INVESTIGATION OF GROUNDWATER POTENTIALS IN IMAKUN OMI COMMUNITY USING ELECTRICAL RESISTIVITY METHOD

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ABSTRACT

Groundwater is described as the water found beneath the surface of the earth in underground streams and aquifers and has become popular as a source of drinking potable water in Nigeria due to its quality when compared to other water sources. The Electrical resistivity method was employed in Imakun Omi Community, a coastal town in Ogun Waterside Local government area of Ogun State with the aim of determining the groundwater potential of the area. A total of twenty (20) Vertical Electrical Soundings (VES) points were carried out in the area using the Schlumberger configuration with maximum current electrode separation (AB) of 300m using the ABEM SAS 1000 Terrameter. The results obtained were interpreted quantitatively and qualitatively using partial curve matching and computer iteration programs WINRESIST and SURFER 11 for the interpretation from which the reflection coefficient was computed. The groundwater potential of the rock units were evaluated and 40% of the stations show high yield, 50% of the stations show medium yield and 10% of the stations was observed to have low yield. The aquifer thicknesses are very thick with values ranging from 6.9 m to 79.3 m, hence an average of 43.1mand overburden thicknesses ranging from 9.7m to 96.5 m, with an average of 53.1m.

Keywords: Groundwater, Reflection coefficient, Terrameter, Vertical Electrical Sounding.

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INTRODUCTION

Many people in rural communities in Nigeria are battling with the problem of inadequate availability of potable water for their daily activities. In Imakun Omi, many of the villagers depend on streams and hand dug wells for daily water supply. Groundwater is described as the water found beneath the surface of the earth in underground streams and aquifers (Anomohanran, 2011). Olorunfemi *et al.,* (1999) puts its volume at 2000 times that of the volume of water in all the world's rivers at any given time. Hence, groundwater development constitutes a viable option or supplement to the expensive concrete dam system of surface water supply, where potential groundwater is good. Various researchers have employed different methods in exploring this very essential life sustaining resource. Geophysical surveys have been most widely used because of the basic advantage of providing more accurate results than other methods (Anomohanran, 2013). This advantage includes, simplicity in field techniques and data handling procedures. The electrical resistivity survey method is the detection of the surface effects produced by the flow of electric current inside the earth (Afuwai, 2014). This method enables the determination of subsurface resistivity by sending an electric current into the ground and measuring the electrical potential produced by the current. The subsurface resistivity distribution is related to physical conditions such as lithology, porosity and presence of voids in the rocks. The apparent resistivity is the bulk average resistivity of all soils and rock influencing the current. The objectives of the study are to determine the lithology of the subsurface and

determine the depth to freshwater aquifer in the study area.

Location and Geology of the study area

Imakun Omi is situated in Ogun Waterside Local Government Area in the Ijebu Division of Ogun State. A tropical rain forest region in the Southern Sub-Saharan, located in the eastern part of Ogun state sharing boundaries with Ondo state in the north, Lagos state in the south and Ijebu East local government area in the west (figure 1). About half to three quarters of the length of the local government area is surrounded by water extending from Lagos state to Ondo state. It is close to the Atlantic Ocean and has relative endowment with a complex network of streams, rivers, brackish water. Imakun Omi is located on longitude 4°24'E and latitude 6°26'N, and lies within the coastal plain which is characterised by sand bars and lagoon creeks which is almost encompassed by the Lagos lagoon system, hence the terrain is sedimentary.

Materials and Methods

For the purpose of this research, 20 Vertical Electrical Soundings were carried out in the study area using Schlumberger electrode array. The basic field equipment used for the study is the ABEM TERRAMETER SAS 1000 which display apparent resistivity value digitally as computed from Ohm's law.

In the VES, the four electrodes are positioned symmetrically along a straight line, the current electrodes on the outside and the potential electrodes on the inside. Measurements of current and potential electrode positions are marked such that $AB/2 \geq MN/2$.

where $AB/2$ = Current electrode spacing and
$MN/2$ = Potential electrode spacing

The results of the measurements are recorded in the log-log sheet and later inputted into the computer for interpretations. Processing of the field data was done using the partial curve matching for manual interpretation and then the computer iterated technique. The subsurface models were then generated from the geo-electric parameters by computer aided iteration softwares; WINRESIST 1.0 and SURFER 11. The models obtained from the provided data such as the resistivity's and overburden thickness which were used to plot the isopach map, isoresistivity map and reflection coefficient map.

Results and Discussions

The results are presented in form of field curves (figure 2) which was used to infer the lithology of the study area. The result reveal perfect matched curves, layered parameters and RMS error and it the various numbers of layers, their resistivity values with varying depth and thickness.

