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EXPLORATORY ENVIRONMENTAL SCIENCE RESEARCH

Original Research Article

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Geoelectrical estimation of depth to fractured shale aquifers within Alex Ekwueme Federal University Ndufu Alike, South Eastern Nigeria

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ABSTRACT

The depths to the fractured Shale aquifer at various points within the study area were determined using the electrical resistivity method. Twenty (20) vertical electrical soundings (VES) in the Schlumberger configuration were acquired with ABEM SAS 1000 Terrameter with a maximum half current (AB/2) electrode spacing of 200m. We determined layer parameters using partial curve matching techniques while processing and modelling was carried out with the IPI2win™ software. The VES results were interpreted to obtain layer parameters (aquifer thickness, resistivity and depth to aquifer) for the entire area. Interpretative cross-sections taken along three profiles was used to delineate aquifer thickness and the depth to the fractured shale aquifers in the study area. Results show that aquifer thickness ranges from 5.5 m to 44.7m while depth to aquifer ranges from 10.93m to 56.9m. These findings are fundamentally very important and should be considered exploiting for water resources in the area.

KEYWORDS

Modelling; Fractures; Shale; VES; Water.

INTRODUCTION

Alex Ekwueme Federal University Ndufu Alike was established in 2011 by the Goodluck Ebele Jonathan adminstration as part of efforts to increase access to tertiary education in Nigeria. The University is situated in Ikwo, on Asu River Shales of the Lower Benue Trough. Shales have numerous tiny pores in their matrix but very little or no permeability. Shales are classified as aquicludes because of their low permeability[20]. It is a well known fact that Shales in their natural state are not aquifers due to their low or near zero permeability. Shale permeability could be improved through fracturing occasioned by tectonic or human activities. The Benue Trough represents the failed arm of an RRF triple junction formed as a result of the separation of South America from the African continent in the early Cretaceous[6,7,13]. The Benue Trough is geographically sub-divided into Upper, Middle and Lower regions[21]. The present study falls within the Lower Benue Trough and several research works have been documented on the application of electrical resistivity method for ground water search in some parts of the Lower Benue Trough[1-5,8-12,14-19].

In the present study, we shall use the electrical resistivity method to characterize fractured shale aquifers within Alex Ekwueme Federal University Ndufu Alike. The findings will be invaluable to ground water development in the area

THE STUDY AREA: LOCATION, ACCESSIBILITY, TOPOGRAPHY, AND GEOLOGY

The study area is located between latitudes 6.113° - 6.137°N and Longitudes 8.137° - 8.153° E with an average elevation of 52m (Figure 1). The area is accessible through Abakaliki-Enyigba-Ikwo or Onueke-Ezza routes. The area is situated within the tropical rain forest of Nigeria. Two seasons are prominent in the area - dry and rainy seasons. It has a humid tropical climate with high temperature, with a mean daily maximum and minimum annual temperatures of 32.2°C and 23°C respectively. The annual rainfall rate is about 1820mm while mean daily temperature ranges from 30°C during the rainy season to about 34°C in the dry season. The annual mean of the relative humidity in the area is 71% while the rate of evaporation is about 3.4mm/yr. Soil temperature measurements at depths of 5cm, 10cm, 20cm, 30cm, 50cm and 100cm gave values of 32°C, 31°C, 30°C, 30.5°C, 27°C and 30°C respectively while the average monthly sunshine hours is about 6.6 hours (Federal University Ndufu Alike Ikwo Weather Station data). The study area is drained by the Ebonyi River and its numerous tributaries. The pattern is dendritic.

Geologically, the study area falls within the Lower Benue Trough. The dominant lithology in the study area is Asu River Group and comprises of Shales which are generally weathered, fissile, thinly laminated and highly fractured and varies between greyish brown to pinkish red in colour. The Asu River Group is the oldest formation directly overlying the basement in the lower Benue Trough.

