0.6
	2	503	5.5	0.6-6.1
	3	1387	13.7	6.1-18.8
	4	712	68.5	18.8-87.3
	5	115	282.6	87.3-369.9
	6	23		
5	1	232	0.9	0.0-0.9
	2	853	4.2	0.9-5.1
	3	1602	4.8	5.1-9.9
	4	1218	60.7	9.9-70.6
	5	431	100.9	70.6-171.5
	6	31		
6	1	343	0.8	0.0-0.8
	2	1128	7.1	0.8-7.9
	3	1259	10.8	7.9-18.7
	4	684	66.3	18.7-85.0
	5	268	146.0	85.0-231.0
	6	26		
7	1	185	1.2	0.0-1.2
	2	440	5.8	1.2-7.0
	3	777	28.5	7.0-35.5
	4	447	96.1	35.5-131.6
	5	221	150.4	131.6-282
	6	41		

8	1	116	0.7	0.0-0.7
	2	216	2.9	0.7-3.6
	3	688	18.9	3.6-22.5
	4	663	63.6	22.5-86.1
	5	123	238.2	86.1-324.3
	6	19		
9	1	87	0.7	0.0-0.7
	2	393	2.9	0.7-3.6
	3	781	37.3	3.6-40.9
	4	253		
10	1	146	0.9	0.0-0.9
	2	711	3.8	0.9-4.7
	3	1285	7.5	4.7-12.2
	4	519		
11	1	220	1.0	0.0-1.0
	2	469	3.7	1.0-4.7
	3	820	55.1	4.7-59.8
	4	220		
12	1	94	1.2	0.0-1.2
	2	218	2.8	1.2-4.0
	3	1171	19.2	4.0-23.2
	4	400		
13	1	202	0.9	0.0-0.9
	2	496	2.7	0.9-3.6
	3	964	7.6	3.6-11.2
	4	460	13.3	11.2-24.5
	5	1383		
14	1	93	1.0	0.0-1.0
	2	449	5.0	1.0-6.0
	3	1709	4.3	6.0-10.3
	4	582	65.2	10.3-75.5
	5	235		
15	1	63	0.9	0.0-0.9
	2	91	3.4	0.9-4.3
	3	1491	7.8	4.3-12.1
	4	667	47.0	12.1-59.1
	5	240		
16	1	50	1.0	0.0-1.0
	2	98	2.6	1.0-3.6
	3	1220	8.7	3.6-12.3
	4	389		
17	1	63	1.1	0.0-1.1
	2	282	3.6	1.1-4.7
	3	1098	37.1	4.7-41.8
	4	456		
18	1	88	1.0	0.0-1.0
	2	216	6.2	1.0-7.2
	3	1285	18.7	7.2-25.9
	4	352		

4.0 DISCUSSION

4.1 Geoelectric configuration

From the geoelectric sections (Figs 5-6), there are four to six geoelectric layers. The first geoelectric layer with resistivity 50-343Ωm and thickness 0.6-1.2m form the top soil and consists of decomposed organic materials. The second geoelectric layer is composed of lateritic-clay with thickness 2.7-7.1m and resistivity 216-1128 Ωm. However beneath VES 15 and 16 where a layer thickness of between 2.6 and 3.4m and resistivity 91-98 Ωm consist of clay was delineated. Underlying the laterite overburden is the clayed-sand layer of thickness 4.3-37.1m and resistivity 964-2168 Ωm, and sandy-clay layer of thickness 18.9-55.1m with resistivity 688-820 Ωm. The fourth geoelectric layer consists of sandy clay/clayey-sand layer of resistivity 447-3994 Ωm and thickness 19.1-96.1m, and sand layer of resistivity 220-400 Ωm. The clayey sand and sand layers delineated along this geoelectric section forms the first major aquifer unit in the study area.

The fifth geoelectric layer represents the second and third major aquifer units in the area with resistivity 115-431 Ωm and thickness 100.9-284.5m and consists of sand. The resistivity of the sixth geoelectric layer is between 19 and 41 Ωm and consists of clay. The material types for the first three geoelectric layers were based on examination of samples derived from the hand dug well, that were being drilled at the study area at the time of the survey.

