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GEOPHYSICAL INVESTIGATION OF GROUNDWATER CONTAMINATION USING DC RESISTIVITY TECHNIQUE AT THE MALE HOSTEL OF ISA KAITA COLLEGE OF EDUCATION DUTSIN-MA, KATSINA STATE, NIGERIA

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ABSTRACT

A geophysical investigation involving Vertical Electrical Sounding (VES) using the Schlumberger array was carried out at the Isa Kaita College of Education specifically at the Male Hostel. The aim of the investigation is to explore the groundwater contamination of the area with the objectives: to determine the depth to basement of the study area, to determine the aquifer thickness, to determine the depth to aquifer, to determine the conductivity of the aquifer and to determine the thickness of topsoil and its variation in resistivity. A total of four (4) vertical electrical soundings were carried out using Schlumberger configuration. Terrameter signal averaging system (SAS) model 300 was the instrument used. The survey area is dominated by mainly four layers, namely: Topsoil, Weathered basement, fractured basement. The value of VES 03 and VES 04 have high electrical conductivities which likely shows they are contaminated, The topsoil resistivity along the profile ranges from approximately $1\Omega m$ to 154 Ωm, The depth to basement (basement topography) Varies from 4.94 m to 7.59 m, The thickness of aquifer range from 1 m to 6.8 m. Therefore VES 02 has high Potential for groundwater because it has retaining capacity and good aquifer thickness and is therefore recommended for borehole establishment. It is recommended that the management of Isa Kaita College of Education should provide a concrete dumping site to avoid leaching of waste in ground thereby contaminating the groundwater.

Keywords: Aquifer, Groundwater, Aquifer Thickness, Resistivity

INTRODUCTION

The most common disposal practice involves dumping of organic waste in open receptacle place in different location on the study area. The degradation of the organic waste produces stench and leachate when finally taken to dumpsites. Leachate percolation into the groundwater repositories has been identified by researched as the major groundwater contaminant the movement of leachate from the in saturated zone to the saturated zone (aquifer zone) is in fluency by the gravitational pull of the earth. The in consolidated or porous permeable nature of the soil allows for easy percolation of leachate into the subsurface aquifer zone. If the land surface is flat, the retention time of rain water will increase due to the nature of land surface, thus increasing infiltration into the surface (Nwaikwaola and Ngah, 2014). Dumpsite, which are potential source of leachate are randomly located and can be seen closed to residential areas for example, the male Hostel in Isa Kaita College of Education thus contributing to environmental problem. Increase in population, urbanization and industrialization; also encourage rapid increase in waste generation leads to increase in dumpsite location (Afolabi *et al*, 2013). Areas closed to the vicinity of dumpsites are exposed to the contaminants emanating from the dumpsite and greater possibility of groundwater contamination. The contamination to aquifer depends on factors such as the depth of water table, concentration of contaminant, permeability of subsurface layers, geological setting and the direction of groundwater flow. Groundwater compared with surface water has chemicals in the waste are dissolve by water (leaching) resulting to leachate, which have the potential to pollute groundwater after as a result of the contaminants percolation into the subsurface (Al-Tarazi, 2008). There is need for proper knowledge of the subsurface since groundwater is the major source of waste supply.

Generally, electrical resistivity method is preferred in groundwater study to its high resolving power, economic viability and it's minimal to non-invasiveness researchers have used electrical resistivity method in characterizing groundwater problem related to contamination by delineating zones of leachate generation, migration and there extent of contamination, (Bayowa, 2015, Abdullahi et al. 2013) The use of electrical resistivity method is very important in environment monitoring and assessment, This method is based on the response of the surface to the flow of current and the vertical electrical surrounding employed measured the vertical variation of resistivity with depth. The VES point where thickness of the overburden is large also have large Aquifer thickness and Vice-Versa, There is also correlation between the overburden thickness and depth to basement. Area where the overburden thickness is low have low depth to basement, such Areas are considered suitable for waste disposal system, owing to the fact that the groundwater potential in such areas are not sustainable. (Afuwai, 2013). Refuse disposal is the one of the major possible factors that leads to the underground water contamination. Large volume of waste are generated daily from industries, residential and institutional environments and this can lead to dangerous epidemic diseases if the waste are not properly disposed, improper disposal can lead to ground water pollution due to contamination by rainwater that leaches into groundwater as leachate from open dumps and sanitary landfills usually contains both biological and chemical constituents (Dauda and Osita, 2003; Slomczynska and Slomczynski, 2004). Solid waste management has emerged as one of the greatest challenges facing state and local government environmental protection agencies in Nigeria. The volume of solid waste being generated continues to increase at a faster rate than the ability of the agencies to improve on the financial and technical resources needed to parallel this growth. Solid waste management in Nigeria is characterized by inefficient collection methods, insufficient coverage of the collection system and improper disposal of solid waste (Ogwueleka, 2003; Ogwueleka, 2009). The effect of groundwater contamination in Isa Kaita College of Education is a major one. The place where the waste is not adequate, little amount available was contaminated. Hence, thus would result to in comfortable life. Therefore, there is need to located good water bearing rocks to important at domestic usage. The rate at which Isa Kaita College is becoming more populated is alarming as such there is greater demand for clean water to guard against water borne diseases such as; cholera, and typhoid. Hence, need for this research.

Dutsin-Ma LGA lies on latitude 12°26'N and longitude 07°29'E. It is bounded by Kurfi and Charanchi LGAs to the north, Kankia LGA to the east, Safana and Dan-Musa LGAs to the west, and Matazu LGA to the southeast (Figure 1). Dutsin-Ma LGA has a land size of about 552.323 km2 with a population of 169 829 as at 2006 national census (Federal Republic of Nigeria, 2012). The people are predominantly farmers, cattle rearers and traders. Katsina State is underlain by three major formations, namely; the Illo Gundumi Formation of the Sokoto Basin, the Chad formation and the Basement Complex area of Nigeria. The Illo Gundumi and the Chad formations make up 20% of the total area of Katsina State while 80% of the geology is underlined by the Basement Complex of Nigeria which is characterized by older granite, migmatite gneiss and metasediments. Field studies revealed that the crystalline rocks present in the area are gneisses, schists (younger metasediments) and the older granites. All these are rocks of the basement complex of Nigeria (Russ, 1957).

