HYDROGEOLOGIC INVESTIGATION USING VERTICAL ELECTRICAL SOUNDING METHOD IN AGBARHA OTOR, DELTA STATE NIGERIA

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ABSTRACT
Vertical resistivity sounding measurements were conducted at fifteen(15) locations in Agbarha-otor in Ughelli North Local Government Area in Delta State using Schlumberger electrode configuration. The field data where interpreted qualitatively as well as quantitatively. Five basic geoelectric layers were delineated in the area such as topsoil, laterite, fine sand and medium-coarse grain sand with resistivity ranging from 257- 3873Ωm, 479-3022Ωm, 519-3071Ωm and 1137-3735Ωm and a depth ranging from 0.6-1.5m, 3.8-9.5m, 11.6-51.6m respectively. The result of the study shows that, at a depth of 5.1-51.6m lies the aquifer in the area with resistivity ranging from 990-3071Ωm and the thickness of the aquifer in the area was observed to be between 9.1-47m. The NE part of the region is prone to contamination from human activity such as landfill as a result of the shallow depth to the top of the aquifer. Portable water can be obtained from VES8 and VES9 in NE-SW direction of the study area due to aquifer thickness of 47m and 43m respectively.

Keywords: Schlumberger, Isopach, Geoelectic section, aquifer, Agbarha-otor

INTRODUCTION

Technological advancement has transformed ordinary search for water into prospecting for steady and reliable subsurface or groundwater in boreholes. In Nigeria, presently, borehole has rescued the citizenry from acute shortage of water (Alile *et al.,* 2008). The electrical resistivity technique has been found to be very reliable for groundwater studies over the years (Atakpo and Akpoborie, 2008).

Groundwater consists of all the subsurface water in soil pore spaces and in fractures in rock and sediment beneath the Earth's surface (Sophocleous, 2002). The depth at which soil pore spaces or fractures in rocks become completely saturated is called the water-table. It is a non-flat surface which reflects ground undulations or surface topography. There also exists perched water table which may be due to lenses of clay or other impervious materials which has formed a layer above the normal water-table.

Water is used in industries, for irrigation, in oil refineries, paper-mills, chemical plants, breweries, food processing plants, etc. As civilization progresses, and human population increases, the usage of groundwater intensifies. Groundwater becomes a more important source of uncontaminated water. Partly for this reason, geophysical methods are playing an increasingly important role in groundwater investigations. Of all the geophysical methods, the electrical resistivity has been the most widely used in groundwater investigations.

However, electrical resistivity method does not yield complete information, even under favourable conditions, completely replace test drilling. They can, though, in many cases substantially reduce the amount of test drilling required by allowing a more intelligent selection of test hole sites. This research is aimed at using the electrical resistivity method involving vertical electrical sounding (VES) technique in determining the depth to water-table at Agbarha-Otor in Ughelli-North Local Government Area of Delta State. The depth to water is high at a maximum of 5m below the ground surface in the dry season and less than 1m in the wet season. Direct measurement of the height of water levels with steel tapes in 41 hand-dug wells located in the study area revealed an average depth of about 3.11m to 4.58m.

The presence of water at a particular location is generally indicated by a decrease in measured resistivity at that location. This decrease can arise from the existence of rocks containing aqueous solutions. Thus to determine sites for drilling for water simply implies locating sites with rocks or soils whose resistivities are low compared to the surrounding country rock.

LOCATION OF THE STUDY AREA

Agbarha-Otor is located in Ughelli-North Local Govenrment Area of Delta State. Agbarha-Otor in Ughelli North Local Government Area in Delta State, it lies between longitude 5°96′E and 6°04′E and latitudes 5°30′N and 5°40′N .The road serves as a major link from which a number of linked roads branch out linking to various places as streams, foot path, farms, markets, settlement etc. The area plays host to several industrial corporation outfits which include the Shell Petroleum Development Company, SPDC and a host of others.