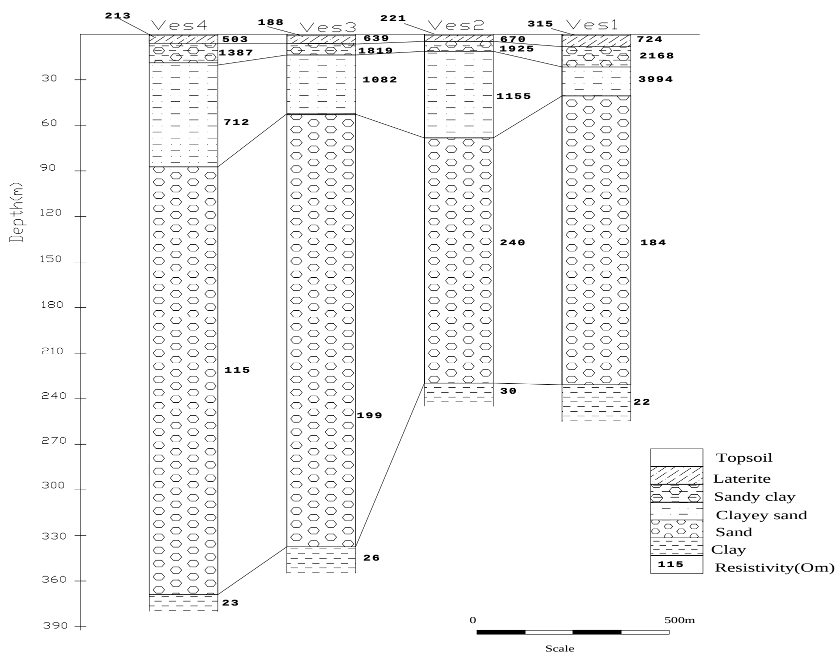


Fig. 5a: Geoelectric section in the W-E direction beneath VES 1-4

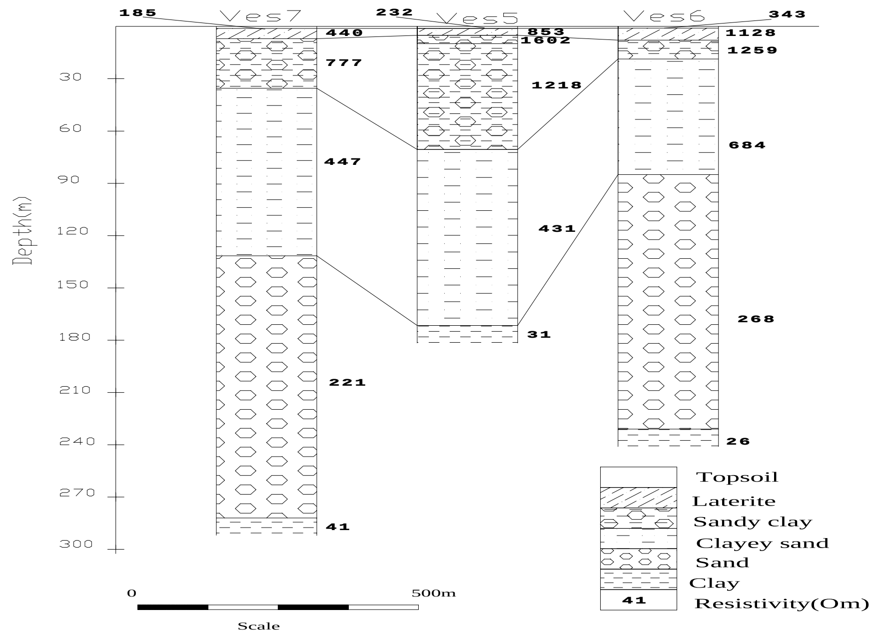


Fig. 5b: Geoelectric section in the W-E direction beneath VES 5-7

Three geoelectric sections were prepared for the study area (Figs 5-6). Figure 6a is the geoelectric section trending West-East direction. It shows the existence of a very thick aquifer unit (161.4-285m) with resistivity 115-240 Ωm and lies within a depth of 40.6-370m beneath the surface. This represents the major freshwater aquifer in the study area. Based on the inference of Zohdy *et al.,* 1993, the aquifer unit along this traverse with resistivity 115-240 Ωm is presumed to contain very good quality freshwater. Figure 5b is the second West-East geoelectric section. It shows the presence of two types of aquifer characterized by clayey-sand with resistivity 431-684 Ωm and thickness of 66.3-100.9m and sand with resistivity 221-268 Ωm and thickness of 146-150.4m. The resistivity range of these aquifer units presumed that they contain very good quality freshwater.