The number of layers inferred from the twenty (20) VES points range from four (4) to five (5) and are described as topsoil, lateritic sand, alluvium, clay, shale, clay, sandy clay, clayey sand, saline clay, sandstone, coarse sand and freshwater sand based on the values of their corresponding resistivities. The summary of the subsurface obtained from the computer interpretation is presented in table 1.

Table 2 shows the occurrence of the curves types in a frequency, percentage and degrees and this was used to design a Pie-chart depicting the occurrence of the curves type in figure 4. In Imakun Omi, as shown in Figure 4, KQ curve type is most predominant 40%, followed by KQQ with 20% and KQH with 15% while KHA, KH, AKQ, QH and HK are the least predominant each having 5% occurrence in the study area.

The topsoil has resistivity values ranging from 1131.6 Ωm to 7721.7 Ωm, having an average resistivity value of 4426.6 Ωm. The thickness value corresponding to the topsoil range from 0.3m to 3.9 and having an average layer thickness of 2.1m. The resistivity of the weathered layer ranges from 130.9 Ωm to 5180.2 Ωm with an average 2655.5 Ωm and aquifer thickness ranging from 6.9m to 79.3m, hence an average of 43.1m. The basement resistivity ranges from 106.6 Ωm to 487.9 Ωm, and average of 297.2 Ωm for the fractured basement while fresh basement range from 1653.5 Ωm to 31801.1 Ωm an average of 16727.3 Ωm while the depth to bedrock range from 9.7m to 96.5m with an average of 52.2m while the overburden thickness ranges from 9.7m to 96.5m, with an average of

53.1m.

Isopach Map

Isopach Map is a map illustrating thickness variation within a layer, tabular unit or stratum. The overburden thickness is the sum total of the thickness of the layers that is above the bedrock in a given location. It is also important in hydrogeological investigation as it shows the distances of layers that is above the aquifer and groundwater has been observed to be present in areas which have a considerable overburden thickness (Coker *et al.,* 2013). The Isopach maps for Overburden thickness as depicted in figure 4 shows Imakun Omi has high thickness at the central and towards the south yet lowest at the southwest and averagely high at the northeast.

The Aquifer thickness is the thickness of the layer that bears sufficient amount of groundwater in a given location. It is however expected that the groundwater yield is proportional to the thickness of the aquiferous layer. Hence, the higher the thickness of the aquifer, the more its capacity to bear groundwater. Imakun Omi has very high aquifer thickness at the central and lowest at the southwest and northwest ends and rising slightly towards the east and the southeast as shown in figure 5.

Isoresistivity map

The bedrock resistivity is the resistivity of the last layer within the study area. The resistivity of the bedrock has been found useful in many aspects of geology and hydrogeophysical surveys as it plays a vital role in the evaluation of groundwater because the resistivity of bedrock has the ability to reveal if there is fracture in some bedrock and this has been considered to be the major host of groundwater in some areas. Imakun Omi too has generally low but very high at the southeastern edge as depicted in figure 6. The we athered resistivity map records very high at the southeast r

Reflection Co-Efficient

The reflection coefficients (r) of the study area were calculated using the method of Loke (1999), equations 1 and 2. The reflection coefficient is an important parameter because it helps to indicate fractured areas that host groundwater i.e areas with reflection coefficient values < 0.8

Reflection Coefficient (R.F) =

$$\frac{\text{Resistivity of (Last Layer} - \text{Second to the Last Layer)}}{\text{Resistivity of (Last Layer} + \text{Second to the Last Layer)}} \quad (1)$$

$$r = \frac{(\rho n - \rho(n-1))}{(\rho n + \rho(n-1))} \quad (2)$$

where ρ_n is the layer resistivity of the nth layer

$\rho_{(n-1)}$ is the layer resistivity overlying the nth layer.

The Reflection Coefficient have been found useful in hydrogeological aquifer investigation because it reveals if bedrock fracture is filled with water and there must be a direct correlation with the anisotropy coefficient value for this parameter to be considered. The nature of the basement is not dependent on the absolute resistivity values but rather dependent on its reflection coefficient values, which measures the competency of the rock (Olayinka, 1996). Areas with relatively lower reflection coefficient represent areas where the bedrock is either fractured or weathered. Such areas have higher groundwater potential than areas with higher values of reflection coefficient (> 0.8) i.e fresh basement. The Reflection Coefficient value within the study area ranges from 0.05 to 2.1 hence, an average of 1.1. As shown in figure 8, it is highest at the West and at the North.