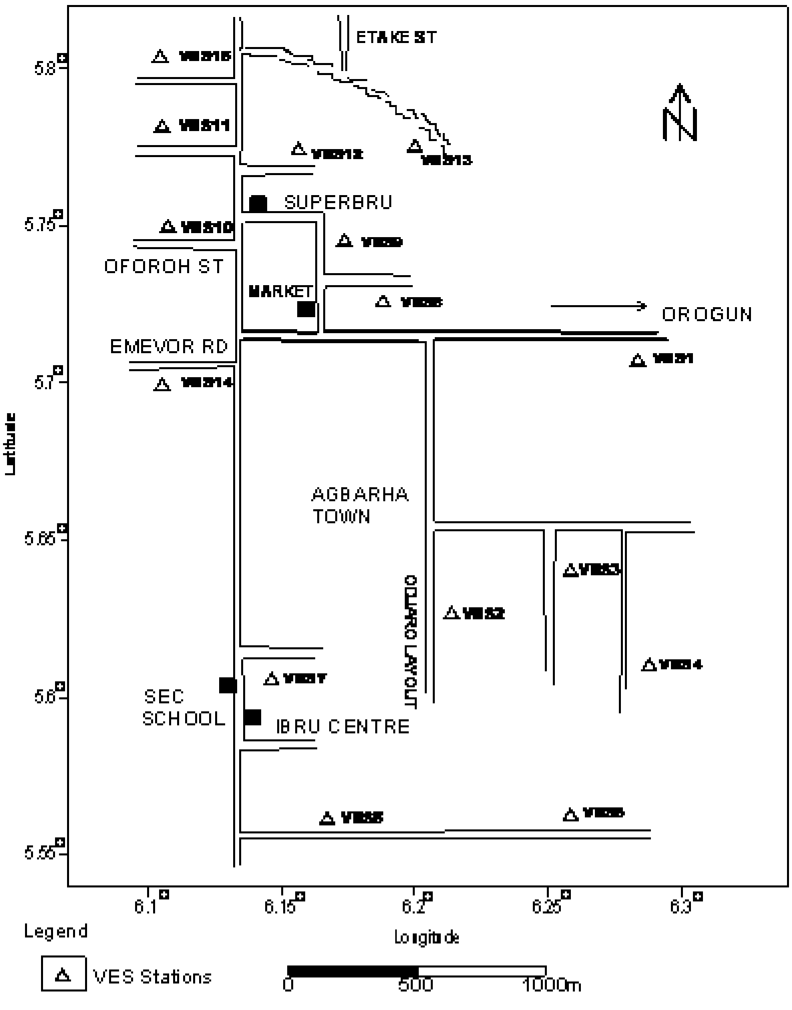


Fig 1: Location map of the study area

GEOLOGY OF THE STUDY AREA

The area under survey is characterized by overlying sediments of loose sand, sandy loam, clay loam and clayey sand arranged almost uniformly over each other. The sand ranges from fine to coarse. The survey area is characterized by a nearly level seaward sloping terrain with an elevation of less than 10m above sea level. Annual rainfall in the area is about 250mm to 350mm. Rainy season commences around April and extends to November with July/August as the peak month, while the dry season occurs between December and March, reaching its peak in January when the harmatan wind sweeps across the area (Iloeje, 1981).

The depth to water is high at a maximum of 5m below the ground surface in the dry season and less than 1m in the wet season. Direct measurement of the height of water levels with steel tapes in 41 hand-dug wells located in the study area revealed an average depth of about 3.11m to 4.58m measured in the rainy period of the year. The study area is rich in industrial minerals such as silica, ball clay, etc.

Three distinct facies belts have been identified in the Niger delta (Short and Stauble, 1967; Asseez, 1989) and they include; The Benin Formation (Miocene to Recent), within which the study is housed, consists of predominantly massive, highly porous fresh water-bearing sandstone, with local interbed of shale, with a thickness of 2100m, the Agbada Formation, between Lower/Middle Miocene to Pliocene, consists of alternating sandstones and shales of the delta front, distributary-channel and delta plain origin, and the Akata Formation aged Eocene to Recent, is made up of a sequence of under-compacted marine clays with minor sandy and silty beds. The Agbada formation constitutes the main hydrocarbon habitat in the Niger Delta (Evamy *et al.,* 1978).

The survey area falls under the Niger-Delta basin situated on the continental margin of the Gulf of Guinea on the west coast of central Africa, between latitude 3^o and 7^o N and longitude 5^o and 8^oE. Niger-Delta basin ranks amongst the world's most prolific petroleum tertiary deltas that together accounts for 5% of the world's oil and gas reserves and for about 2.5% of the present day basin areas on earth (Reijers, 1996). The Niger-Delta holds enormous petroleum reserves estimated at about 30 billion barrels of oil and 260 trillion cubic feet of natural gas.