Figure 6 is the South-North representation of the geoelectric section within the study area. This section similarly reveals the presence of two types of aquifer along this traverse characterized by clayey-sand and clean sand. Although the sand aquifer cannot be clearly delineated along this traverse as the electrode current terminated within this layer. However the clayey sand aquifer beneath VES 14 and 15 were clearly delineated with resistivity 582-667 Ωm and thickness 47.0-65.2m. From these three geoelectric sections, one can deduce that the study area has a very high hydrogeologic potential capable of sustainable industrial development as there exists the presence of thick freshwater aquifer units that can easily sustain economic and industrial development that may occur in the study area as a result of the construction of the fourth mainland bridge.

4.2 Seismic sections

Four seismic sections were prepared (Figures 7a-10a). The velocity of first layer ranges from 150-366 ms^{-1} with a refractor thickness of 1.0-3.3 m, indicative of topsoil. The second refractor layer denotes laterite. Its velocity varies from 578 ms^{-1} to 878 ms^{-1} with layer thickness between 4.5 m and 10.5 m except beneath shot points 7, 11, 13, 16 and 20 because the impact of energy source terminated within this zone. The third refractor layer is symptomatic of sandy clay having velocity variation 1000-2500 ms^{-1}. Its layer thickness could not be ascertained due to the weak energy source used.

