Groundwater Exploration in Ikorodu, Lagos-Nigeria: A Surface Geophysical Survey Contribution

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ABSTRACT

Surface geophysical surveys, as a veritable tool in groundwater exploration, have the basic advantage of saving cost in borehole construction by locating target aquifers before drilling is embarked upon. This may be achieved with precision, when the results are interpreted with adequate knowledge of the geology of an area. This system is applied in the study outlined in this paper.

Ikorodu, Lagos-Nigeria, is underlain by multi-aquiferous formations that span from the Cretaceous to Quaternary in age. Some of the aquifers are tiny and others may be too deep for groundwater exploitation. A vertical electrical sounding (VES) exercise carried out at Selewu-Ikorodu shows that the best aquifers for the construction of shallow boreholes are in the Quaternary Benin Formation. However, the groundwater quality may be poor, as this shallow aquifer may be susceptible to contamination because of the arenaceous nature of its materials.

On the other hand, deep boreholes can be drilled into the deeper Tertiary sands of the Akinbo and Oshosun Formations. Evidence from a borehole has been merged with results from the VES exercise and used in delineating the formations underlying Ikorodu, for profitable exploitation of the groundwater.

(Key words: vertical electrical sounding, VES, aquiferous formations, boreholes, groundwater).

INTRODUCTION

Lagos is a coastal city in the western part of Nigeria. The abundant surface water resources include creeks, lagoons, and the Atlantic Ocean. During the rains and at some unprotected times, parts of the city become flooded as a result of heavy rainfall, low relief, high tides, and poor structural planning of buildings and drainage facilities.

Lagos is highly industrialized and the discharge of industrial effluents into surface water bodies makes the water a lot more saline, and so, more costly to treat for public supplies. The Lagos State Water Corporation therefore embarks on the use of groundwater to augment supplies from surface water.

Groundwater is often considered pure and therefore can be served with little or no treatment. This may be true for deep boreholes. The problem of saline water intrusion and aquifer contamination through anthropogenic activities such as the disposal of domestic wastes may, however, endanger the use of shallow groundwater in Lagos.

Generally in Nigeria, shallow groundwater is synonymous with shallow dug-wells and boreholes while deep groundwater is associated with deep boreholes. "The definition of [a] 'shallow' or 'deep' water well will vary with the hydrogeological conditions considered to be standard within an area" (Clark 1996). For this study, shallow wells/boreholes will refer to water wells not more than 70m deep, while deep boreholes will refer to those deeper than 70m, which must be completed with steel casings and screens.

Private individuals and households own most shallow water wells in Lagos. The cost of construction of the boreholes is cheap, in terms of both labour and material. The drilling can be carried out manually by as few as three drilling personnel; and the well can be completed with PVC screen and casing pipes. On the other hand, mostly corporate companies and the government own deeper boreholes, because of the high cost of constructing such water wells. The basic problem with the construction of deep boreholes in Ikorodu is the location of the aquifer to supply and sustain the need for which such boreholes are intended.

GEOLOGY / HYDROGEOLOGY

The geologic succession in Lagos spans through the Cretaceous Abeokuta Formation, which unconformably overlies the rocks of the Basement Complex, to the Quaternary Deltaic Plain Sands (Table 1). Ikorodu is directly underlain by the Benin Formation (Figure 1). The Benin Formation consists largely of sands/ sandstones with lenses of shales and clays. The formation is thin in Ikorodu and this, therefore, does not favor it as an important aquifer. Elsewhere in Lagos, it "provides a ready answer to the groundwater problems"; and where pebbly beds occur, they give "rise to high yielding boreholes" (Offodile 2002). In addition to the thinness of the aquifer in Ikorodu, the arenaceous nature of the Benin formation makes it susceptible to contamination from anthropogenic sources.

Table 1: Formational Succession in the Lagos Area.

Quaternary	Deltaic Plains Benin formation
Tertiary	Ilaro Formation Oshosun Formation Ewekoro Formation
Cretaceous	Abeokuta Formation Basement

