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Research Article

Aquifer Parameters Estimation using Electrical Resistivity Data from Taraba State University, Jalingo, North East Nigeria

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Abstract

The present work aimed at estimating Aquifer Parameters within the Taraba State University Campus using electrical resistivity method. A total of 15 Vertical Electrical Sounding (VES) data were collected using Schlumberger Configuration in a basement terrain in Taraba state university Jalingo. The data obtained were analyzed with IX1-D v.3 Interprex software. The Hydraulic conductivity and Transmissivity determine from empirical relationships range from 33114 m/day to 314113m/day and 41937.38m^2/day to 696891.35m^2/day respectively. Three groundwater potential rating were defined based on the aquifers Hydraulic conductivity and Transmissivity data; poor (45%), fairly good (35%), and good (20%). Vertical electrical sounding revealed that the area is characterized by 4-5 and 6 subsurface geo-electric layers with the 6- layer type being the dominant type. Longitudinal unit conductance of the overburden units ranged from 2285mΩ to 642 mΩ. It was observed that areas of good groundwater potential also have good aquifer protective capacity. Groundwater development should therefore be concentrated more in areas of good groundwater potential for continuous and steady supply of potable water.

Keywords: Aquifer parameters; Vertical electrical sounding; Electrical resistivity data; Geophysical.

Introduction

The quest for good quality water to sustain life on and in the planet earth, has caused a reasonable drift from ordinary search of surface water to prospecting, exploring and exploitation of sub-surface or ground water potentials for steady and reliable supply. Electrical resistivity method is one of the most useful techniques in groundwater geophysical exploration and because of rocks that contained water or aquifer are good conductors electrical resistivity's [1]. The method allows quantitative results to be obtained by using a controlled source of specific dimension. Record showed that the depth of aquifer differ from place to place because of variation in geo-thermal and geo-structural occurrence [2].

Few available boreholes in the area often fail to sustain regular water supplies, because of the complex sub-surface geology [2], therefore, aquifer parameter estimation of the area will be into considered properly delineated. The study area lies between latitude, 8^0, 53'18"N'8^0 and 54'25"N of the equator and longitude, between 11^{0}18'25"E to 11^0 19'45"E.The overall objective of the search is to detect groundwater potential and provide data for the development of the boreholes in the area. The study will derive the resistivity of the sub-surface geology boundaries from their conductivity and use same to determine geo-electrical parameters and establish the geo-electric sections, determine the depth and thickness of each geology layer. To access groundwater potentials of the area delineate the thickness of aquifer units and estimate the aquifer parameters. Hence the research will characterized the aquifer dimension in the area for substantial groundwater at any particular point in time.

Scarcity of groundwater is a major threat to the environment due to the fact that the inhabitants of the study area (Taraba state university campus) are mostly students and staff who need regular water supply. Due to the future demand for water resource in respect to the population growth, there is need to ascertain the potential of groundwater shade area of the campus, because with this increasing population

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growth, it is an undeniable fact that there will be pressure on the water resource in the area.

The aquifer parameters of a surface are very important in groundwater exploitation and management. The study will be of importance to the University in sitting of boreholes, for further studies of groundwater regime and for assessment of any contamination in the study area. Geophysical resistivity data provides a cheaper means of estimating aquifer parameters and provides rapid effective techniques for groundwater exploration and aquifer evaluation.

The present study was aimed at estimating the parameters of aquifer in Taraba State University Premises for groundwater management and optimal exploitation using geophysical resistivity data of the study area.

Materials and methods

Field instrument

The instruments used during the field works are, Geotron G41 (resistivity meter), brass rod, measuring tape, current and potential wire, clips, hammer and writing material. The Geotron (G41) displays apparent resistivity values digitally as computed by Ohm's law. It has a 12.5V DC battery as its power source. Other accessories to this equipment included four metal electrodes (two potential and two current), connecting cables, for current and potential electrodes and GPS (global positioning system) was also used for the field work (Fig. 1).