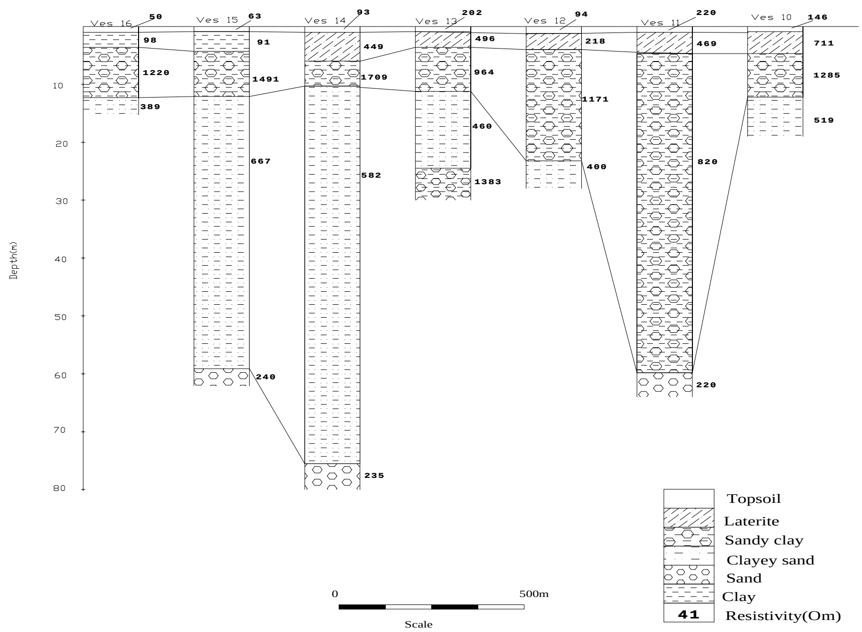


Fig. 6: Geoelectric section in S-N direction beneath VES 10-16

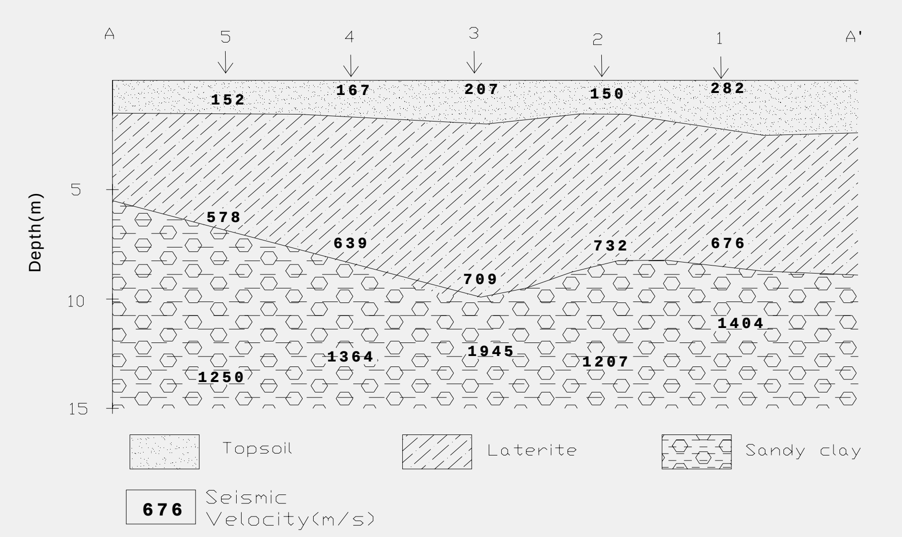


Fig7a:Seismic Section for A-A'

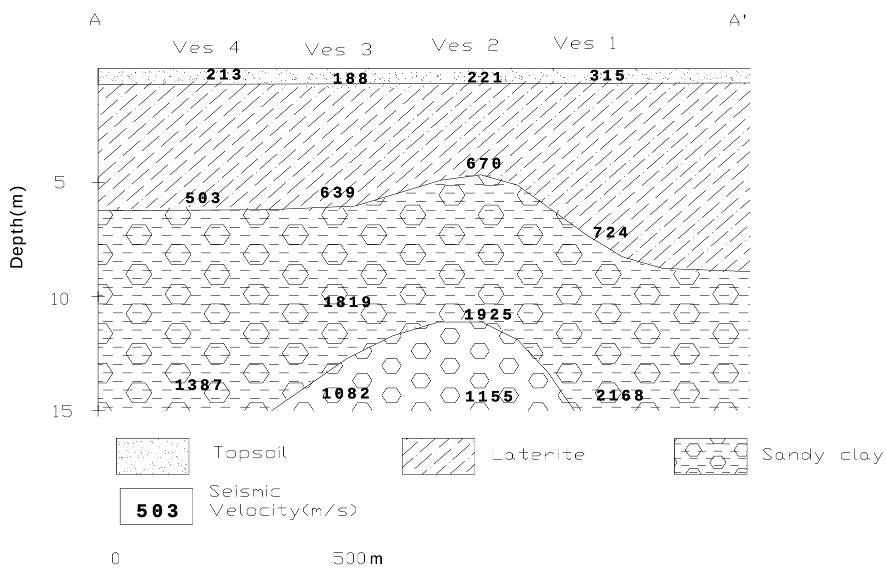


Fig 7b:Resistivity Geoelectric Section for A-A'

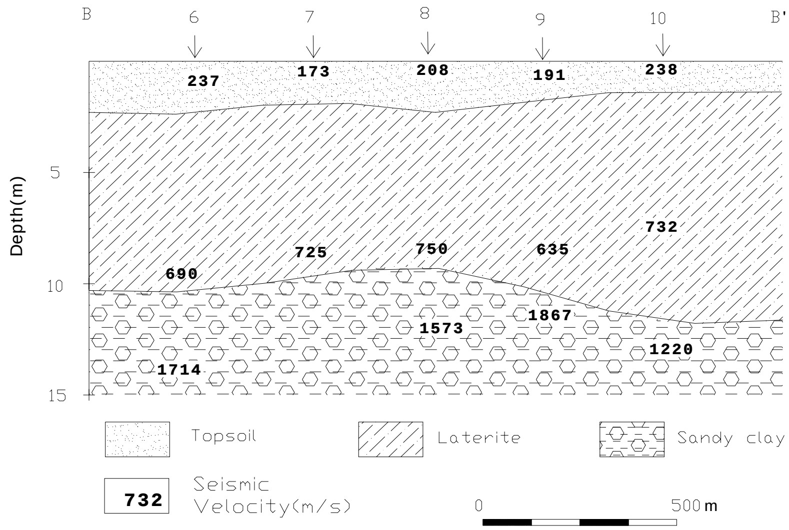


Fig8a:Seismic Section for B-B'