The influence of basement tectonics on the structural evolution of the Niger Delta was largely limited to movement along the equatorial Atlantic Ocean fracture e zone, which extend beneath the Delta and determines the initial locus of the proto-Niger Delta in the Benue trough. As the Delta advanced into thinned continental crust and possibly later into actual oceanic crust, continuous subsidence and thinning of the basement created more space for the thick sediment pile of the pro-grading canzoic Niger Delta, (Reigers, 1996).

MATERIALS AND METHODS

The equipment ABEM, SAS 1000 digital Terrameter was used to generate current into the ground through a pair of electrodes. The potential electrode positions was kept constant for successive measurement, but changed only when the voltage reading becomes too small to be accommodated by the instruments sensitivity.

The Schlumberger array design was adopted for the data acquisition. The electrode spread of AB/2 was varied from 1 to a maximum of 600 m. The expected depth of investigation was (D) = 0.125 L, where L = AB/2 and AB the current electrode separation.

Fifteen VES stations were occupied during the surface hydrogeophysical investigation to achieve a relatively good coverage of the area. The current electrodes were spread to a maximum field allowable distance of 600m from each centre point occupied.

The data obtained from the electrical resistivity survey was plotted on a log-log graph paper with apparent resistivity values along the ordinate and the electrode separation AB/2 along the abscissa. The field curves were interpreted through partial curve matching (Koefoed, 1979) with the help of master curves (Orellana and Mooney, 1966) and auxiliary point charts (Zohdy, 1965; Keller and Frischnecht, 1966). The thickness and resistivity values obtained from the partial curve matching were then used for a quantitative computer iteration using the Resist Software (Vandern Velpen, 1988). A summary of the

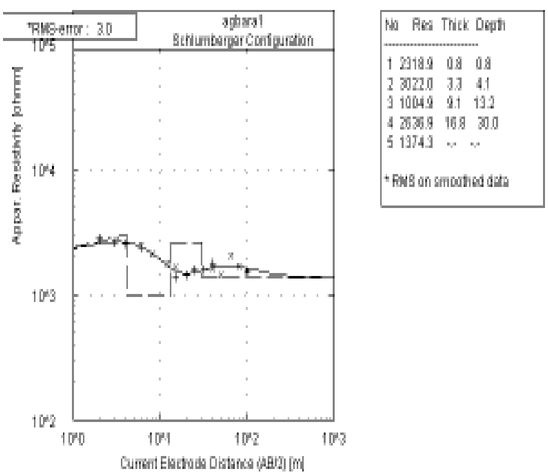
Table1: Presentation of results from computer iteration

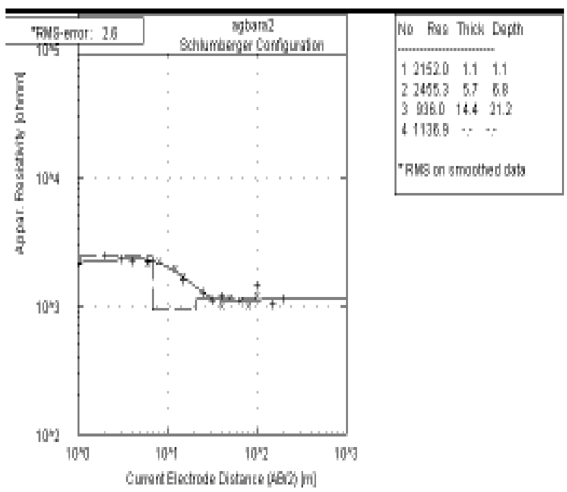
Station	Layer	Resistivity (Ωm)	Thickness(m)	Depth(m)	Curve type
VES 1	1/2/3/4/5	2318/3022/1005/2637/1374	0.8/3.3/9.1/16.8	0.8/4.1/13.2/30	KHK
VES 2	1/2/3/4	2152/2455/936/1137	1.1/5.7/14.4	1.1/6.8/21.2	KH
VES 3	1/2/3/4/5	1159/2285/1319/3735/1291	0.8/3.6/7.3/16.1	0.9/4.3/11.6/27.7	KHK
VES 4	1/2/3/4/5	2368/2616/2563/3514/2097	1.0/4.9/9.3/25.7	1.0/5.9/15.2/40.9	KHK
VES 5	1/2/3/4	2760/2043/3071/1239	1.1/7.8/31.2	1.1/8.9/40.1	HK
VES 6	1/2/3/4	1820/2122/1688/2223	0.9/7.1/22.6	0.9/8.8/30.6	KH
VES 7	1/2/3/4	257/643/519/2489	0.65.8/42.1	0.6/6.4/48.5	KH
VES 8	1/2/3/4	995/667/977/1318	0.8/3.1/47.0	0.8/3.8/50.8	HA
VES 9	1/2/3/4	1074/1376/990/2731	1.0/7.3/43.3	1.0/8.3/51.6	KH
VES 10	1/2/3/4	574/479/1065/1421	0.7/5.9/18.6	0.7/6.6/25.3	HA
VES 11	1/2/3/4	287/690/622/1272	0.8/7.6/20.7	0.8/8.4/29.1	KH
VES 12	1/2/3/4	319/1453/845/3179	1.5/6.6/15.5	1.5/8.1/23.6	KH
VES 13	1/2/3/4	1416/1842/2054/2844	1.5/6.8/19.2	1.5/8.3/27.5	AA
VES 14	1/2/3/4	3872/1171/2409/1354	1.6/5.1/14.1	1.66.7/20.8	HK
VES 15	1/2/3/4	3825/2183/897/3657	1.5/8.8/15.7	1.5/9.5/25.3	QH