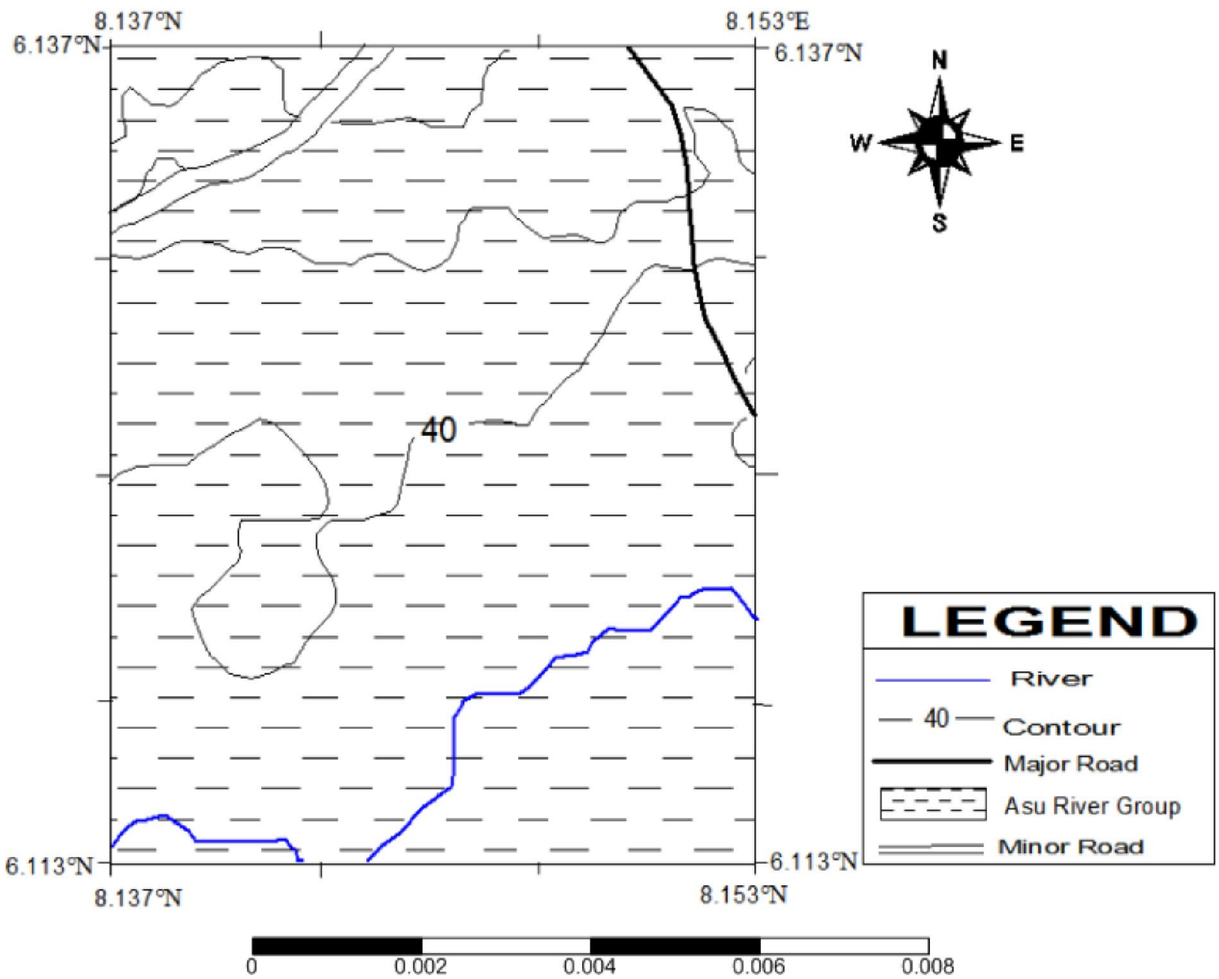

Figure 1: Geology map of the study area

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MATERIALS AND METHODS

The study started with literature review of studies done in the study area and other areas with similar geology in order to provide a background for the study. This was followed by the acquisition of 20 Schlumberger vertical electrical soundings (VES), with ABEM SAS 1000 Terrameter and a maximum current electrode (AB) spacing of 200 m. The technique involves the passage of current into the ground through a pair of current electrodes (AB) and measuring the resultant potential with another pair of potential electrodes (MN) (Figure 2).