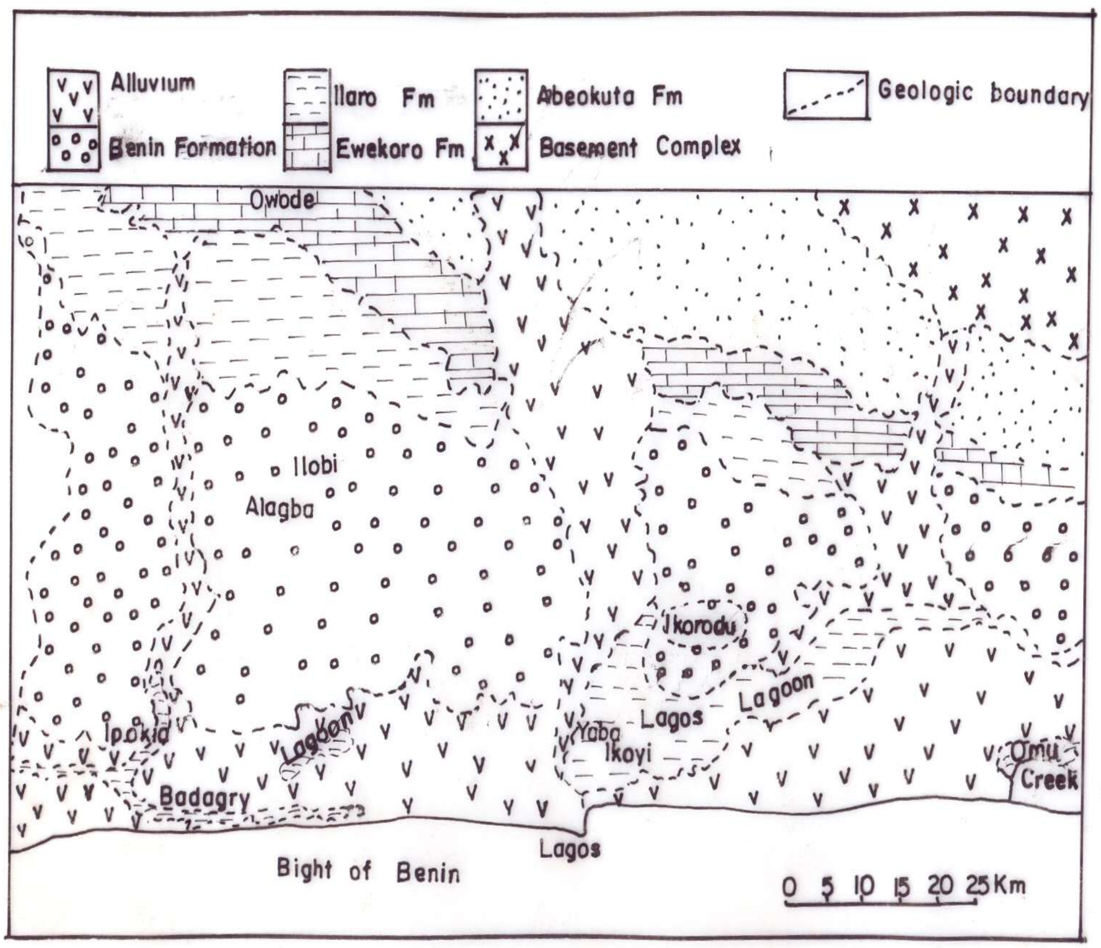


Fig. I: Geologic map of Lagos area (Modified from Offodile, 2002)

The Ilaro Formation consists of fine to coarse sands alternating with shales and clays. The formation can only sustain very poor boreholes. The Ewekoro/Akinbo/Oshosun Formations, as discussed by Adegoke (1980), consist of a sequence of sandstones, shales, limestones and clays (Offodile 2002).

The Ewekoro Formation has poor groundwater potential because of the argillaceous nature of the rock. The Abeokuta Formation consists of arkosic sandstones and grits, tending to be carbonaceous towards the base. The formation has good potential for ground water except that the bituminous materials associated with the sands could affect the quality of the water (Offidile 2002).

All of the formations are multi-aquiferous, but the relatively high depths of the aquiferous zones of both the Ewekoro and Abeokuta Formations at Ikorodu make them economically unattractive for water prospecting through boreholes. Most of the boreholes in the area tap water from the Akinbo Formation (Hydro 1993). To locate these multi-aquifers, however, is not a very easy task; but it must be done in order to make borehole construction in Ikorodu economically less distressful.

GEOPHYSICAL SURVEY

Multi-aquifers are mostly confined by layers of clays and shales. This makes drilling into such aquifers difficult. In addition, they may be very thin beds, making it difficult to locate them. It is therefore pertinent to carry out a surface geophysical survey before embarking on a deep-drilling venture in Ikorodu. Such a survey will help eliminate wastages of human and financial resources that usually arise from "blind" drilling.

In this study, surface geophysical investigations carried out at the Igbogbo area, Ikorodu–Lagos are compared with an earlier drilling work by Hydro Construction and Engineering Company, Ltd. at the Lagos Road Waterworks, Ikorodu, for the Lagos State Water Corporation, 1993.