RESULTS AND DISCUSSION

A total of 15 VES locations, spread over the study area (Figure 1) were occupied. The processed data were subjected to both detailed interpretation aimed at unraveling the subsurface groundwater potential in the study area. The interpretation assessed the prevalent type curves in the study area, determined the geoelectric properties of the subsurface layers and delineate the aquifers in terms of the thickness and resistivity. The results were presented in form of sounding curves, geoelectric sections, isoresistivity and isopach maps.

The interpretation of the sounding curves show the following curve types, KHK, KH, HK, HA, QH and AA (figure 2) with the KH type curve dominating.





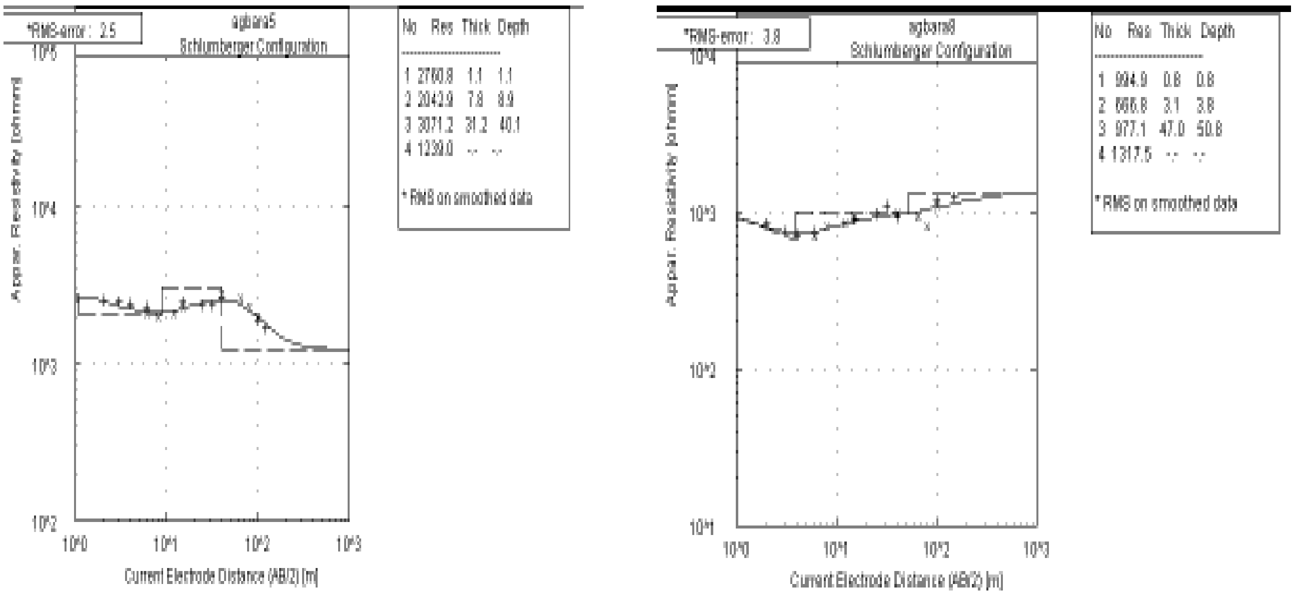


Figure 2: Typical type curves obtained from the study area.