Groundwater potential evaluation

Olayinka (1996) observed that the resistivity of the basement cannot be solely relied on to identify areas of promising aquifers. Hence, the consideration of its reflection coefficient brought a better result. It shows the degree of fracturing of the underlying basement better, than depending solely on the resistivity values. Good aquiferous zones are usually found either where the overburden is relatively thick and or where the reflection coefficient is low (< 0.8). Three basic criteria were considered in evaluating promising points for groundwater potential (i.e areas with high yield, medium yield and low yield) which are:

I. Areas with overburden thickness greater than 13m (even if their resistivity is relatively high).
ii. Areas with reflection coefficient less than 0.8
iii. Areas with resistivity less than 2000Ωm.

In order to ensure maximum and perennial yield, boreholes are best sited in areas where the regoliths could be maximally penetrated. As shown by Olayinka (1996), this was used to produce the parameters for categorizing the groundwater potential yield into: high, medium and low. VES's 3, 4, 9, 15, 16, 17, 19 and 20 show high yield which makes 40% of the stations in the town. Medium yield is observed at 1, 2, 6, 7, 8, 10, 12, 13, 14 and 18 making 50% of the stations. Low yield is observed at VES's 5 and 11 making 10% of the stations in the town as shown in table 3.

Table 1: Geoelectric Parameters

VES NO	NO OF LAYERS	CURVE TYPE	RESISTIVITY (? m)	THICKNESS (m)	DEPTH (m)	LITHOLOGY
1	5	KQH	1217.6	0.4	0.4	Topsoil
			8324.3	1.3	1.8	Laterittic Sand
			1006.2	9.9	11.6	Shale
			130.9	79.3	91.0	Sandy clay
			5381.4	--	--	Fresh Basement
2	4	KQ	3469.2	0.4	0.4	Topsoil
			73686.7	1.7	2.1	Laterittic Sand
			1328.9	27.0	29.1	Shale
			106.6	--	---	Sandy clay
3	4	KQ	4637.5	0.5	0.5	Topsoil Laterittic
			26230.2	4.1	4.6	Sand
			2003.7	25.5	30.2	Shale
			452.9	--	---	Alluvium
4	5	KQQ	7721.7	0.3	0.3	Topsoil
			40815.8	2.2	2.5	Laterittic Sand
			3623.4	14.6	17.1	Shale
			481.9	49.1	66.2	Alluvium
			164.6	--	--	Sandy clay
5	4	KQ	1524.4	0.4	0.4	Topsoil
			27378.0	1.4	1.8	Laterittic Sand
			823.4	10.2	12.0	Shale
			364.1	--	--	Alluvium
6	4	KQ	1498.0	0.5	0.5	Topsoil
			20092.8	2.3	2.8	Laterittic Sand
			1068.1	12.5	15.3	Shale
			373.0	--	--	Alluvium
7	5	KQH	1185.3	0.4	0.4	Topsoil
			21592.7	1.6	2.0	Laterittic Sand
			965.3	2.3	4.3	Shale
			315.9	73.1	77.4	Alluvium
			2612.7	---	---	Fresh Basement
8	4	QH	2191.8	3.7	3.7	Topsoil
			982.7	8.4	12.1	Sandstone
			248.8	22.2	34.3	Alluvium
			2379.2	--	---	Fresh Basement
9	5	KHA	1853.4	1.1	1.1	Topsoil
			2502.7	4.1	5.2	Laterittic Sand
			445.9	12.0	17.1	Alluvium
			5180.2	22.9	40.0	Dry Sand
			31801.1	---	---	Fresh Basement
10	4	KH	1833.0	2.8	2.8	Topsoil
			2427.5	3.7	6.6	Laterittic Sand
			320.7	12.6	19.1	Alluvium
			4945.7	---	--	Fresh Basement