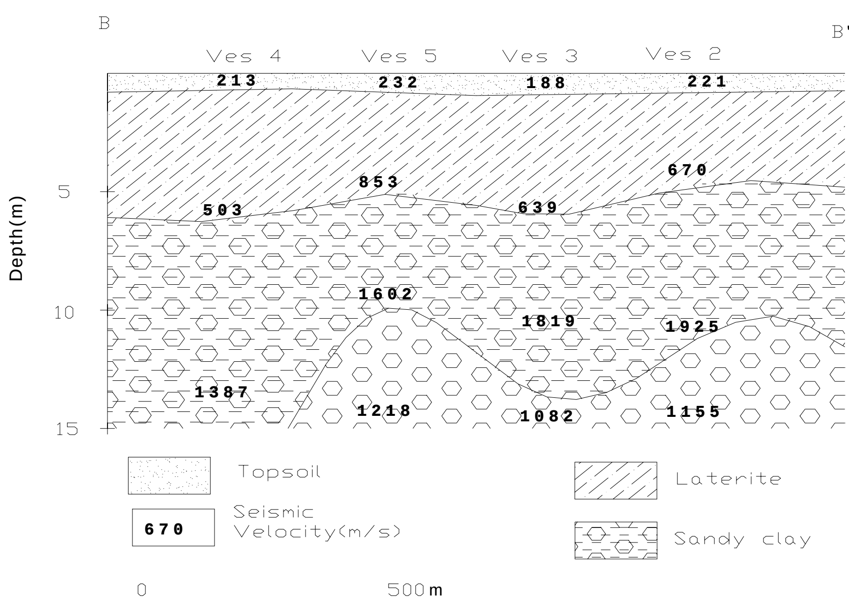


Fig 8b:Resistivity Geoelectric Section for B-B'

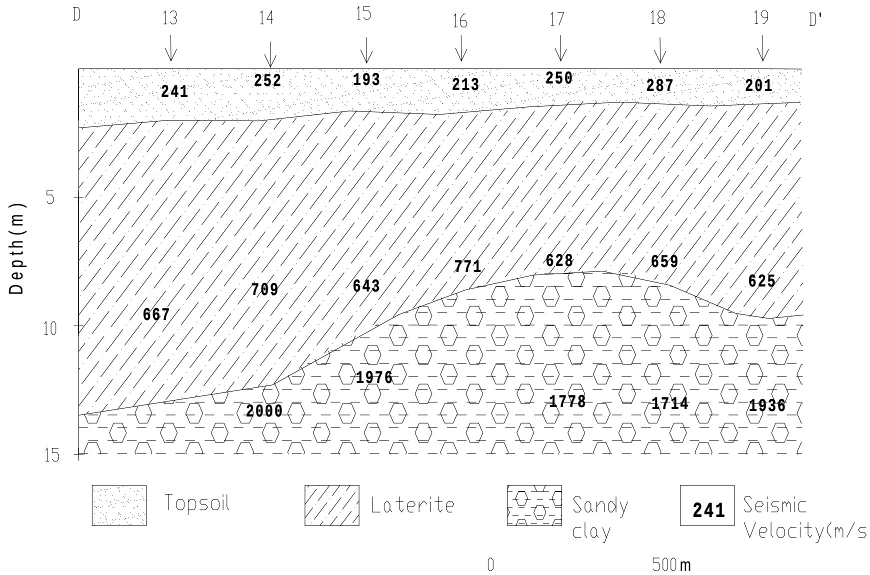


Fig 9a:Seismic Section for D-D'