The delineation of five geoelectric sections in the area would be a useful tool in advising borehole makers on the most viable depth to drill, depending on the intended use of the borehole.

Four sites were sounded for this study. The investigation was carried out with ABEM

Terrameter, SAS300C, employing the vertical electrical sounding (VES) technique of the Schlumberger configuration. The choice of the shot spots (VES points) was restricted by available space, and the maximum current electrode half spread (AB/2) in each case was 500m.

Measured field resistance values ® (ohm, Ω) have been converted to apparent resistivity values (ρa) (ohm metre**,** Ωm) (Table 2), using the following formula (Telford et al, 1984):

$$\rho_a = \frac{\pi L^2}{2l}\left(\frac{\Delta V}{I}\right)$$

Where L = AB/2 and l =MN/2. AB is the current electrodes space, in meters (m) and MN is the potential electrodes space, in meters (m).

$\frac{\Delta V}{I}$ is the resistance, in ohms (Ω).

This is the direct instrument reading for any spread of AB and MN.

The term $\frac{\pi L^2}{2l}$ is called the geometric factor (K).

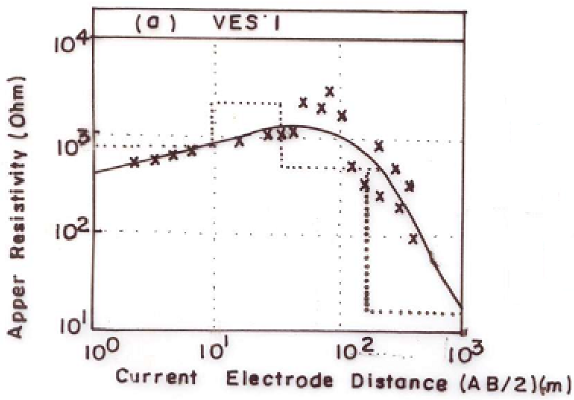
The apparent resistively values (ρ_a) were plotted against the current electrodes separation (AB/2) on log-log graph papers, in order to generate initial values to use for the computation of analysis and interpretation with a computer iterated software known as RESIST.

The curves generated by the RESIST are shown in Figure 2 (a-d), and their interpretations in Table 3. All the curves trend alike.

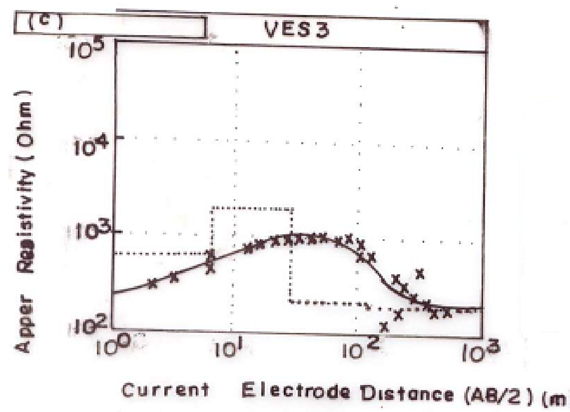
Their interpretation shows each to represent a 5-layer geoelectric section (Table 3), with the first layer, the topsoil having an average thickness of 1.0m. This is part of the sandy clay layer. The last layer is a clay base. Sandwiched between these layers are layers of sands and sand–clays admix.

Table 2: VES Field Data.