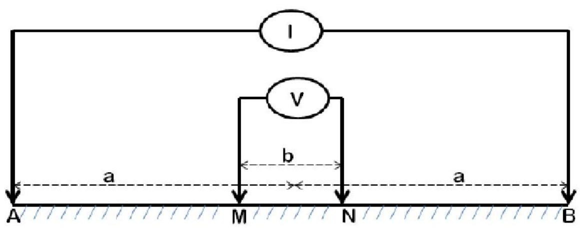

Figure 2: Schematic of the Schlumberger method

The acquired data were converted to apparent resistivity by multiplying with the Schlumberger Geometric factor K such that:

$$\rho_a = \pi \left(\frac{a^2}{b} - \frac{b}{4} \right) R$$

where $\pi\left(\frac{a^2}{b} - \frac{b}{4}\right)$ represents the geometric factor for the Schlumberger array. a = Half current electrode spacing; b = Potential electrode spacing; R = measured resistance $= \frac{V}{I}$, where V = Voltage and I = current.

The apparent resistivity values were plotted on the ordinate (y-axis) against half current electrode spacing on the abscissa (x-axis) on a bi-logarithmic graph paper. Modelling, processing and determination of layer thicknesses was done using the IP12 Win software. The results were interpreted both qualitatively and quantitatively to determine depths to fractured Shale aquifers within the study area.

RESULTS AND DISCUSSION

Layer parameters

TABLE 1: Layer parameters of the study area

VES No.	Layers	Thickness (m)	Depth (m)	Resistivity (Ωm)	Inferred lithology
VES 1	1	0.983	0.983	1961	Laterite
	2	2.18	3.17	622	brownish Shale
	3	13.8	17	37.7	partly Fractured Shale Grey
	4	12	29	7.53	Fractured Shale
	5	-	-	1838	Hard Shale
VES 2	1	3.23	3.23	892	Laterite
	2	5.3	8.54	21.2	brownish Shale
	3	10.1	18.6	111	partly Fractured Shale
	4	17	35.8	9.31	Fractured Shale
	5	-	-	1478	Dark Shale
VES 3	1	0.65	0.65	892.7	Latertie
	2	2.13	2.78	170.6	brownish Shale
	3	5.6	8.41	20.31	partly Fractured Shale
	4	13	21.4	279	Fractured Shale
	5	-	-	15.63	Dark Shale
VES 4	1	0.5	0.5	789	Latertic soil
	2	0.75	1.25	248	brownish Shale
	3	19.8	21.1	79	partly Fractured Shale
	4	21.1	43.2	11.9	Fractured Shale
	5	-	-	461	Dark Shale

(Continue TABLE 1)

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VES No.	Layers	Thickness (m)	Depth (m)	Resistivity (Ωm)	Inferred lithology
VES 5	1	0.5	0.5	1379	Laterite
	2	2.181	2.681	489.7	brownish Shale
	3	2.742	5.423	911.7	Dark Shale
	4	5.504	10.93	72.7	Fractured Shale
	5	-	-	26.49	Fractured Shale
VES 6	1	0.53	0.53	676.1	Laterite
	2	3.4	3.9	320.9	brownish Shale
	3	8.2	12.13	12.02	Fractured Shale
	4	44.7	56.9	40.31	Fractured Shale
	5	-	-	1119	Dark Shale
VES 7	1	0.8	0.8	634	Laterite
	2	1.81	2.5	142	brownish Shale
	3	4.61	7.18	32	Fractured Shale Grey
	4	29	36.2	164	Fractured Shale
	5	-	-	19.4	Dark Shale
VES 8	1	0.6	0.6	1184	laterite
	2	4.4	4.9	165.6	brownish Shale
	3	12.5	17.43	35.28	Fractured Shale
	4	12.83	30.22	554.8	Dark Shale
VES 9	1	1.69	1.69	1296	laterite
	2	3.11	4.8	75.1	brownish Shale
	3	5.25	10	265	Shale
	4	19.8	29.8	20.4	Fractured Shale
	5	-	-	5318	Hard Shale
VES 10	1	0.5	0.5	594	Laterite
	2	1.32	1.82	335	brownish Shale
	3	10.3	12.1	86.3	partly Fractured Shale
	4	21	33.1	21.1	Fractured Shale
	5	-	-	977	Dark Shale
VES 11	1	0.623	0.623	698.3	Laterite
	2	5.3	5.9	160.6	brownish Shale
	3	14.8	20.67	47.17	Fractured Shale
	4	25.52	46.2	332.5	Hard Shale
VES 12	1	1.202	1.202	404.3	Shaley Lateritic overburden
	2	6.044	7.247	30.44	brownish Shale
	3	6.884	14.13	97.52	partly Fractured Shale
	4	15.96	30.1	5.391	Fractured Shale
	5	-	-	900.5	Dark Shale
VES 13	1	0.5	0.5	330.1	Shaley Lateritic overburden
	2	0.7	1.2	122.2	brownish Shale
	3	1.7	2.9	12.18	partly Fractured Shale
	4	26.75	29.63	34.42	Fractured Shale
	5	-	-	772.5	Hard Shale