11	4	KQ	1457.1	0.6	0.6	Topsoil
			7042.6	2.2	2.8	Laterittic Sand
			1259.6	6.9	9.7	Shale
			141.7	---	--	Sandy clay
12	4	KQ	1390.6	0.7	0.7	Topsoil
			4819.6	3.4	4.0	Laterittic Sand
			607.3	16.1	20.1	Alluvium
			148.1	--	--	Clayey sand
13	4	KQ	1506.8	0.7	0.7	Topsoil
			4207.1	3.7	4.4	Alluvium
			593.5	13.6	18.0	Shale
			124.8	---	--	Sandy clay
14	5	KQH	1161.3	0.7	0.7	Topsoil
			4397.4	2.8	3.5	Laterittic Sand
			755.9	15.0	18.5	Alluvium
			174.0	78.0	96.5	Sandy Clay
			1653.5	--	---	Fresh Basement
15	4	HK	1131.6	3.9	3.9	Topsoil
			220.0	3.5	7.4	Alluvium
			1958.1	25.5	32.9	Dry Sand
			312.8	--	--	Clay
16	4	KQ	2133.1	0.5	0.5	Topsoil
			18088.2	1.8	2.3	Laterittic Sand
			1720.3	24.8	27.1	Dry Sand
			263.4	---	---	Alluvium
17	5	KQQ	2151.3	0.5	0.5	Topsoil
			13696.2	1.7	2.2	Laterittic Sand
			3930.9	12.1	14.4	Shale
			1258.6	38.5	52.8	Dry Sand
			211.4	---	--	Alluvium
18	5	KQQ	1439.8	0.5	0.5	Topsoil
			16674.2	2.0	2.5	Laterittic Sand
			3977.7	8.1	10.6	Shale
			1296.7	36.0	46.6	Dry Sand
			226.5	---	---	Alluvium
19	4	KQ	2078.7	0.6	0.6	Topsoil
			11190.9	3.1	3.7	Laterittic Sand
			2394.0	21.8	25.4	Shale
			487.9	---	---	Alluvium
20	5	AKQ	1717.2	0.7	0.7	Topsoil
			2561.9	11.2	11.9	Laterittic Sand
			2913.0	15.7	27.6	Shale
			1579.5	22.5	50.1	Dry Sand
			481.3	--	---	Alluvium

Table 2: The occurrence of the curves type

Type of Curves	Frequency	Percentage	Degrees
KQH	3	15	54
KQ	8	40	144
KQQ	4	20	72
KHA	1	5	18
KH	1	5	18
AKQ	1	5	18
QH	1	5	18
HK	1	5	18
TOTAL	20	100	360

Table 3: Aquifer Characteristics of the VES Points

Location	Overburden thickness	Reflection coefficient	Basement resistivity	GROUND WATER YIELD
1	91	0.9	5381.4	MEDIUM
2	29.1	0.9	106.6	MEDIUM
3	30.2	0.7	452.9	HIGH
4	66.2	0.7	164.6	HIGH
5	12	0.9	364.1	LOW
6	15.3	0.9	373	MEDIUM
7	77.4	0.9	2612.7	MEDIUM
8	34.3	0.8	2379.2	MEDIUM
9	40	0.7	31801.1	HIGH
10	19.1	0.8	4945.7	MEDIUM
11	9.7	0.8	141.7	LOW
12	20.1	2	148.1	MEDIUM
13	18	1.4	124.8	MEDIUM
14	96.5	0.8	1653.5	MEDIUM
15	32.9	0.7	312.8	HIGH
16	27.1	0.7	263.4	HIGH
17	52.8	0.1	211.4	HIGH
18	46.6	2.1	226.5	MEDIUM
19	25.4	0.6	487.9	HIGH
20	50.1	0.6	481.3	HIGH