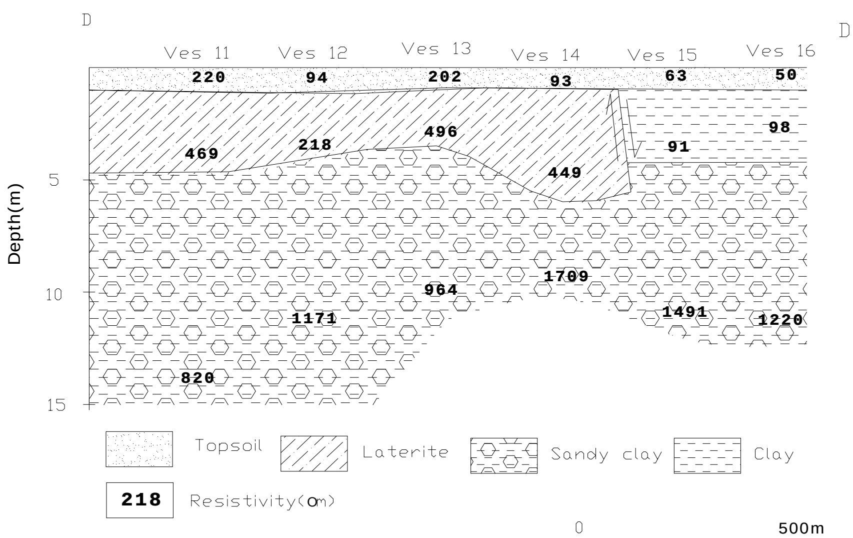
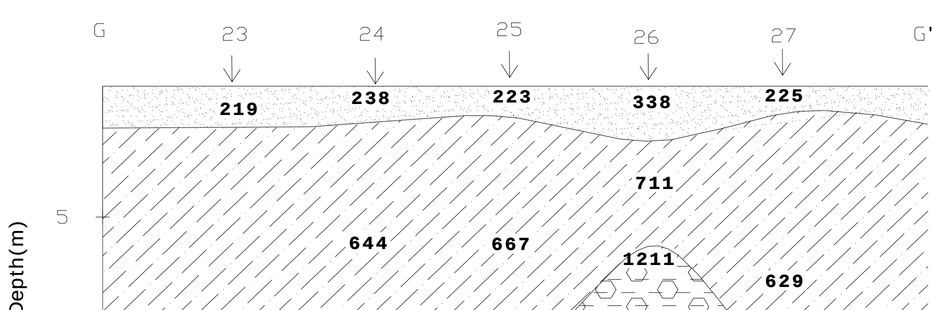


Fig 9b:Resistivity Geoelectric Section for D-D'



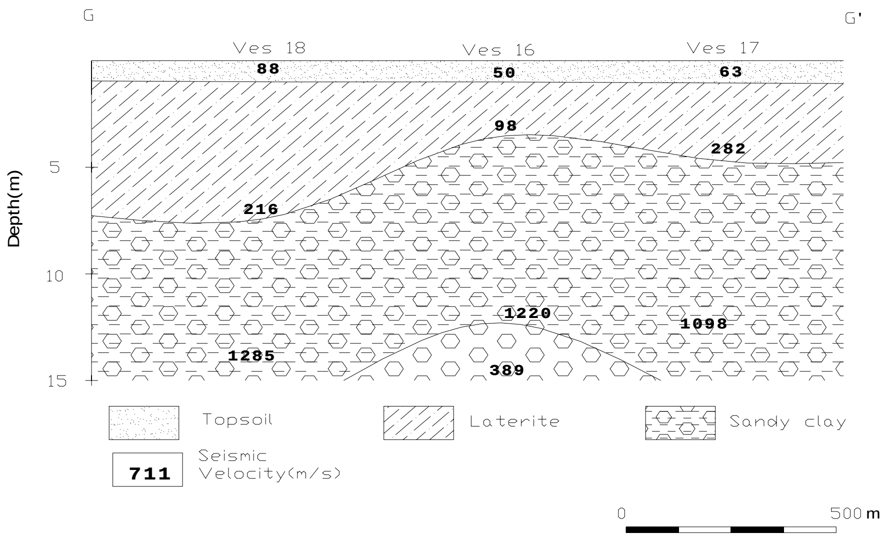


Fig 10b:Resistivity Geoelectric Section for G-G'

4.3 Correlation of seismic refraction section and electrical resistivity Geoelectric section

Seismic refraction sections and electrical resistivity geoelectric sections (Figs. 7-10) were prepared for the top 15m along traverses AA', BB', DD', and GG'. Comparison of the Figures shows that even though the geoelectric cross-sections look alike, a depth variation of 2-4 m exists between the electrical and seismic refraction results. This may be due to the fact that the two methods respond to different properties of the earth. The figures show that the thickness of the overburden material varies from 3.6 to 12.0 m and consists of loose materials. The appearance of a fault-like structure in Figure 3c seems to be a lithological contact when comparing Figures 10a and 10b. Foundation of engineering structures of importance in this area should take into consideration the existence of near surface clay layer in some isolated area as revealed in Figure 10b. However, the general trend is that of increase in velocity with depth.