Geoelectric section in the north-south direction contains VES14, VES10, VES11 and VES15 (Figure 3). The topsoil layer of the geoelectric section has a resistivity value ranging between 287 -3873Ωm at a depth ranging between 0.7-1.6m.The second layer is lateritic with a thickness ranging from 5.1-8.0m. The third layer has more of medium-coarse grain than fine sand with VES 10, VES11 and VES15 having medium-coarse grain while VES14 has fine sand. This region represents the aquiferous layer. The fifth layer contains fine sand.

In the NW-SE direction (Figure 4), the geoelectric section shows the topsoil having a resistivity ranging from 319 -3825Ωm and a thickness ranging from 0.8-1.5m. The second layer is lateritic with resistivity ranging from 667 -2455Ωm and thickness ranging from 3.1-8.0m. The third layer which is the aquiferous layer has medium-coarse grain in all the VES reading except VES 6 with fine sand and has a resistivity ranging from 845 -1688Ωm and thickness ranging from 14.4-47m. The fourth layer contains fine sand.

Also in the NE-SW direction (Figure 5), the topsoil has a resistivity ranging from 257 -1417Ωm and thickness ranging from 0.6m-1.5m. The second layer is lateritic with resistivity ranging from 643 -1842Ωm and a thickness ranging from 3.1-6.8m. The third layer contains medium-coarse grain sand in VES7 and VES8 while VES13 has fine sand. The resistivity ranges from 519 -2054Ωm and a thickness ranging from 19.2-47m