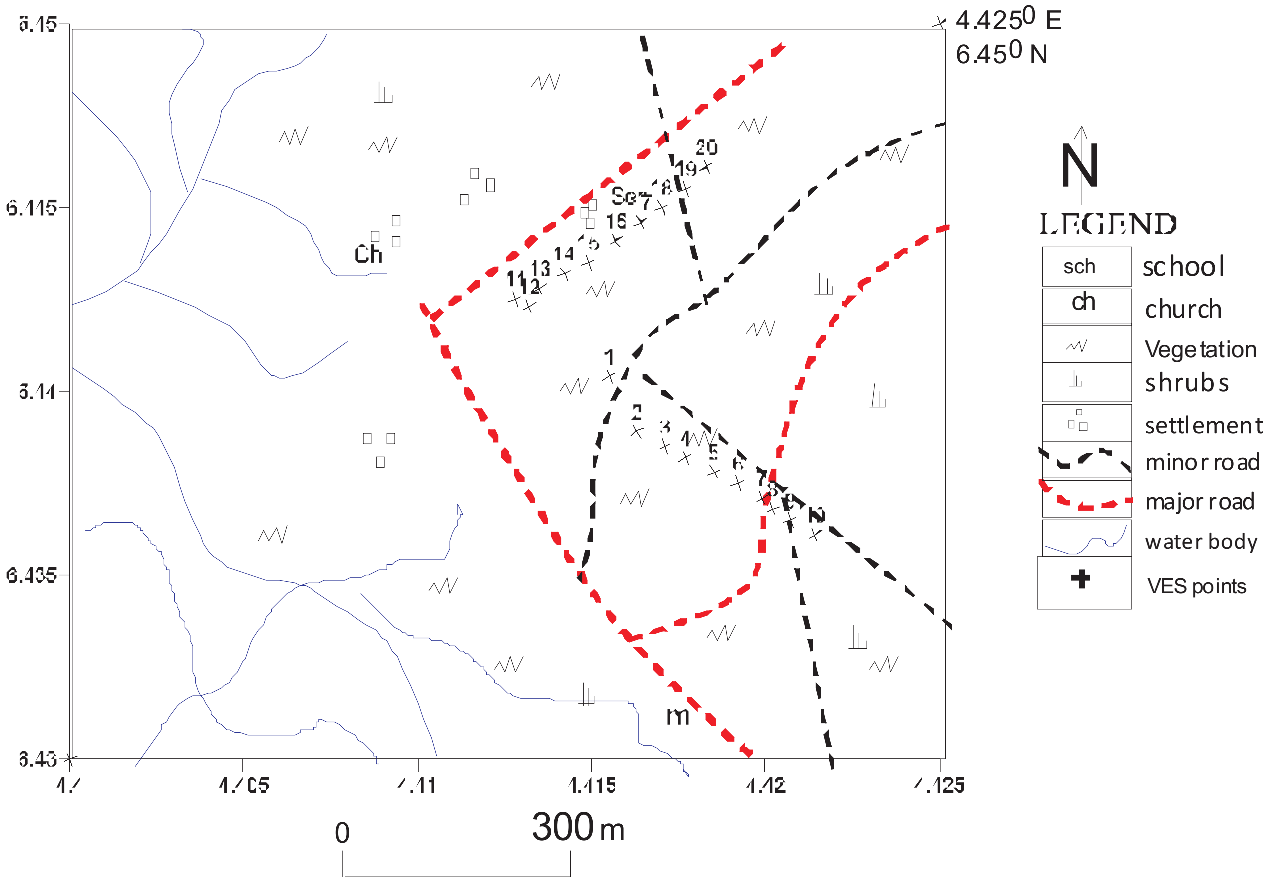

Figure 1: Location map of the study area showing the Sounding points

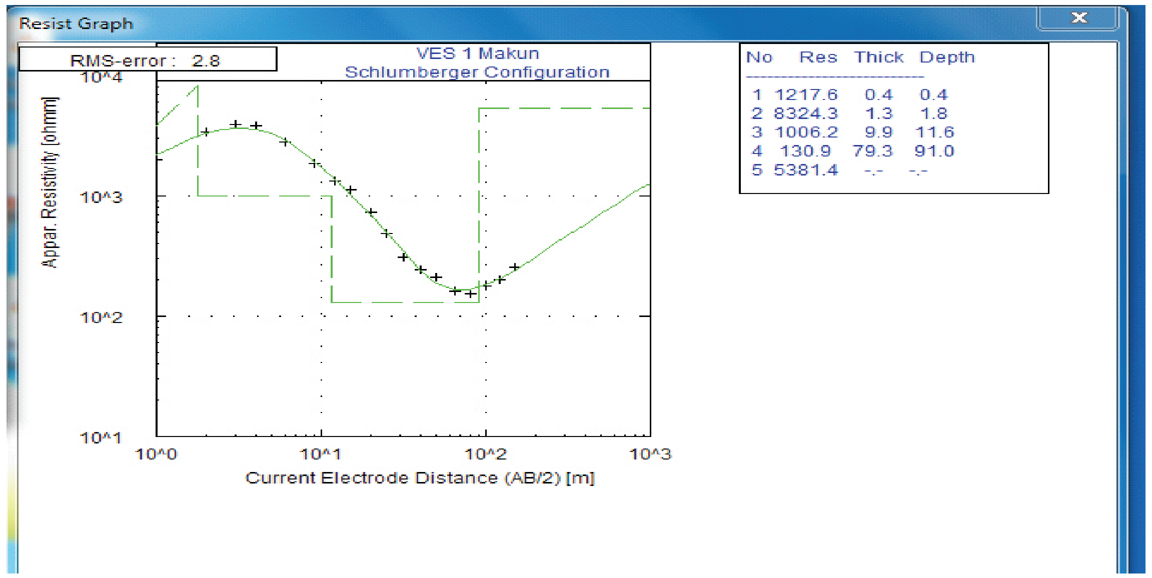

Figure 2: Typical iterated curve for VES 1

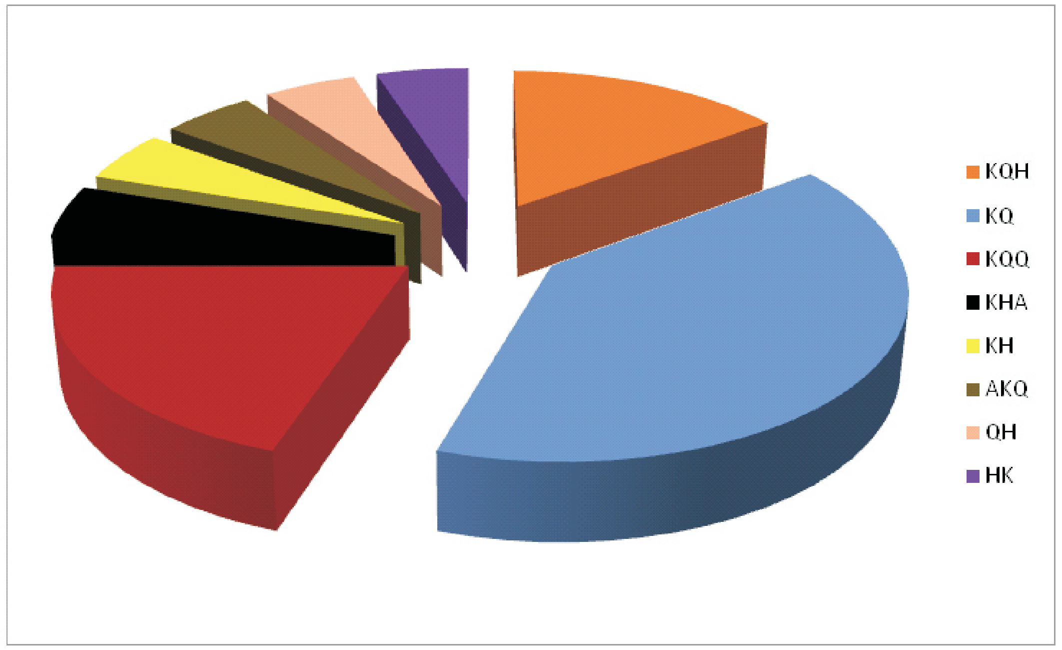

Fig 3: Representation of the occurrence of the curves type

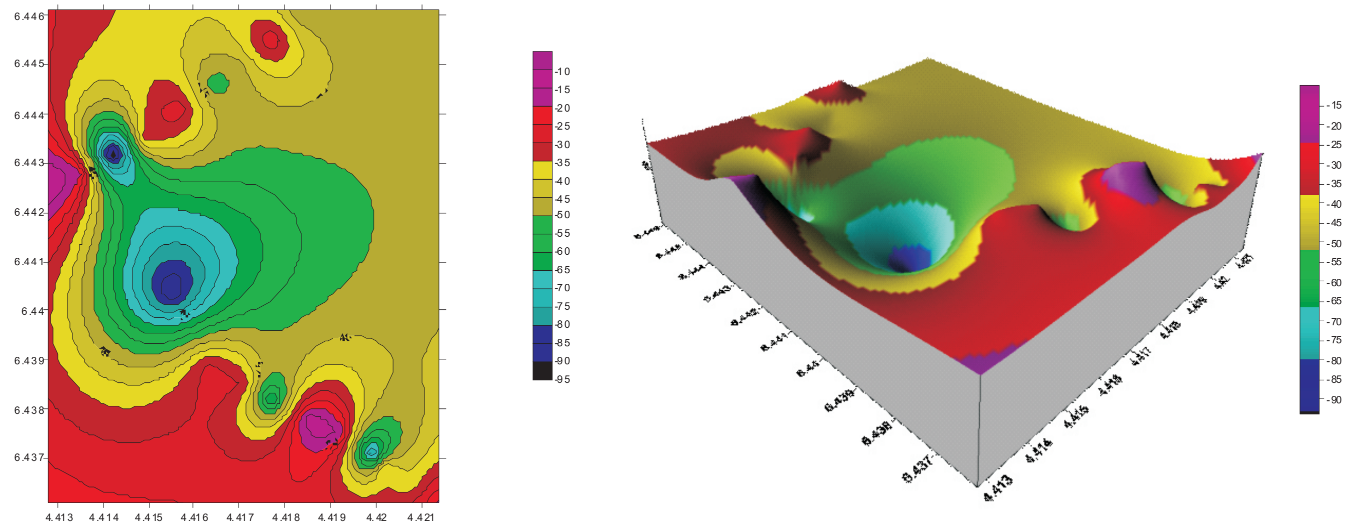

Figure 4: Maps of Overburden thickness

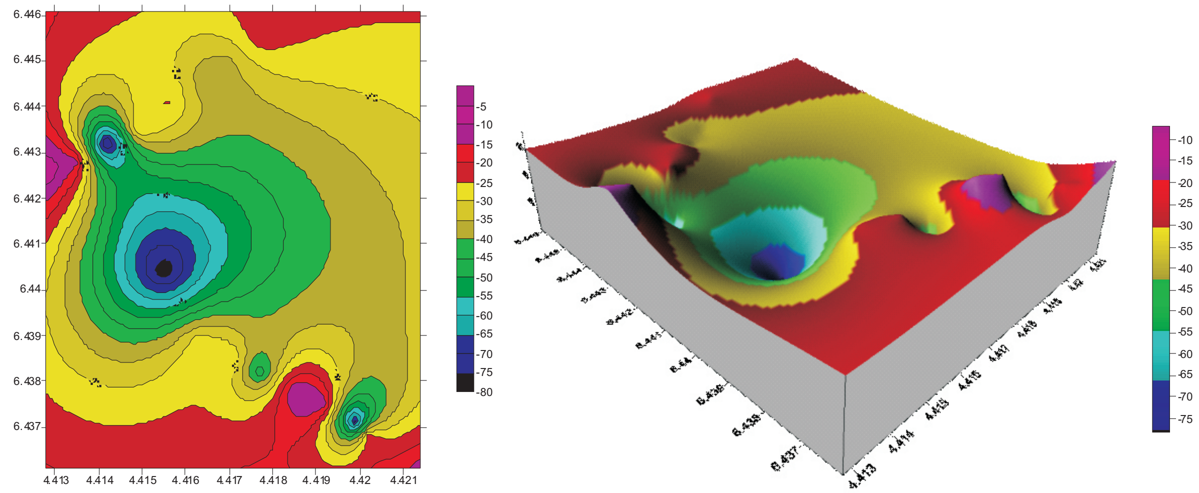

Figure 5: Maps of Aquifer thickness

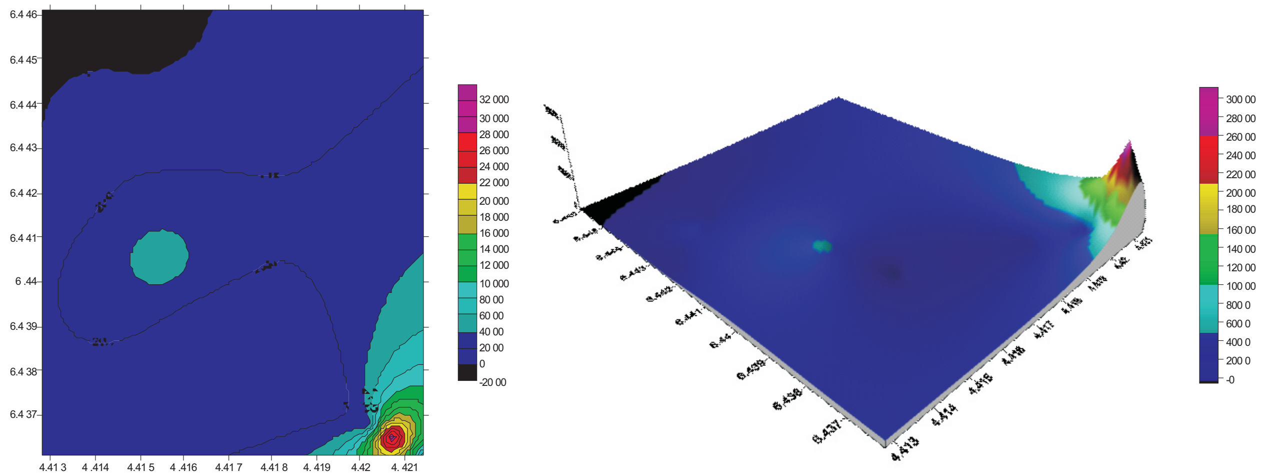

Figure 6: Isoresistivity Maps of basement layer

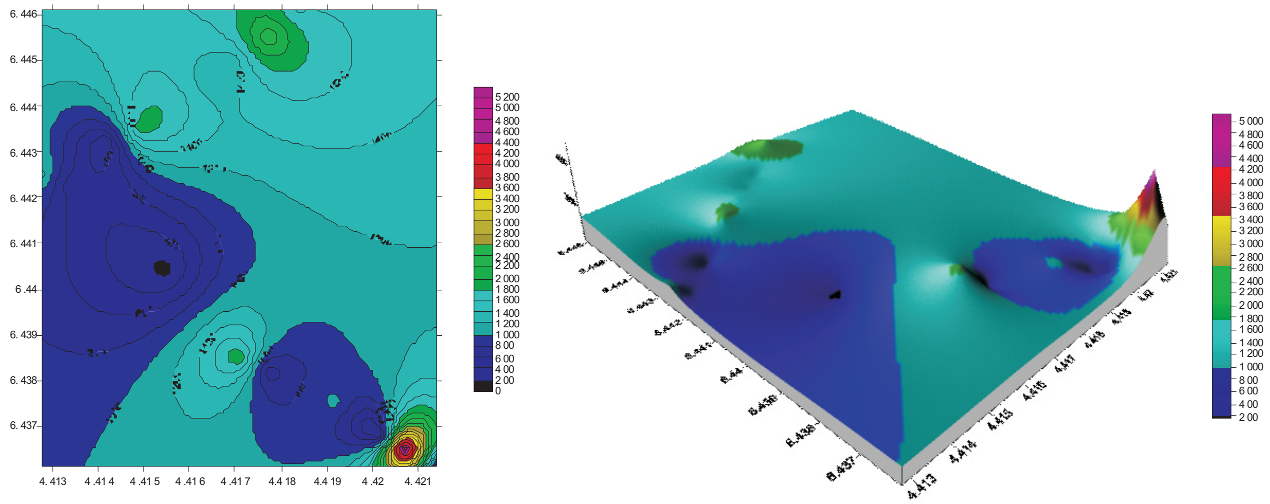

Figure 7: Isoresistivity Maps of weathered layer