Dutsin-Ma is basically underlain by the Basement Complex area. The name “Dutsin-Ma” is coined from the Hausa word ‘Dutse’ meaning rock(s). The entire area is predominantly underlain by gneisses schists and the Older Granite. The rocks are about 600 million years old pre – protozoic. These old granites are known as Granite Suite (GEO – INVEST (NIG) LTD Katsina, 2014).

Location and Geology of the study area

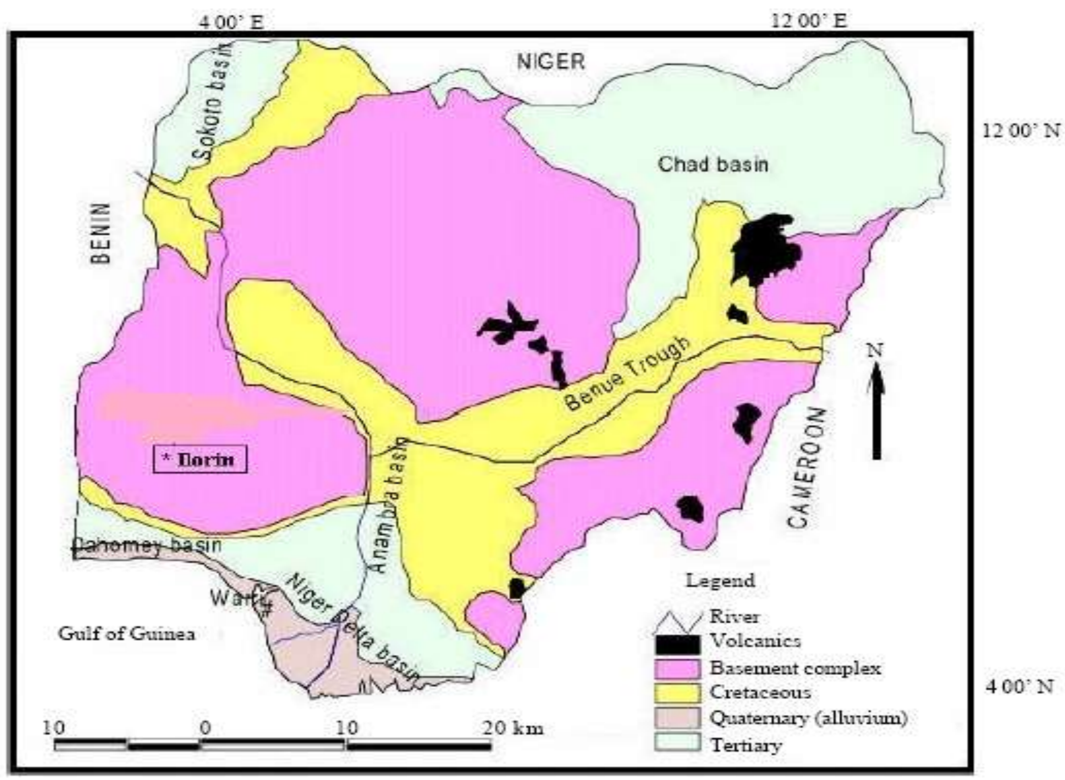


Fig. 1: The geologic map of Nigeria (from: Geological Survey of Nigeria, 1974, modified)

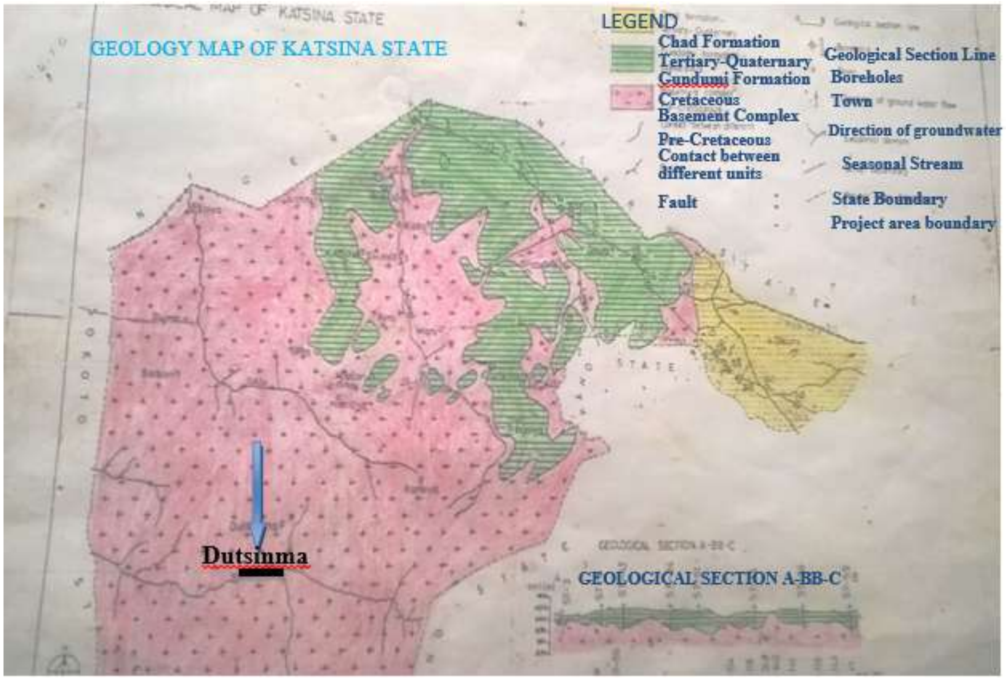


Fig. 2: Geologic map of the northern Katsina State showing Dutsinma LGA (Adapted from GEO- INVEST & BOREWELL (NIG) LTD Katsina; Modified)