Fig. 1. Connection of the Terrameter in field work

Field procedure

The survey area is located in Taraba State University campus at Jalingo, the observation stations was selected within the university area. This selection was based on the possibility of obtaining reasonable current electrode spacing before an obstacle will be encountered. In most cases, attempts side-track an obstacle made it impossible to maintain a perfect straight line of measurement. The field work involved a field crew of five men, at a particular station a point called the center of the array was marked out. Current electrode spacing was then marked out about the point in the opposite directions, along the line of measurement desired. The spacing between the electrodes was made as short as possible especially from the beginning of the VES. This would help to smoothing the curves and to get rid of near surface effects. With the circuit correctly set up the potential and current electrodes of 100 cm long would drive about 50cm into the ground**,** the Geotron G41 Terrameter reading of resistances was recorded against the corresponding current and potential electrode spacing's. While for the half Schlumberger array used the potential electrodes and wire in both sides of the meter and one of the current was placed at one side of the resistivity meter and the other current electrode was also placed at infinity, make an angle of 90^0.

The computed resistance for the investigated subsurface was displayed on the digital screen of the Terrameter. Record of the displayed value was taken at each sounding point while the coordinates and elevation data of each sounding points was collected using a GPS. In each station, depth of investigation was systematically increased by expanding the current electrodes spacing progressively from 1 to 100 m on both sides and taking apparent resistivity reading at each spread. The above processes were repeated for each of the sampled VES locations.

Field data presentation

Reductions, analyses and computer iterations were made on the raw field data. These gave results on such important parameters as number of layers, layer thickness depth and resistivity. The data were further interpreted by iterative/inversion method using computer software Interpex. An initially produced field curve was compared with adjustable theoretical curve until a good match yielding true resistivity, depth and thickness values were gotten. Both qualitative and quantitative results were obtained from the interpretation.

Estimation of aquifer parameters

Some of the estimated parameters are hydraulic conductivity, transmissivity, formation factors, aquifer thickness, longitudinal unites and transverse resistance. Estimation of the aquifer parameters were made based on the following assumptions: The flow of electrical current through the aquifer follows the same general path as the flow of water to a well and this flow is horizontal when observed. A single value of resistivity for an aquifer section will represent the entire saturated thickness just as transmissivity will represent the capacity of an aquifer to transmit water through the entire thickness.

Estimation of formation factor of the aquifers

Estimation of porosity of the saturated rocks was carried out by the eq. (1).

$$F = \frac{1}{\emptyset^2} = \frac{\rho_b}{\rho_w} \qquad (1)$$

Where F=formation factor

$\emptyset$=porosity

ρ_b=resistivity of saturated rock call the bulk resistivity

ρ_w=resistivity of the pore fluid (water).

The bulk resistivity was obtained from the inverse of the conductivity of the water. The conductivity of the water was measured using conductivity meter.

Estimation of hydraulic conductivity of the aquifers

The hydraulic conductivity was estimated using empirical the eq. (2).

$$K = 7.7X10^{-6}F^{2.09}\ (ms^{-1}) \qquad (2)$$

Where K=hydraulic conductivity

Estimation of transmissivity of the aquifers

The aquifer transmissivity was estimated using the eq. (3).

$$T = k.h \qquad (3)$$

Where T=transmissivity in m^2 /day and h= aquifer thickness.

Estimation of transverse resistance of the aquifers

Transverse resistance R_t was obtain from the relation given by this

$$R_t = h.\rho \qquad (4)$$

Where h =is thickness and

ρ =Resistivities of the individual layers.

Interpretation of resistivity sounding curves

Electrical resistivity method consisting of Vertical Electrical Sounding (VES) by Schlumberger electrode technique is employed in the present study. VES are often used in geoelectric survey to learn about the resistivity distribution of the subsurface of the study area and also widely used for the study of concealed aquifer characteristic. The advantage of the electrical resistivity method is that, quantitative modeling is possible using either computer software or published master curves. The interpretation of resistivity data gives the depth, thickness and resistivity of the different layers at that location. The resistivity inferred from the observed data in the field is used to estimate the availability of the groundwater and its quality. The literature available on the electrical resistivity prospecting includes [3,4]. A qualitative interpretation of resistivity depth sounding curves can be made by simple inspection of the manner in which the apparent resistivity values increase or decrease with increase of electrode separation. The VES study is conducted in fifteen locations in the study area using Schlumberger electrode configuration to understand the electrical distribution along the vertical direction. The half current electrode (AB/2) separation was spread up to 100 meter. The interpreted results were checked with lithological obtained in the field.