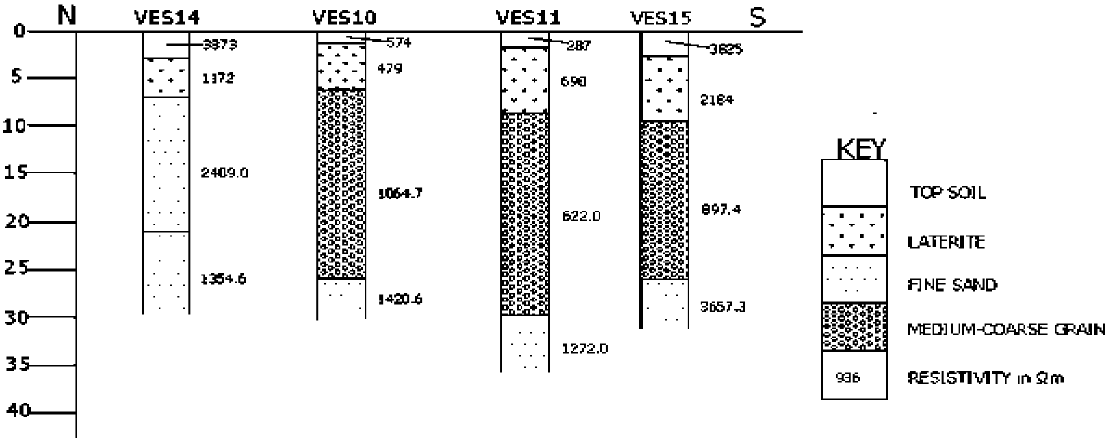


Figure 3: Geoelectric section in the N–S direction

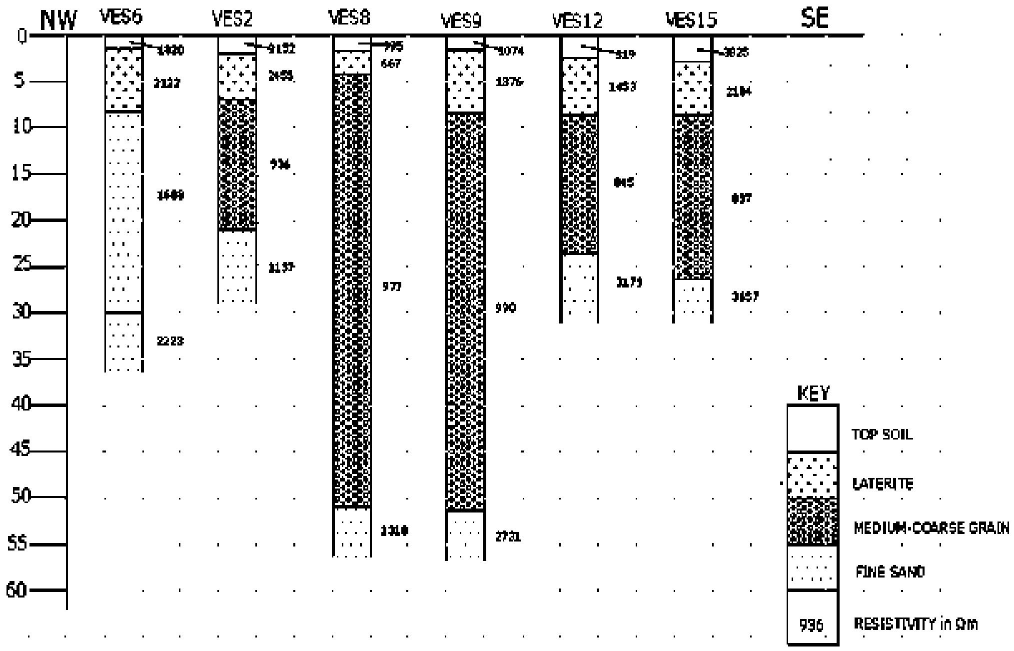


Figure 4: *Geoelectric section in NW–SE direction*

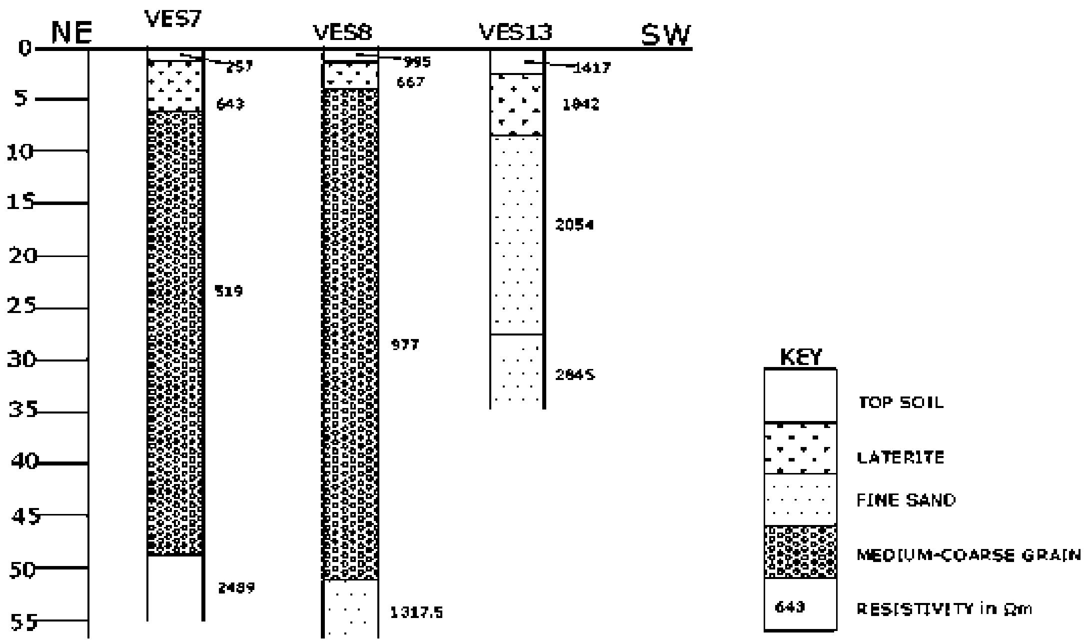


Figure 5: *Geoelectric section in NE–SW direction.*

The results of the study show that an aquifer is encountered at an average depth of about 5.1 m in Agbarha-Otor community as shown in the depth to the top of aquifer map (Figure 6)