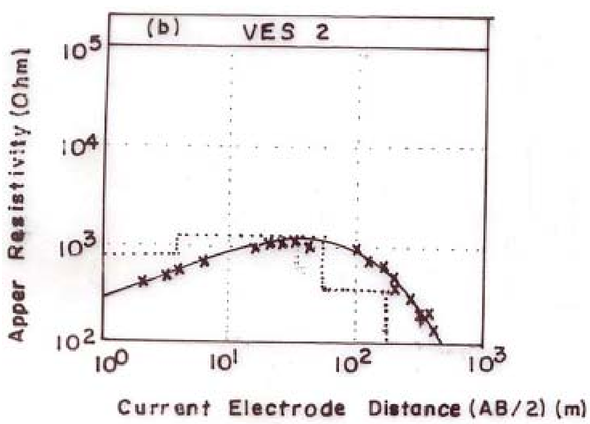
Current Electrode separation AB/2 (m)	Potential Electrode separation AB/2 (m)	Geometric factor K $= \frac{\pi L^2}{2l}$	R1(Ω)	Pa1(Ω m)	R2(Ω)	Pa2(Ωm)	R3(Ω)	Pa3(Ωm)	Pa(Ω)	Pa4(Ωm)
1	0.25	6.28	61.3	385	47	295	37.4	235	40	251
2	,,	25.12	20.8	522	16.8	422	11.86	298	14.09	354
3	,,	56.54	9.94	562	8.35	482	6.21	351	6.91	391
4	,,	100.54	6.11	614	5.15	518	4.16	418	4.38	440
6	,,	226.2	3.19	722	3.03	681	2.63	595	2.33	527
6	0.5	113.1	6.05	684	5.68	642	3.91	442	4.02	455
9	,,	254.47	3.25	827	3.23	822	2.44	621	1.972	502
12	,,	452.4	1.852	838	2.1	950	1.653	748	1.302	508
15	,,	706.86	1.287	910	1.512	1069	1.194	844	0.979	692
15	1.0	353.45	2.56	905	2.7	954	2.24	792	2.09	739
20	,,	628.32	1.634	1027	1.634	1027	1.415	889	1.354	851
25	,,	681.78	1.082	1062	1.113	1093	0.948	931	0.913	896
32	,,	1908.5	0.635	1021	0.669	1076	0.587	944	0.558	988
40	,,	2513.28	0.43	1081	0.398	1000	0.385	968	0.344	865
40	2.5	1005.31	1.176	1182	1.167	1173	1.000	1005	0.89	895
50	,,	1570.8	1.408	2213	0.693	1089	0.618	971	0.495	778
65	,,	2654.65	0.76	2017	0.416	1104	0.347	921	0.308	818
80	,,	4021.24	0.743	2988	0.264	1062	0.253	1017	0.204	820
100	,,	5283.2	0.253	1590	0.143	898	0.138	867	0.117	735
100	5.0	3141.6	0.5	1571	0.323	1015	0.234	735	0.242	760
120	,,	4523.89	0.11	498	0.155	701	0.143	647	0.129	584
160	,,	8042.42	0.04	322	0.08	543	0.015	121	0.054	434
200	,,	12556.38	0.02	251	0.04	503	0.013	163	0.034	427
200	7.0	8975.98	0.08	781	0.042	377	0.042	377	0.045	404
230	,,	11870.73	0.04	457	0.038	451	0.025	297	0.032	380
250	,,	14024.97	0.03	421	0.022	309	0.019	266	0.021	295
270	,,	17358.72	0.03	491	0.018	294	0.014	229	0.001	16
310	,,	21564.79	0.009	194	0.011	237	0.01	216	0.01	216
310	10	15095.35	0.79	1193	0.0137	207	0.029	438	0.0108	163
350	,,	19242.23	0.017	327	0.0108	208	0.011	212	0.0082	158
400	,,	25132.74	0.004	101	0.006	151	0.007	176	0.0053	133
450	,,	31808.63	0.0029	92	0.0036	115	0.005	172	0.0038	121
500	,,	39269.91	0.0021	82	0.0028	110	0.0045	177	0.0025	98



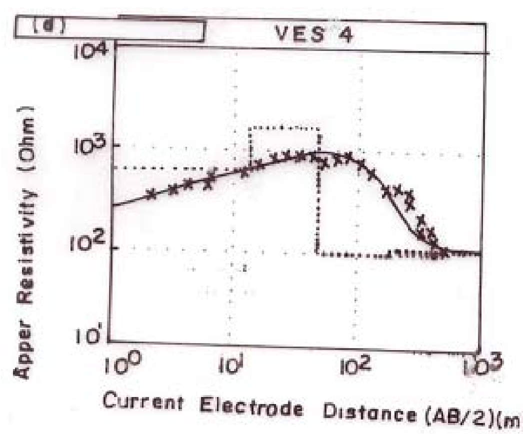
No.	Res	Thickness
1	367.7	0.9
2	799.1	8.4
3	2211.3	24.5
4	478.2	134.7
5	17.5	----



No.	Res	Thickness
1	217.2	1.1
2	629.7	5.4
3	1959.7	21.7
4	206.2	87.5
5	192.4	----



No.	Res	Thickness
1	267.3	0.9
2	801.7	2.9
3	1278.5	50.6
4	371.1	119.4
5	46.4	----



No.	Res	Thickness
1	231.3	0.9
2	632.3	12.1
3	1628.1	34.2
4	97.0	129.5x
5	105.3	----

Figure 2 a – d: Electrical Resistivity Curve and Interpretation for the Ikorodu Area.

Table 3: The VES Results/Interpretations.