5.0 CONCLUSION

The results of the seismic refraction survey and electrical resistivity sounding carried out at Igbogbo, Ikorodu area of Lagos, Southwest Nigeria have been reported. Two aquifer units of good quality freshwater capable of sustainable economic and industrial development envisaged to take place in the area in the advent of the construction of the fourth mainland bridge were delineated The sand thickness 161.4 – 285m for the first aquifer unit while the thickness for the second aquifer varies between 146m and 150m. The velocity of the subsurface layer increases with depth

with favourable disposition to engineering structures except in some isolated cases where near surface clay layer has been identified. The correlation between Seismic refraction and electrical resistivity geoelectric sections shows the first three layers of both are the same but other substratum layers could not be delineated by the seismic refraction method due to energy source used. Thus, to get to deeper depths of penetration as electrical resistivity sounding,
a stronger energy source must be used.

ACKNOWLEDGEMENT
The authors are grateful to the management of IDSL Benin City, Nigeria, for granting the use of seismic refraction equipment and the Department of Physical Sciences, University of Agriculture, Abeokuta for allowing the use of their Terrameter.

REFERENCES

Adeyemi, P.A. (1972). Sedimentology of Lagos Lagoon. Unpublished special B.Sc thesis, Obafemi Awolowo University, Ile-Ife, Osun State, Nigeria.

Ayolabi, E.A. (2004). Seismic refraction survey of University of Lagos, Nigeria and its.implication. Journal of Applied Sciences. Vol.7 No.3, pp4319-4327

Burton, A.N. (1976). The use of geophysical methods in engineering geology, Part 1: Seismic techniques. Ground Engineering.

Drake, C.L. (1962). Geophysics and engineering. Geophysics 27: 193-197

Early, K.R. and Dyer, K.R. (1964). The use of resistivity survey in foundation site underlain by Karst dolomite. Geotechnique 14: 341-348.

Jeje, L.K. (1983). Aspect of Geomorphology in Nigeria. In a Geography of Nigeria. Ed. Oguntoyinbo, J.S., Areola, O.O., and Filani, M. Heinemann Educational Books (Nig.) pp 17-44.

Keary, P. and Brooks, M. (1984). An introduction to geophysical exploration. Blackwell Scientific Publication, Oxford, pp 198-217.

Kurtenacker, K.S. (1934). Some practical application of resistivity measurements to highway problem. Transaction of American Institute of Mining and Metallurgical Engineers 110: 193-205.

Longe, E.O., Malomo, S. and Olorunniwo, M.A. (1983). Hydrogeology of Lagos. Metropolis. Journal of African Earth sciences 6:163-174

McCann, D.M., Culshaww, M.G. and Fenning, P.J. (1997). Setting the standard for Geophysical Surveys in Site Investigation. In: McCann, D.M., Eddleston, M., Fenning, P.J. and Reeves, G.M. (Eds). Modern Geophysics in Engineering Geology. Geological Society Engineering Geology Special Publication No. 12, 3-34.

Nunn, K.R. (1979). Geophysical surveys at two landfill sites in the West Midlands. Symposium on the engineering behaviour of industrial and urban fill.

Odemerho, F.O. and Onokerhoraye, A.G. (1994). Physical Geography- Handbook forthe Tropics: The Benin Social Sciences Series for Africa, University of Benin, Benin City, Nigeria, 16-25

Olorunfemi, M.O. and Meshida, E.A. (1987). Engineering geophysics and its application in engineering site investigations (Case study from Ile-Ife area). The Nigerian Engineer 22: 57-66

Sharma, P.V. (1997). Environmental and En.gineering Geophysics. Cambridge. University Press, UK, pp.475

Stewart, E.E., Williams, J.R. and Walker, C.S. (1997). Seismic Refraction in.relation to Geotechnical information for (road) construction contracts in: McCann, D.M., Eddleson, M., Fenning, P.J. and Reeves, G.M. (eds). Modern Geophysics in Engineering Geology. Geological Society Engineering Geology Special Publication No.12, 383-390

Zohdy, A.A., Martin, P. and Bisdorf, R.J. (1993). A study of seawater Intrusion using direct current soundings in the Southwestern part of Oxnard plain, California. Open file report. 93-524. U.S. geological survey. pp139.