(Continue TABLE 1)

VES No.	Layers	Thickness (m)	Depth (m)	Resistivity (Ωm)	Inferred lithology
VES 14	1	1.23	1.23	1099	Laterite
	2	7.61	8.84	14.6	brownish Shale
	3	42.8	51.6	43.4	Fractured Shale
	4	-	-	24.8	Fractured Shale
VES 15	1	0.5	0.5	1144	Laterite
	2	1.9	2.4	327.3	brownish Shale
	3	3.7	6.1	43.57	partly Fractured Shale
	4	32.8	38.9	87.68	Fractured Shale
	5	-	-	28.12	Fractured Shale
VES 16	1	0.53	0.53	1268	Laterite
	2	0.33	0.9	3651	brownish Shale
	3	6.95	7.81	55.6	partly Fractured Shale
	4	6.87	14.7	11.4	Fractured Shale
	5	-	-	341	Shale
VES 17	1	1.43	1.43	438	Laterite plus shale
	2	2.26	3.7	92.2	brownish Shale
	3	6.15	9.84	405	Shale
	4	17.4	27.3	13.5	Fractured Shale
	5	-	-	745	Hard Shale
VES 18	1	0.51	0.51	332	Loose superficial deposit
	2	0.6	1.1	955	brownish Shale
	3	0.34	1.44	11.2	partly Fractured Shale
	4	14.1	15.6	52.2	Fractured Shale
	5	-	-	798	Hard Shale
VES 19	1	2.14	2.14	913	Laterite
	2	2.89	5.03	21.9	brownish Shale
	3	7.46	12.5	148	partly Fractured Shale
	4	16.4	28.9	13	Fractured Shale
	5	-	-	3993	Dark Shale
VES 20	1	2.1	2.1	917	Latertie
	2	3.82	5.92	31.1	Brownish Shale
	3	9.98	15.9	107	Partly Fractured Shale
	4	21.3	37.2	16.9	Fractured Shale
	5	-	-	2928	Dark Shale

Selected aquifer parameters

TABLE 2: Selected aquifer parameters of the study area

VES No.	Aquifer Thickness (m)	Aquifer Depth (m)	Aquifer Resistivity (Ωm)	Inferred lithology	VES No.	Aquifer Thickness (m)	Aquifer Depth (m)	Aquifer Resistivity (Ωm)	Inferred lithology
VES 1	12	29	7.53	Fractured Shale	VES 6	44.7	56.9	40.31	Fractured Shale
VES 2	17	35.8	9.31	Fractured Shale	VES 7	29	36.2	16	Fractured Shale
VES 3	13	21.4	279	Fractured Shale	VES 8	12.5	17.43	35.28	Fractured Shale
VES 4	21.1	43.2	11.9	Fractured Shale	VES 9	19.8	29.8	20.4	Fractured Shale
VES 5	5.504	10.93	72.7	Fractured Shale	VES 10	21	33.1	21.1	Fractured Shale

(Continue TABLE 2)

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VES No.	Aquifer Thickness (m)	Aquifer Depth (m)	Aquifer Resistivity (Ωm)	Inferred lithology	VES No.	Aquifer Thickness (m)	Aquifer Depth (m)	Aquifer Resistivity (Ωm)	Inferred lithology
VES 11	14.8	20.67	47.17	Fractured Shale	VES 16	6.87	14.7	11.4	Fractured Shale
VES 12	15.96	30.1	5.391	Fractured Shale	VES 17	17.4	27.3	13.5	Fractured Shale
VES 13	26.75	29.63	34.42	Fractured Shale	VES 18	14.1	15.6	52.2	Fractured Shale
VES 14	42.8	51.6	43.4	Fractured Shale	VES 19	16.4	28.9	13	Fractured Shale
VES 15	32.8	38.9	87.68	Fractured Shale	VES 20	21.3	37.2	16.9	Fractured Shale

Aquifer thickness across the study area

We determined the variations of aquifer thickness within the study area by evaluating three cross-sections (AB,CD and EF) taken along the NE, NE-SW and NS portions of the study area (Figure 3).