Climate, Rainfall and Vegetation of the study area

The climate of Katsina State is the tropical wet and dry type (Tropical Continental Climate), classified by Koppen as Aw climate. Rainfall is between May and September with very high intensity between the months of July and August (Abaje *et al.,* 2014). The average annual rainfall varies from 550 mm in the northern part to about 1000 mm in the southern part of the state. The pattern of rainfall in the state is highly variable. As a result, the state is subject to frequent floods that can impose serious socio-economic constraints (Abaje *et al.,* 2012a).

METHODOLOGY

Resistivity method operates fundamentally on Ohm's law where current, I is sent into the ground through current electrodes alongside with the potential, V via potential electrodes. Ohm's law suggests that at constant physical conditions;

$$V \propto I \quad (1)$$

$$V = IR \quad (2)$$

Hence $R = \frac{V}{I}$ (3)

Where R = resistance (which measures an opposition of the flow of current by the "material").

The electrical resistance, *R* of a material is related to its physical dimension, cross-sectional area, *A* and length, *l* through the resistivity, ρ or its inverse, conductivity, σ by

$$\rho = \frac{1}{\sigma} = \frac{RA}{l} \quad (4)$$

There are two basic procedures in resistivity work. The procedure to be used depends on whether we are interested in lateral or vertical variations in resistivity. Resistivity surveys are made to satisfy the needs of two distinctly different kinds of interpretation problems:

- ❖ The variation of resistivity with depth, reflecting more or less horizontal stratification of earth materials; and
- ❖ Lateral variations in resistivity that may indicate soil lenses, isolated ore bodies, faults, or cavities. For the first kind of problem, measurements of apparent resistivity are made at a single location (or around a single center point) with systematically varying electrode spacing. This procedure is sometimes called vertical electrical sounding (VES), or vertical profiling. The first is called horizontal or trenching profiling.

The basic unit in resistivity survey which was also the principal instrument used for this survey was the ABEM Signal Averaging System, **(**SAS 300) Terrameter other instruments include copper electrodes, 2 reels of wire and connecting wires, twine ropes, crocodile clips, hammers, measuring tapes and the compass were assembled for the field survey.

Electrode Layouts

An enormous number of electrode spreads has been used in resistivity at various time particularly, however the electrodes are almost always in line, otherwise interpretation of result becomes difficult and then field work is complicated. In resistivity surveys there are differences in the results one gets depending on the technique and the kind of arrangement of the electrode (array) adopted for the field survey. For this study the Wenner array and Schlumberger array were adopted due to it less sensitivity to lateral variations in resistivity, it slight fast speed in field operation and provides good depth sensitivity

Wenner Array

This array consists of four electrodes in line, separated by equal intervals. The two outer electrodes are typically the current (source) electrodes and the inner two electrodes are the potential (receiver) electrodes. The array spacing expands about the array midpoint while maintaining an equivalent spacing between each electrode (see Fig 3).

The advantages of the winner array are that the apparent resistivity is easily calculated in the field and the instrument sensitivity is not as crucial as with other array. It is also very sensitive to near surface in homogeneities which may skew deeper electrical responses.

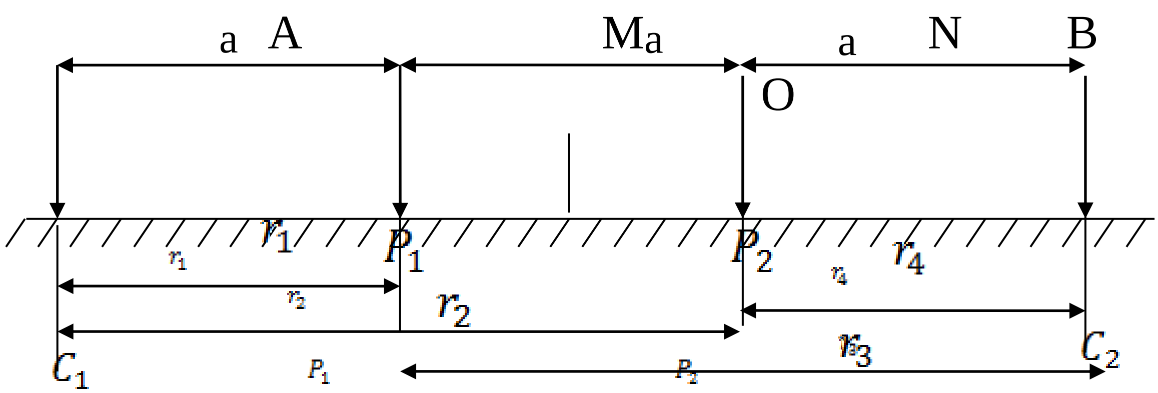
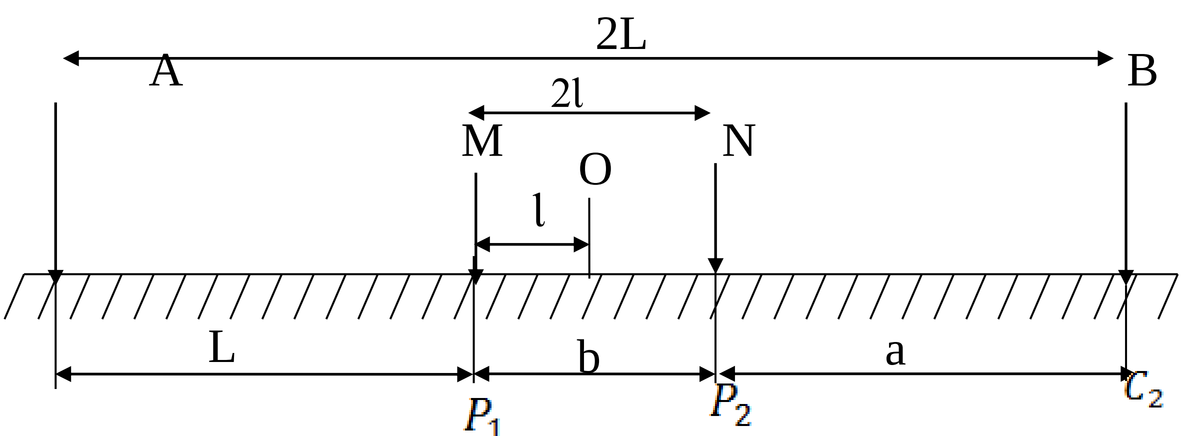