VES pt	h_1(m)	ρ_1(Ω m)	h_2(m)	ρ_2 (Ωm)	h_3(m)	ρ_3 (Ωm)	h_4(m)	$\rho4$(Ωm)	h_5(m)	ρ_5 (Ωm)
1	1.0	380	10.36	887	63.64	1797	190.92	156	∞	46
2	1.0	295	3.40	688	42.50	2080	162.92	340	∞	47
3	1.0	230	5.67	537	36.50	2025	105.00	549	∞	130
4.	1.0	260	4.80	607	39.00	1515	129.94	471	∞	64
Ah	1.0		6.06		45.41		147.2		∞	
Lh	Topsoil (sandy clay)		Sandy clay/ hard clay		Sharp sand /sand stone		Sand admix		Clay/ limestone	

h = thickness of layer ; ρ = resistivity of layer, Ah=average thickness of layer, Lh =lithologic interpretation

THE BOREHOLE REPORT

Hydro (1993) had successfully drilled and completed a borehole for the Lagos State Water Corporation at the Lagos Road Waterworks, Ikorodu. A summary of the lithologic log is given in Table 4. A comparison of Table 4 with Table 3 highlights some problems associated with the acquisition and interpretation of the electric resistivity data. The problems include the following:

First, near-surface resistivity variations, or the intermittent occurrences of thin and thick beds can mask lithologic differences, and so make it difficult to pick the resistivity of especially thin beds. As a result, there may be "lumping" of values for thin-thick bed interfaces. This problem may be overcome if there are prominent differences in the concentrations of ionic species in the interstitial fluids. Fluids with higher ionic concentrations will influence lower resistivity values in rocks more so than will fluids with lower ionic concentrations.

Second, both manual and computer interpretations of resistivity data are limited. Manual interpretation, using the master and auxiliary curves, limits the number of geoelectric layers to a maximum of four. On the other hand, while the use of any computer interpretative package may increase the number of detectable geoelectric layers, some packages, such as RESIST and OFFIX, will require the user to feed in some initial resistivity values as a basis for the computation of data. These initial values may be estimated from a manually-plotted curve or from curves generated from the initial manipulation of data by the computer. Whichever way the initial values are generated, the principle of operation of the computer remains: Garbage in garbage out. That is to say that the quality of the final result depends on the quality of the initial resistivity values fed into the computer.

Table 4: The Borehole Lithology vs. VES Interpretation.

Depth (m)	Borehole Lithology	VES Interpretation	Possible Geologic Formation(s)
0-6	Red clay	Lh_1, Lh_2	Benin
6-18	Sharp sand	Lh_3	
18-48	Clay		
48-57	Clay/ sand		
57-69	Coarse sand	Lh_4	Ilaro Oshosun Akinbo Ewekoro
69-84	Sand		
84-100	Sharp sand		
100-126	Plastic black clay		
126-154	Medium-grained sand		
154-160	Sand		
160-168	Limestone	Lh_5	Abeokuta
168-200	Clay		

A third problem, consequently, will arise from the handling of the terrameter for field data acquisition, and also from handling the data during interpretation. This calls for some level of expertise on the side of the operators.

The fourth problem, which is conspicuously important to note, arises from overlooking the known geology of an area while concluding on the interpretation of a geophysical survey. If resistivity survey interpretations are concluded without considering the known geology of an area, the drilling may only become exploratory.

The first three problems may have affected the data used in this work. An attempt at using average thickness values from Table 3 in explaining Table 4 will adequately minimize the possibility of occurrence of problem number 4. This attempt also will suggest possible formational boundaries of the geoelectric sections. This arrangement is integrated in Table 4.

Table 3 compares well with the approximate electrical resistivity ranges of some rock types (Offodile 2002), modified from Abem Geophysics and Electronic Memo 5/72; and also with the summary of the completion of the borehole (Table 5). The borehole was successful. "The yield was estimated to be $30m^3/h$ and the static water level was 33.00m below ground level" (Hydro, 1993).

Table 5: Summary of the Completion of the Borehole.

+ 0.60 –121m = casing
121 – 123m = screen
123 – 154m = casing
154 – 160m = screen
160 – 200m = casing

CONCLUSION

The application of surface geophysical survey in groundwater exploration in the IKorodu area of Lagos, Nigeria, is important in locating important aquiferous sands in the multi-aquiferous formations underlying the area. The interpretation of such surveys, based on the existing knowledge of the geology of Lagos has made it possible to delineate the formational boundaries using the resistivity values obtained from the interpretation of field data. The top sandy layers could be a major supply source of shallow well water. But the aquifers may be susceptible to contamination because of the arenaceous nature of the Benin formation. Deep boreholes can reach a depth of 170m without missing targets. The boreholes will tap water from Tertiary formations, and their water quality will definitely be better than that from shallow boreholes. Drilling beyond 180m may be unnecessary and wasteful because of the existence of hard clays and limestones. A subsurface geophysical log will help to pick target beds more precisely.

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