Cross-section along AB

The cross-section traversed VES 10,11,12,13,14, 15 and 16 with varying thicknesses along the profile. The fractured Shale aquifer thickness ranges from 6.87m at VES 16 to 42.8m at VES 14.

Cross-section along CD

The cross-section traversed VES 3,4,5 and 6 with thickness values ranging from 5.5 m at VES 5 to 44.7m at VES 6, with an average of 21.1 m.

Cross-section along EF

The cross-section traversed VES 1,2,17,19 and 20 with thickness values ranging from 12 m at VES 1 to 21.3 m at VES 20, with an average of 16.82 m.

Depth to aquifer within the study area

The depth to the fractured Shale aquifer was evaluated along three cross sections - AB, BC and CD (Figure 4). AB falls within the southern section of the study area along an E-W direction, BC was taken along the NW-SW section of the study area while CD falls within the North Eastern section of the study area (Figure 4).

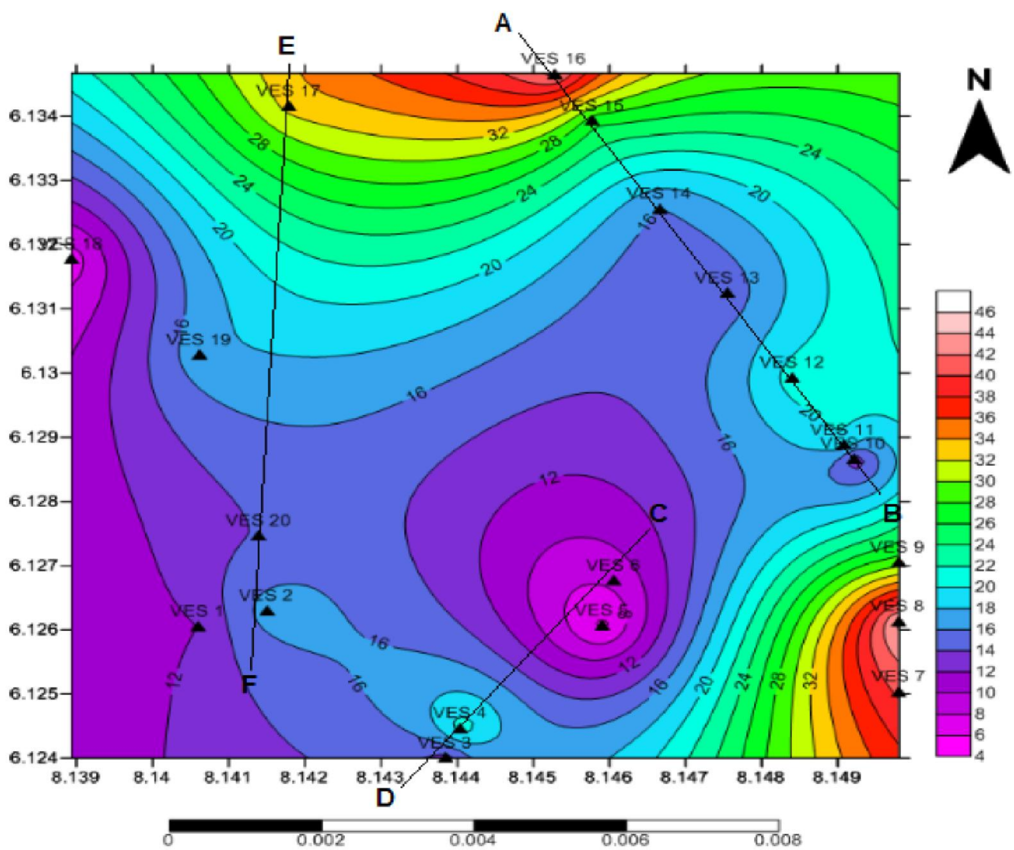

Figure 3: Map of the study area showing aquifer thickness

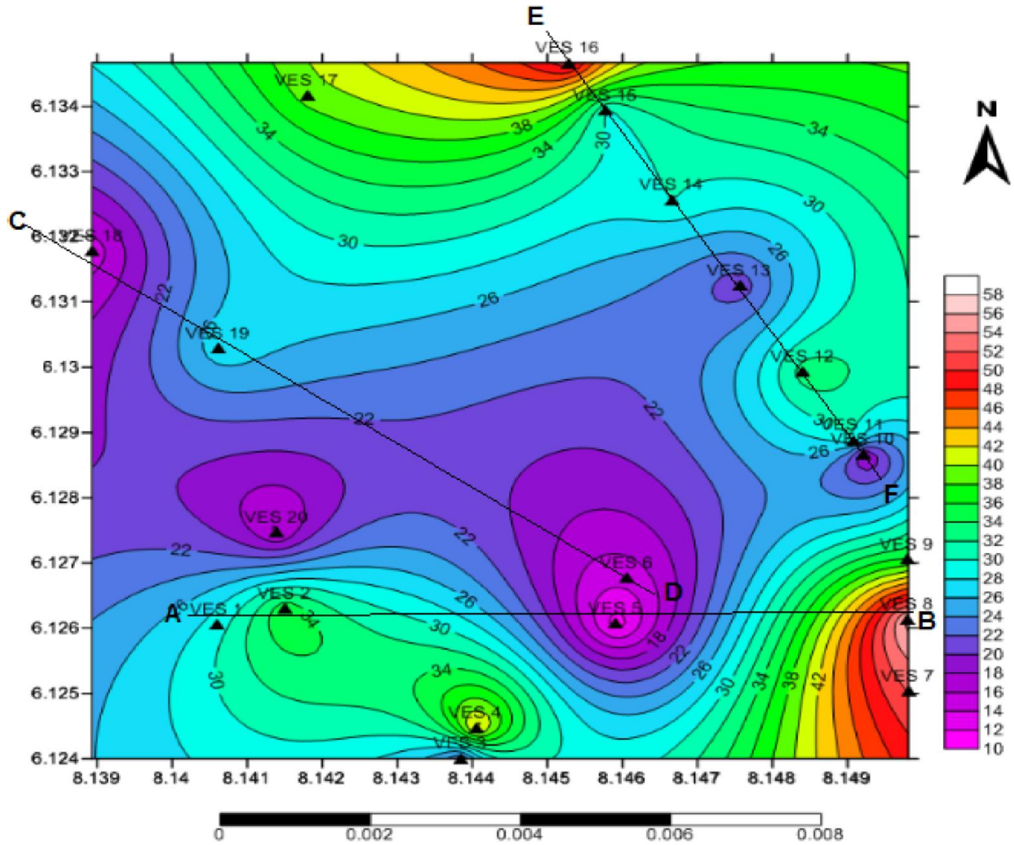

Figure 4: Map of the study area showing aquifer thickness

Cross-section along AB

The cross-section stretches along an E-W direction within the southern portion of the study area (Figure 5). The profile traversed VES 1,2,5 and 8. The depth to aquifer ranges from 10.93m at VES 5 to 35.8m at VES 2 (Figure 5).