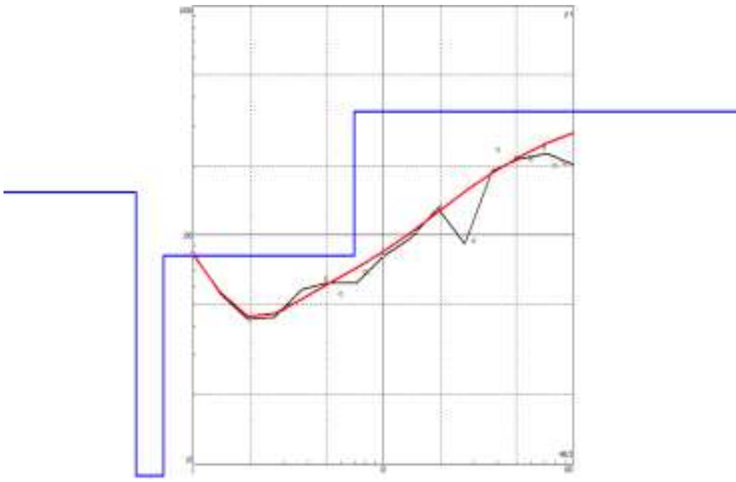
Fig. 3 Showing Wenner array

Schlumberger Array
This type of configuration deals with vertical electrical sounding. Electrical sounding is the process by which the variation of resistivity with depth below a given point on the ground surface is deduced and it can be correlated with the available geological information in order to infer the depths (or thicknesses) and resistivity of the layers (formations) present. The procedure is based on the fact that the current penetrates continuously deeper with the increasing separation of the current electrodes. Fig. 4 bellow Showing Schlumberger array, the current electrodes are spaced much further apart than the potential electrodes. The potential electrodes remain fixed while the current electrodes are expanded symmetrically about the center of the spread.



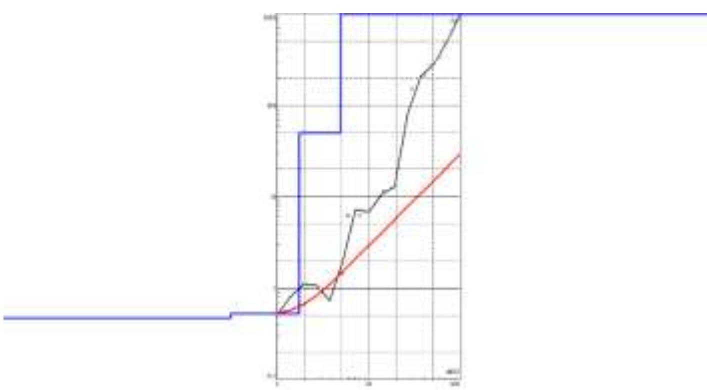
RESULTS AND DISCUSSION
The data analysis was performed using IPI2Win computer software for the automatic interpretation of Schlumberger sounding curves. This method was used to obtain the model for the apparent resistivity of each sounding. Based on the IPI2Win software used, the field curves were found to be averagely four (4) layers (Figure 5). The results of the Geoelectrical soundings delineate swells and swales in the surface of the crystalline bedrock, which is overlain by about ~50 m of surficial deposits (sandy clay/sand layer underlain by weathered/ fractured basement).
The soundings also identified plumes of contaminated water issuing from the sewage ponds. The result of the geophysical mapping was corroborated by the geologic logging of the pits and the chemical analyses of the water samples obtained from them.
Base on the results of the interpreted VES data the resistivity of the topsoil varies from 154 m to 115 Ωm with an average value of 134.5 Ωm. The thickness of the weathered basement varied from 0.238 to 1.82m with an average value of 1.029 m, while depth to this layer varies from 0.747 to 1.49 m with an average value of 1.1185 m. The thickness of the fractured basement vary from 6.84 to 3.2 m with an average value of 5 m, while depth to this layer vary from 7.59 to 4.94 m with an average value of 6.265 m. The thickness of the aquifer varies from 0.238 to 1.82 m with an average value of 1.029 m, while depth to aquifer varies from 0.747 to 1.49 m with an average value of 1.1185 m. The depth to aquifer varies from 0.698-1.74 m with an average value of 1.219 m. The depth to basement varies from 7.59 to 4.94 m with an average value of 6.265 m. The thickness of top soil varies from 0.509 to 0.313 with an average value of 0.411 m. Correlating the resistivity of the topsoil with the aquifer thickness and depth to basement of the individual VES points, it was observed that in the regions of high resistivity of the topsoil, aquifer thickness and depth to basement are relatively low and vice versa. Similar studies in

basement complex terrain reveal that areas with thick overburden cover have high potential for groundwater



N	ρ	h	d	Alt
1	154	0.5	0.5	-0.5
2	6.29	0.198	0.698	-0.6977
3	81	6.33	7.03	-7.025
4	347			