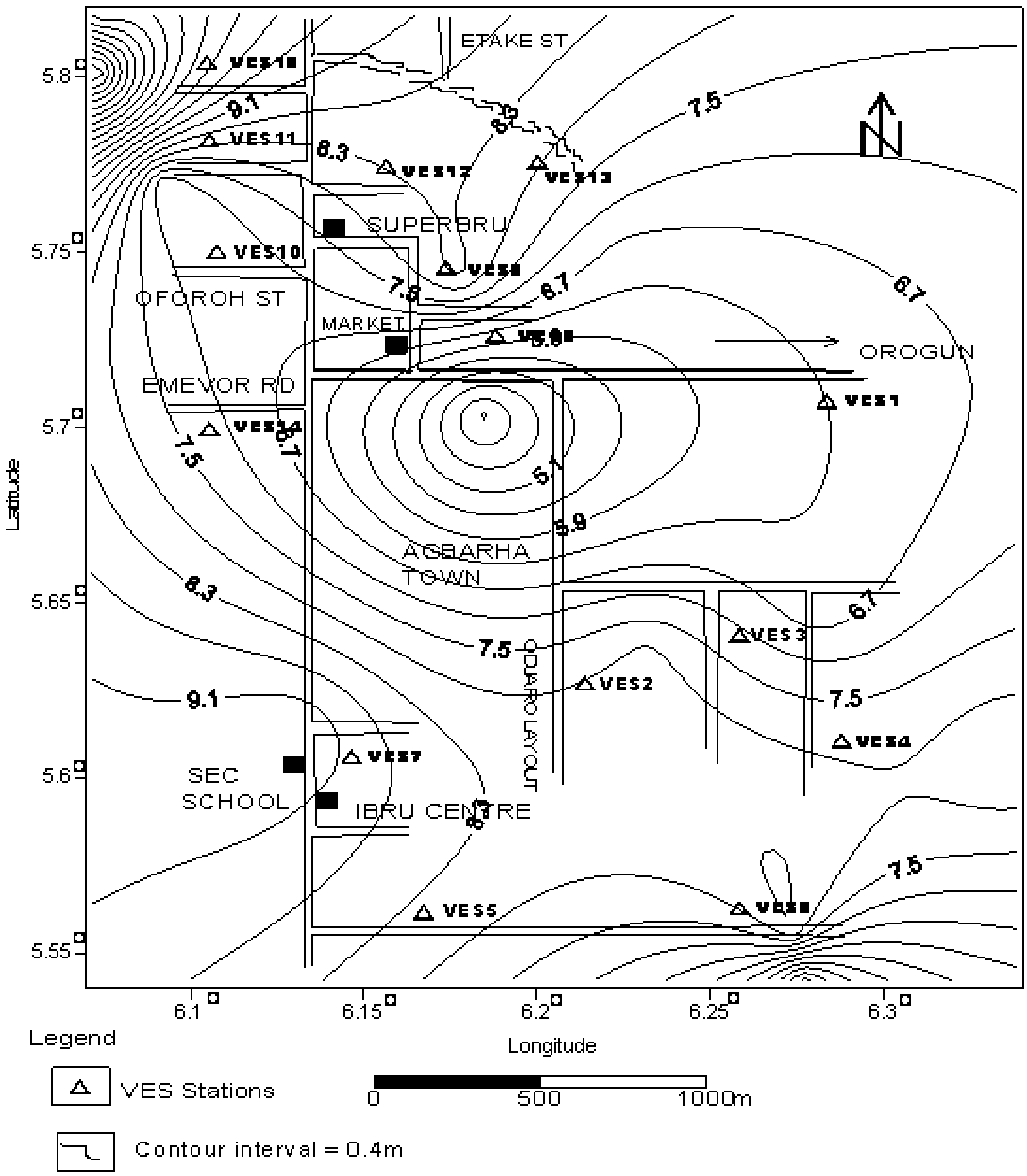


Figure 6: *Map of the depth to the top of aquifer.*

The isopach map (Figure 7) produced from the VES results shows a variation in the thickness of the aquifer ranging from 14.1-47m. In the NE-SW portion of the study area, the thickness of the aquifer ranges from 19.2-47m. The maximum aquifer thickness is encountered beneath VES 8 in the study area. This area may be good prospects for drinking boreholes with high yield expectations (Omosuyi *et al.,* 2008). VES8 and VES9 in the NW-SE direction and VES 7 in the NE-SW direction in the study area is the best area for groundwater development