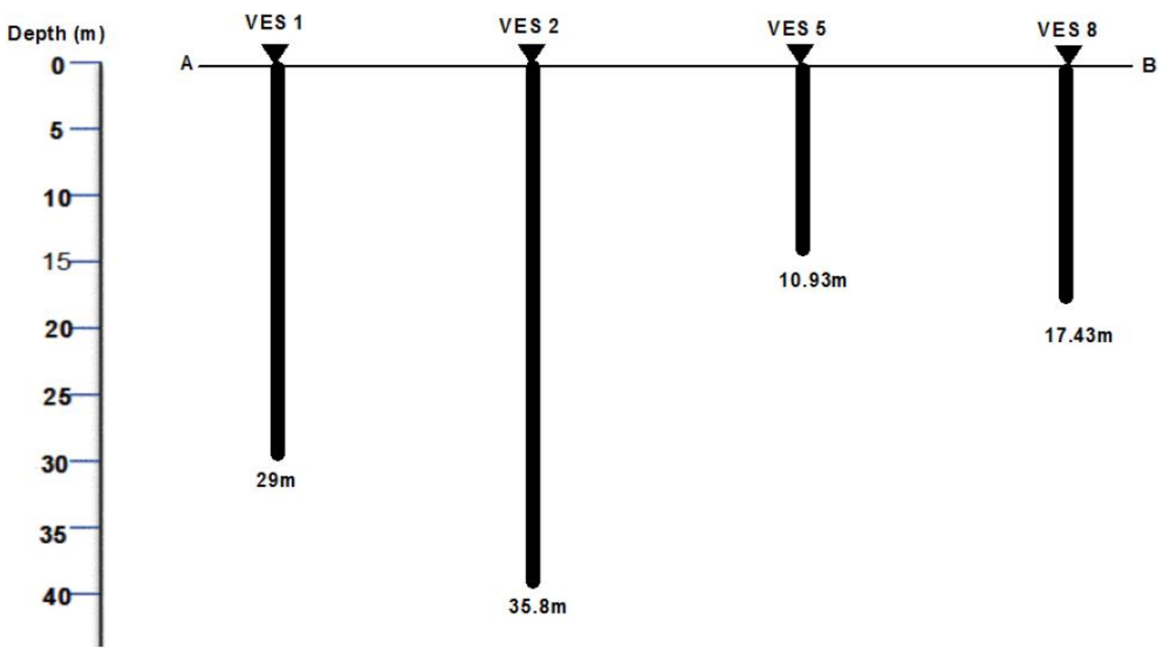

Figure 5: Cross-section AB showing depth to the fractured Shale aquifer

Cross-section along CD

The cross-section was taken along the NW-SW flank of the study area and cuts across VES 6, 8 and 19 respectively. The depth to the aquifer ranges from 17.43m at VES 8 to 56.9m at VES 6 (Figure 6).

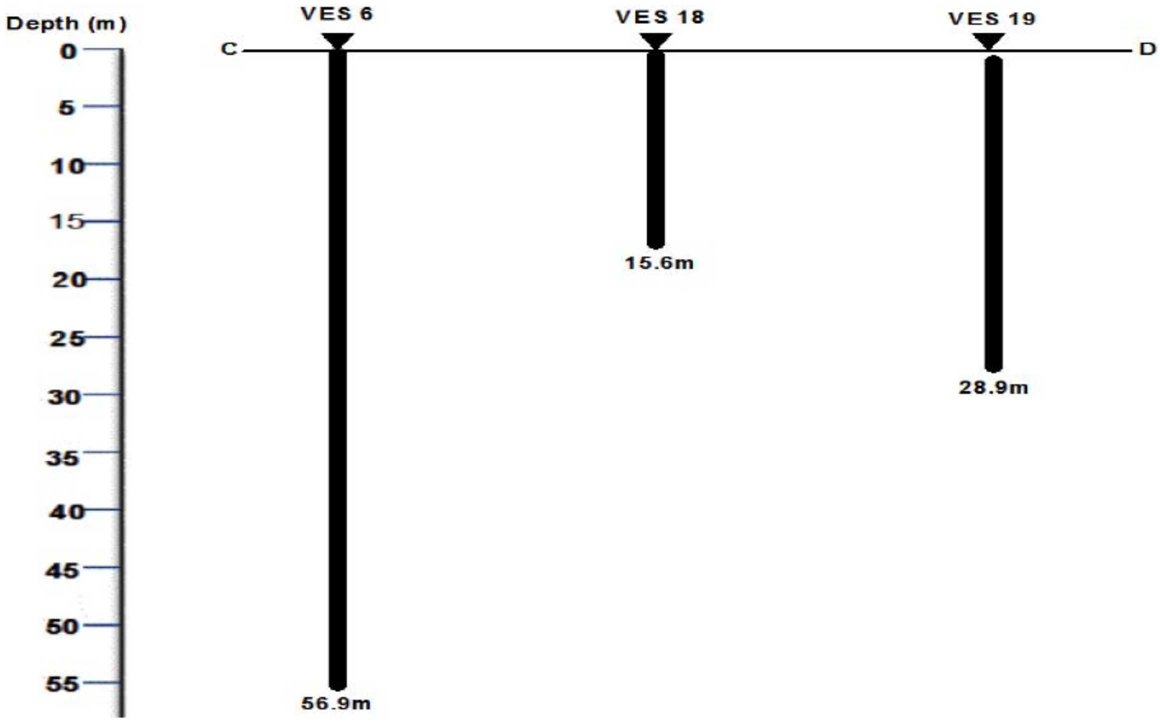

Figure 6: Cross-section CD showing depth to the fractured Shale aquifer

Cross-section along EF

The cross-section traversed VES 10,11,12,13, 14, 15 and 16 (Figure 7). The depth to the fractured Shale aquifer ranges from 14.7m at VES 16 to 51.6m at VES 14 (Figure 7)