A typical curve for VES 02



N	ρ	h	d	Alt
1	0.471	0.313	0.313	-0.3131
2	0.525	1.42	1.74	-1.738
3	50.3	3.2	4.94	-4.936
4	10140			

A typical curve for VES 03

Figure 5. Typical digitized/field curves of VES Points 01 and 02

Table 1: Station Interval and the Resistivity Reading of the horizontal Profiling

Station number	Distance (m)	Resistivity (Ωm)
1	20	1.25
2	40	0.31
3	60	0.48
4	80	0.64
5	100	0.55 VES 02
6	120	0.62
7	140	1.16
8	160	0.47 VES 01
9	180	0.63

Vertical Electrical Soundings (VES) Result

Table 2: Shows the Readings for VES01

$\frac{AB}{2}$	$\frac{MN}{2}$	Resistivity(Ω)	Geometric factor K(m)	Apparent Resistivity(Ωm)
1	1	40.8	2.36	96.29
2	1	4.33	11.8	11.8
3	1	2.24	27.5	61.6
5	1	0.74	77.8	57.57
6	1	0.64	112	71.68
6	2	1.33	55	73.18
8	2	0.55	99	54.47
10	2	0.37	156	57.72
10	5	1.13	58.9	66.57
15	5	0.44	137	60.28
20	5	0.22	247	54.34
30	5	0.10	562	56.20
40	5	0.06	1001	60.06
40	15	0.42	323	135.66
50	15	0.41	512	158.72
60	15	0.26	742	192.92
70	15	0.22	1014	223.08
80	15	0.19	1320	250.8
80	30	0.43	647	278.21
90	30	0.33	825	272.25
100	30	0.39	1024	399.36

Table 3: Shows the Readings for VES02

$AB/2$	MN(m)	Resistance(Ω)	Geometric factor K(m)	Apparent Resistivity(Ωm)
1	1	2.1	2.36	52.56
2	1	2.26	11.8	26.69
3	1	1.08	27.5	29.7
5	1	0.52	77.8	40.46
6	1	0.31	112	34.72
6	2	0.62	55	34.10
8	2	0.43	99	42.57
10	2	0.32	156	49.92
10	5	0.82	58.9	48.29
15	5	0.45	137	61.65
20	5	0.32	247	79.04
30	5	0.10	562	56.20
40	5	0.14	1001	140.14
40	15	0.43	323	138.89
50	15	0.25	512	128
60	15	0.17	742	126.14
70	15	0.14	1014	141.96
80	15	0.09	1320	118.80
80	30	0.31	647	200.56
90	30	0.25	825	206.25
100	30	0.22	1024	225.28

Table 4 Shows the Readings for VES03

S/N	AB/2(m)	MN/2(m)	Resistance(Ω)	Geometric factor K(m)	Apparent Resistivity (Ωm)
1	1	0.5	27.4	2.36	64.664
2	2	0.5	12.55	11.8	148.09
3	3	0.5	4.58	27.5	125.95
4	5	0.5	2.35	77.8	182.83
5	6	0.5	7.09	112	794.04
6	6	1.0	2.70	55	148.5
7	8	1.0	1.53	99	151.47
8	10	1.0	1.05	156	163.8
9	10	2.5	0.82	58.9	48.298
10	15	2.5	0.60	137	82.2
11	20	2.5	0.40	247	98.8
12	30	2.5	1.90	562	1067.8
13	40	2.5	1.51	1001	1511.51
14	40	7.5	1.28	323	413.44
15	50	7.5	1.04	512	532.48
16	60	7.5	0.90	742	667.8
17	70	7.5	0.91	1014	922.74
18	80	7.5	0.93	1320	1227.6
19	80	15	0.94	647	627.59
20	90	15	0.96	825	792
21	100	15	0.93	1024	952.32

Table 5: Shows the Readings for VES04

S/N	$\frac{AB}{2}(m)$	$\frac{MN}{2}(m)$	Resistance(Ω)	Geometric factor K(m)	Apparent Resistivity (Ωm)
1	1	0.5	97.5	2.36	230
2	2	0.5	39.2	11.8	462.56
3	3	0.5	17.8	27.5	489.5
4	5	0.5	10.47	77.8	814.566
5	6	0.5	33.5	112	3752
6	6	1.0	17.0	55	935
7	8	1.0	9.44	99	934.56
8	10	1.0	5.76	156	898.56
9	10	2.5	3.8	58.9	223.82
10	15	2.5	2.3	137	315.1
11	20	2.5	12	247	2964
12	30	2.5	6.4	562	3596.8
13	40	2.5	3.2	1001	3203.2
14	40	7.5	2.1	323	678.3
15	50	7.5	1.33	512	680.96
16	60	7.5	1.20	742	890.4
17	70	7.5	0.6	1014	608.4
18	80	7.5	0.3	1320	396
19	80	15	0.11	647	71.17
20	90	15	0.10	825	82.5
21	100	15	0.11	1024	112.64

Depth to basement in Figure 6 below shows that the maximum resistivity value is 7.6 m while the minimum is 3.2 m. The study reveals high values of depth to basement where notice at the North-East of the profile with values ranging from 6.2-7.6 m at the central part of the profile the depth to basement varies considerately with values ranging from 5.4-6 m. The lowest values of the depth to basement where noticed at the South-West of the survey area with values ranging from 3.2-4.6 m. When correlated with the resistivity of the topsoil and aquifer thickness of the individual VES points, it was observed that in the regions of relatively high depth to basement, resistivity of the topsoil is relatively high and the aquifer thickness is relatively low and vice versa. The resistivity of the Top soil map in Figure 7 shows that the maximum resistivity value is 160 Ωm while the minimum is -10 Ωm. The highest resistivity value of the topsoil where at the far eastern part of the survey area with value ranging from 110-160 Ωm the lower values of the resistivity value of the topsoil where noticed at the North-