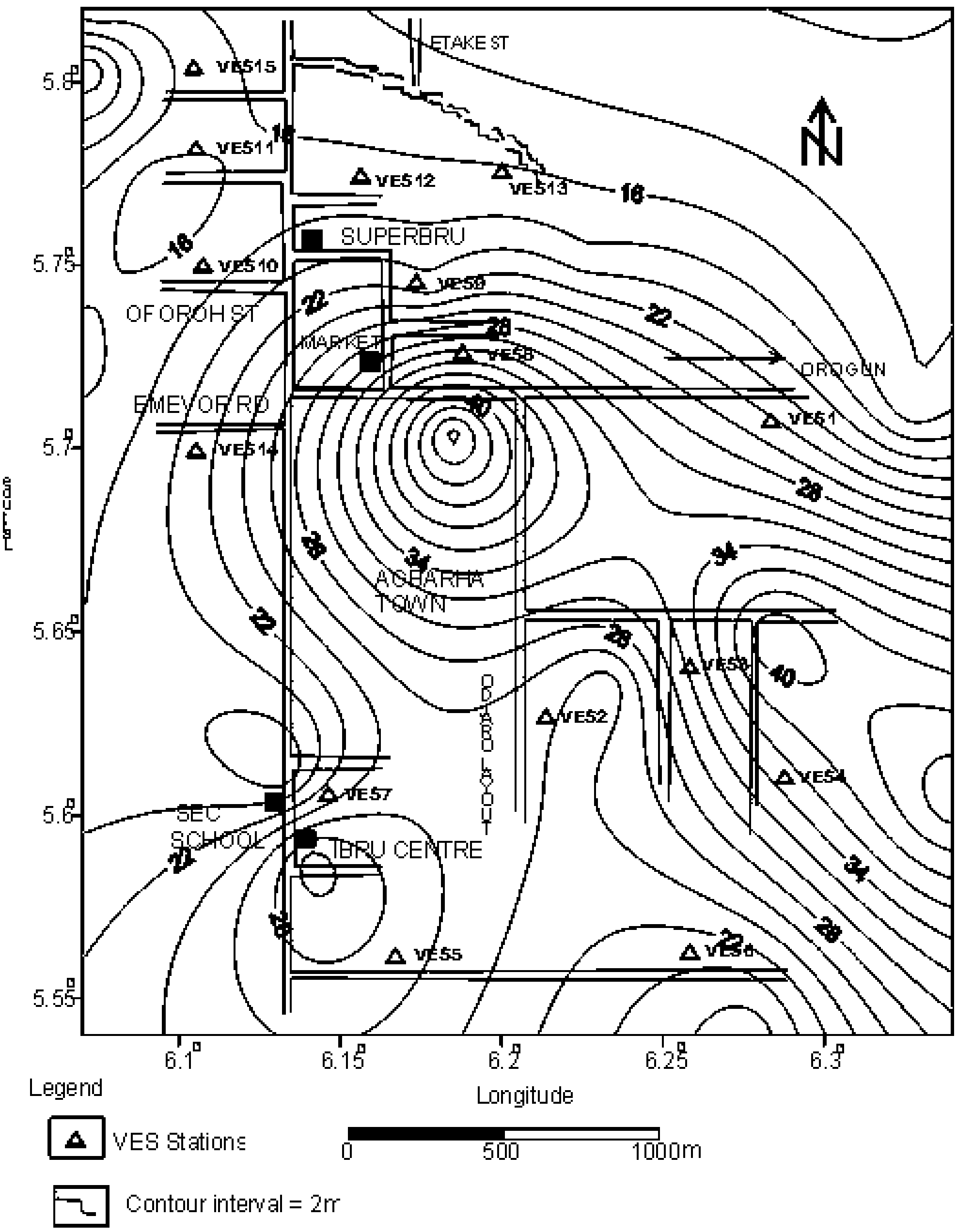


Figure 7: *Isopach map of the aquifer*

CONCLUSION

The vertical electrical sounding method used in this study has greatly assisted in evaluating groundwater potential in the study area. A total of fifteen vertical electrical soundings (VES) data were collected in Agbarha-Otor in Ughelli North Local Government Area in Delta State using Schlumberger Array. The geoelectric parameters obtained from the inverted Vertical Electrical resistivity sounding data were used to evolve maps and cross sections which were analyzed in terms of hydrogeologic importance of the area (Ofomola *et al.,* 2010).The result as revealed in the geoelectric section shows that aquifer is encountered at a depth of about 5.1m to 46m indicating medium to fine-grained sand and better groundwater saturation condition. The integration of lithologic logs and other drilling data with surface geoelectric studies in the delineation of the aquifer systems and quantification of aquifer vulnerability in the area would enhance the accuracy of the results. However, this study constitutes a background information, or useful guide for more elaborate groundwater development programme in the area.

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