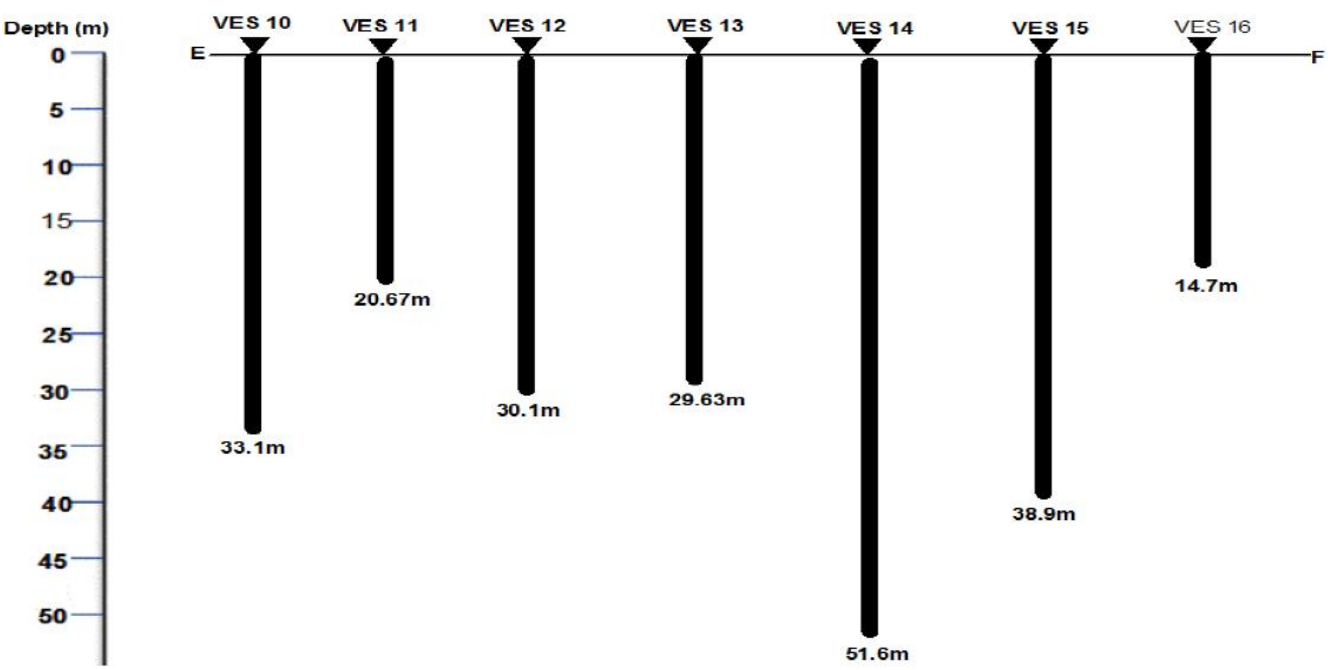

Figure 7: Cross-section CD showing depth to the fractured Shale aquifer

CONCLUSION

The electrical resistivity method has proven to be a veritable tool for the delineation of depths to the fractured Shale aquifer at various points within the study area. The fractures were mapped by their characteristic lower resistivity values when compared with the adjoining non-fractured shales. Interpretative cross-sections taken along three profiles was used to delineate aquifer thickness and the depth to the fractured shale aquifers in the study area. Aquifer thickness ranges from 6.87m to 42.8m while depth to aquifer ranges from 10.93m to 35.8m along profile AB. The variation in aquifer depth ranges from 17.43m at VES 8 to 56.9m at VES 6 along profile CD while the depth varies between 14.7m at VES 16 to 51.6m at VES 14 along profile EF.

We however recommend that an hydro-chemical study be carried out to ascertain the potability of the water for both domestic and agricultural use.

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