West with little traces at the Southern part with values ranging 0-20Ωm. When correlated with the aquifer thickness and depth to basement of the individual VES points, it was observed that in the regions of high resistivity, aquifer thickness and depth to basement are relatively high and vice versa. The thickness of aquifer map in Figure 8 shows that the maximum resistivity value is 0.32 m while the minimum is 0.195 m. The study reveals area with the highest aquifer thickness is around North-East part and toward the central part of the survey area with values ranging from 0.28-0.32 m lowest aquifer thickness value is also found ranging from 0.195-0.26 m. However we also noticed at the South-West part of the area is characterized by relatively lower aquifer thickness values ranging from 0-0.24 m. When correlated with the resistivity of the topsoil and depth to basement of the individual VES points, it was observed that in the regions of relatively low aquifer thickness, resistivity of the topsoil is relatively high and the depth to basement is relatively high and vice versa.

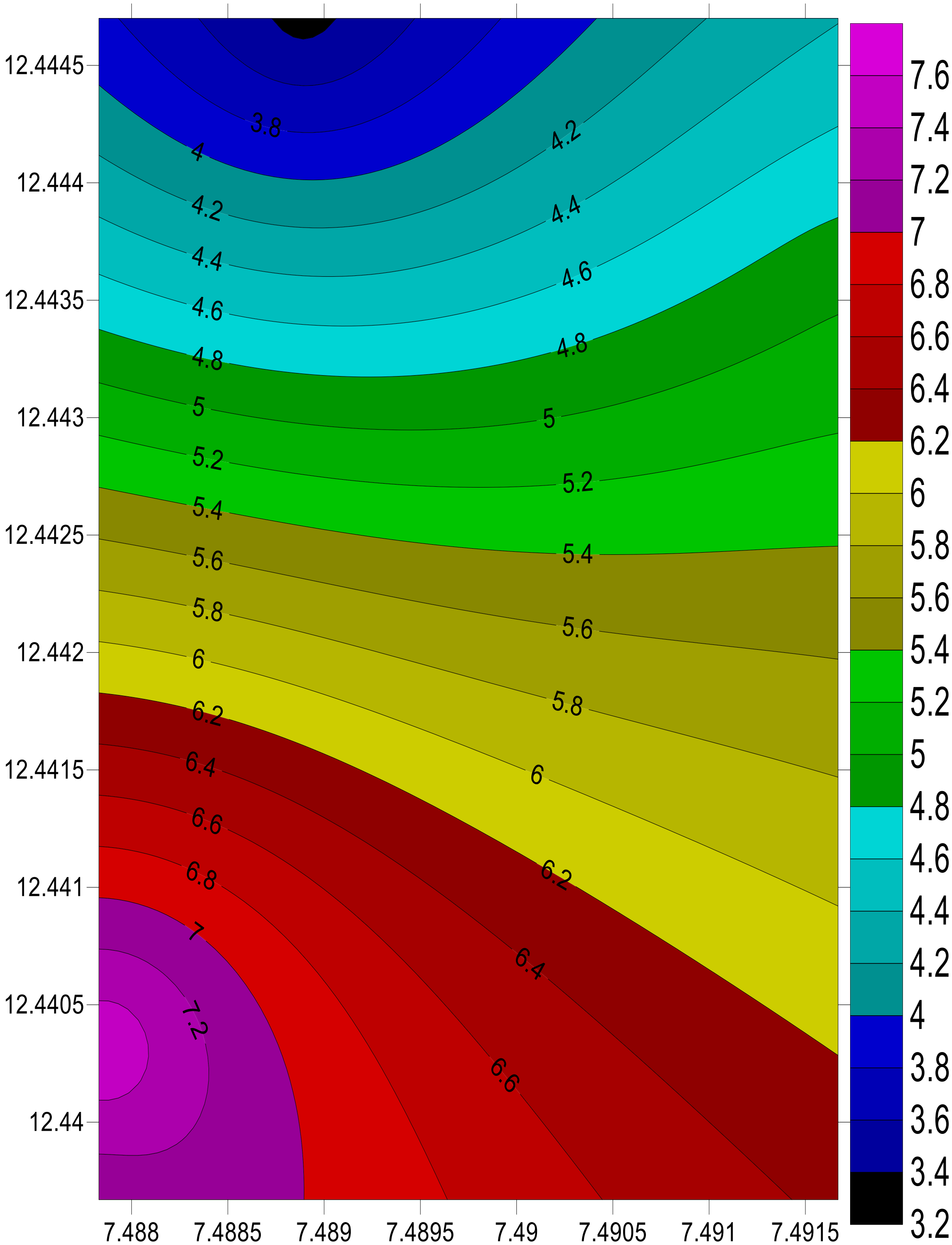


Figure 6: Depth to Basement

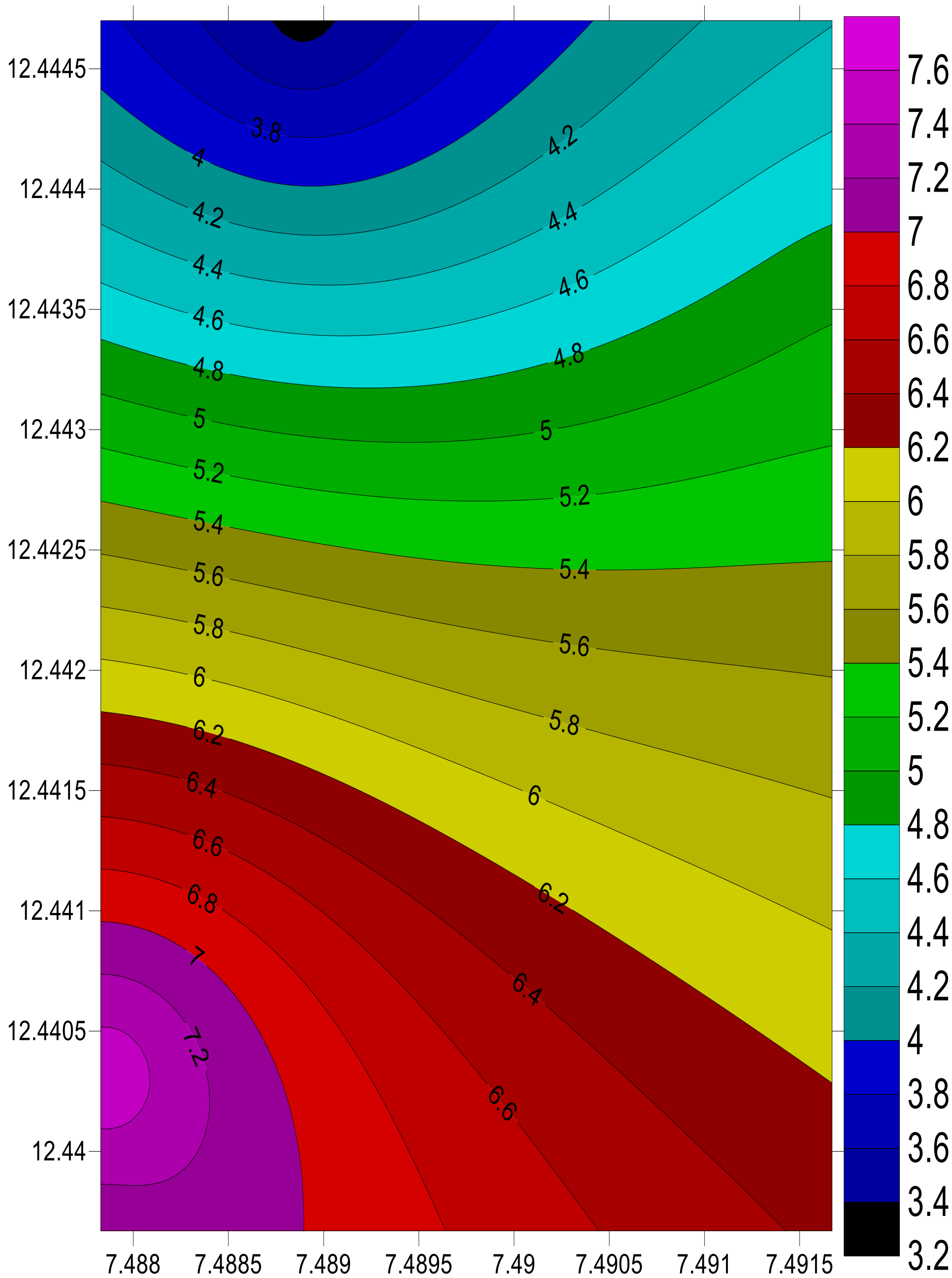


Figure 7: Resistivity of Topsoil

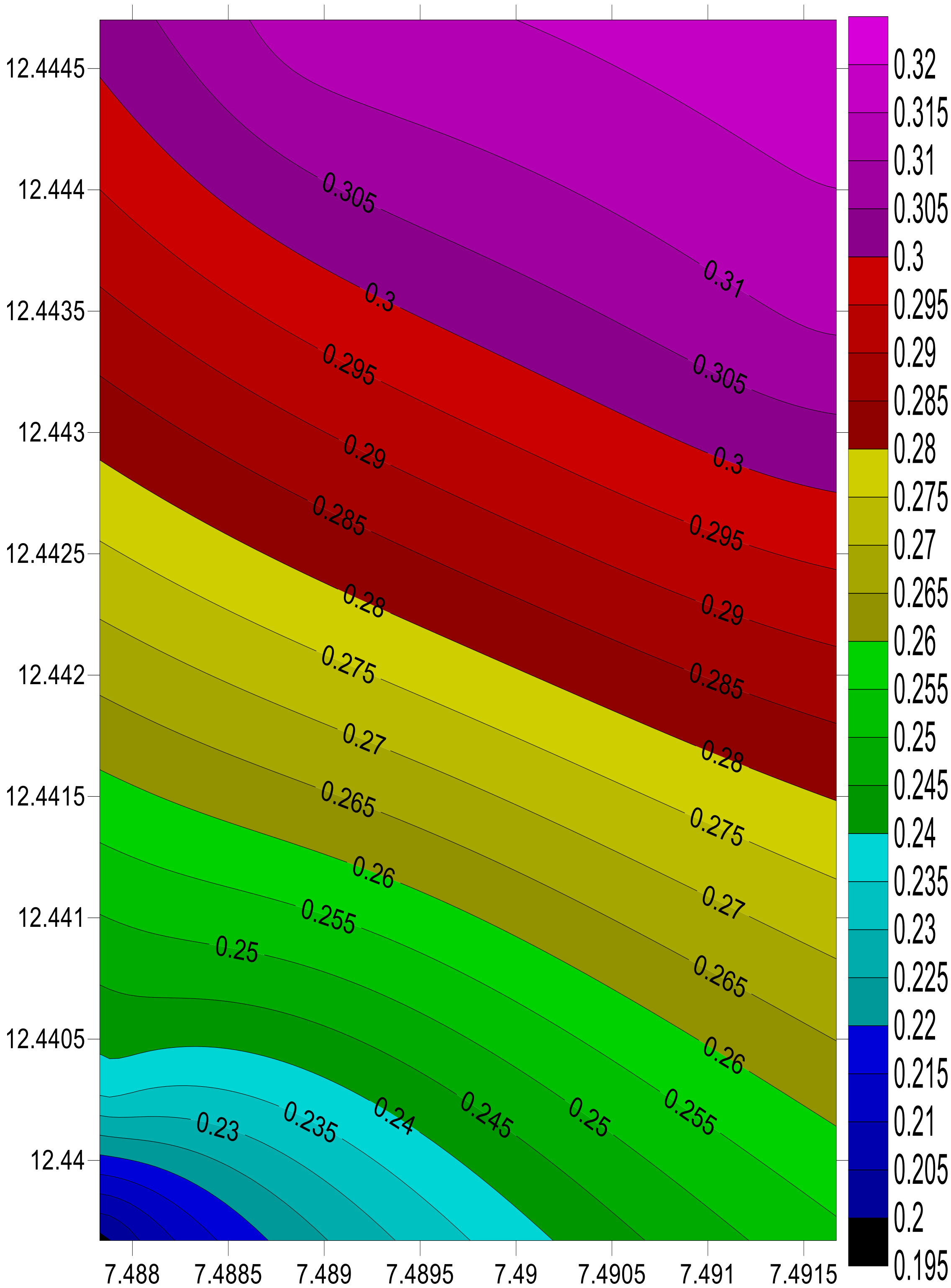


Figure 8: Aquifer thickness map of the Area

Four (4) VES Points were sounded along the Profile of 200m length in the N-S direction. The image (Figure 9: Shows that the groundwater bearing layer is found at VES01 and VES02 with the aquifer thickness of 6.84 m and 6.33 m respectively. The topsoil resistivity along the profile ranges from approximately 1 Ωm to 10140 Ωm. The depth to basement (basement topography) varies from 11.0 m to 20.0 m. The image does not show much evidence of groundwater contamination along the dumpsite.

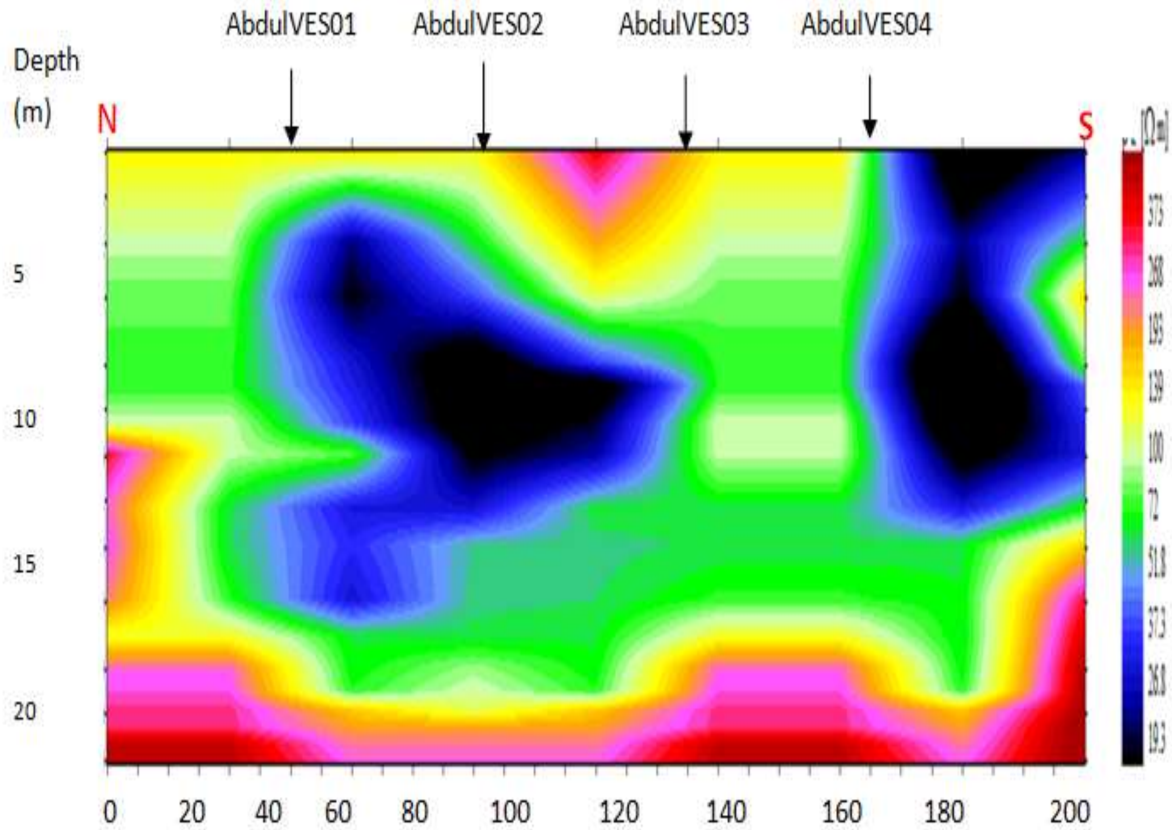


Figure 9: Geoelectric Section along the Profile

CONCLUSION

Vertical electrical sounding and Schlumberger array to delineate the sub-surface geology of the study area. Terrameter signal averaging system (SAS) model 300 was the instrument used. Five VES stations were probed within the study area and the data obtained were interpreted using IPI2win and SURFER 10 computer software. The survey area is dominated by mainly four layers, namely: Topsoil, Weathered basement, fractured basement and Fresh basement. The weathered and fractured layers constitute the aquiferous zone in all the stations. The Third aquifer layer was identified along the Forth layer with resistivity values ranging from 0.471 to 10140 Ωm and depth of 0.313 to 3.31 m. Analysis of this layer revealed that this aquifer is unconfined and prone to pollution since it underlay's a loose sand and very thin clayey sand formation. The First aquifer located in the Second layer is a viable portable water formation whose resistivity values ranged between 115 and 29997 Ωm. While the depth was between 0.509 and 7.59 m.

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