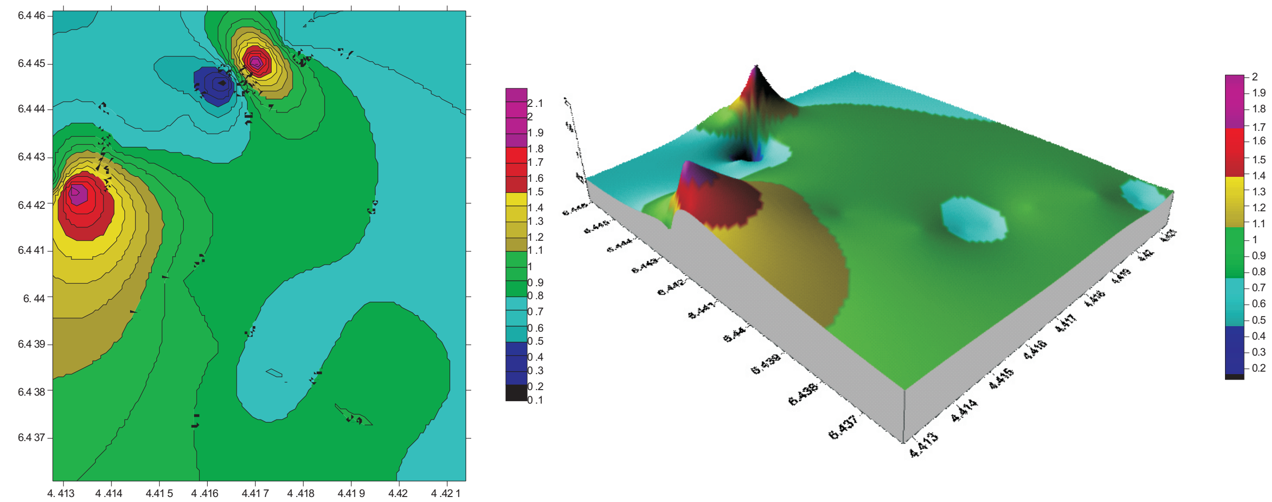

Figure 8: Reflection Coefficient maps

Conclusion

This work assessed the subsurface lithology, aquifer depth, thickness, aquifer characteristics and pollution vulnerability in Imakun Omi community. The aim is to minimize the rate of ground water exploitation failures, evaluate groundwater potential and yield and delineate areas most vulnerable to underground water pollution. The groundwater potential and protective capacity evaluation of the rock units were evaluated. 40% of the stations show high yield, 50% of the stations show medium yield and 10% of the stations was observed to have low yield. The protective capacity rating of the study area shows a mix of poor, weak and moderate ratings of the VES points. Areas that are classified as poor and weak are indicative of zones of high infiltration rates from precipitation. Such areas are vulnerable to infiltration of leachate and other surface contaminants. The groundwater in the area of weak protective capacity is therefore vulnerable to pollution if there is leakage of buried underground storage tanks; a source of serious environmental hazard.

The study has however been able to highlight the importance of resistivity method in effective hydrogeologic assessment of aquifers and its vulnerability to near-surface contaminants that might have pave way into the aquifers. Future groundwater development and facilities such as underground petroleum storage tanks in the study area by government should be concentrated within the medium ground water potential zones with moderate aquifer protective capacity. The results of this study have provided reliable information for an elaborate groundwater abstraction and environmental factors necessary for planning and development of residential and industrial estates in this town.

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