Inversion result of all the fifteen VES points are interpreted and subsequently correlated to resolve the lithology condition in the study area, Variations of resistivity of the rocks are the main sources of electrical anomaly.

Results and discussion

Result of the study revealed variation of the aquifer characteristics across the study area. The least value of the Transmissivity 35865.94 m^2/day was recorded at VES15 at fig. 9 and the highest value 989152.34 m^2/day was recorded at VES7 point at fig. 11. The Transmissivity estimation reveals the variation of aquifer Transmissivity, with the highest in school clinic region. The estimation of hydraulic conductivity values also revealed highest values 314113.35 m/day at VES11 at fig. 5 and lowest values 33114.23 m/day. The estimation of the aquifer thickness reveals variation of the thickness, with the highest at VES3 at fig. 5. An overlay of the aquifer characteristics revealed the highest values of these parameters at VES7point fig. 11 suggesting that the aquifer at VES7 point is saturated with groundwater.

Interpretation

The observed electrical resistivity data were first analyzed by visual inspection considering some features on the graphs, viz., shape of the curves, longitudinal conductance (S), minimum resistivity for minimum AB/2 separation etc. Though a wide range of theoretical curves are available in literature for quantitative interpretation of sounding curves. The results of interpretation using partial curve-matching were compared with the total depth obtained from longitudinal conductance (S-line) of the field curves. The interpreted results were also checked with lithological; the results of soundings near the existing borehole at the study area were correlated with the corresponding lithology of these wells. For better $\rho t(\Omega m)$r accuracy, the entire VES data were interpreted using the software called Interpex.

Qualitative results of VES

The summary of the results of the vertical electrical sounding data are presented in table 1. The following curves types was observed from fig. 3,4 and 5 are H curve type, fig. 6,7 and 8 are QH curve type, fig. 9 is AH curve type and finally fig. 10 is A curve type. The most prevalent of the curve types was H types which occurred six times, the QH type curve occurred five times and the AH and A types each of which occurred two times.

Quantitative results of VES

The two aquifers horizon types were defined in the area namely, upper (shallow depth) and lower (deeper depth) horizons. The upper horizon aquifers are observed between the depths range of 1 to 25 m. This aquifer type occurred in a few number of the sounding points (VES 6 and 13), in the study area. The aquifer has high tendency to dry up during the dry session especially those shallow depth. The lower horizon aquifers were observed at depth greater than 25 m. These aquifer are tapped by boreholes in the area and represents a region of weathered /fractured shale with sand.

Top soil

This is a surface dry layer of high resistivity that ranges at fig. 3 from 12.93 Ohm'sm to 2783.2 Ohm'sm. Its thickness varies at table 1 from 1.12 to 11.5 m. The low resistivity end is diagnostic of sandy clay and clay while a high resistivity end indicates laterite. However, very high resistivity could be an intruded in fresh basement.

Weathered layer

This layer is thought to be highly decomposed crystalline rock. From table 1, the resistivity value ranges from 28.48Ohm's m to 216.3 Ohm'sm. The thickness varies from 5.29m to 54.34 m. The layer is highly decomposed by weathering to form sand and clay sand depending on the local variation of the mineralogy.

Fractured layer

From fig. 3, the resistivity value range from 62 Ohm's m to 280 Ohm'sm, the thickness varies from 14.32 to 30.27 m. These researches notified this layer to be the major aquifer unit, where as in some places, fracture zones occur immediately beneath the weathered horizon.

Table 1. Resistivity Details of VES location of the area

S. No.	Location	Latitude	Longitude	Elevation	Resistivity (Ωm)	Curve Type
1	Old Laboratory	011⁰18’57.1”	08⁰54’07.3”	676	228.67	H
2	Science Complex	011⁰19’01.8”	08⁰53’59.6”	683	230.83	H
3	BEHIND HALL 18	011⁰19’03.8”	08⁰53’53.1”	670	303.56	H
4	New Library	011⁰19’00.0”	08⁰53’47.9”	694	185.72	QH
5	Library	011⁰19’07.0”	08⁰53’44.0”	670	180.61	AH
6	Admin Block	011⁰18’50.9”	08⁰53’44.7”	720	114.72	AH
7	Clinic	011⁰19’08.1”	08⁰54’05.8”		356.89	A
8	Eng Complex			699	171.33	QH
9	Zenith Hall	011⁰18’41.0”	08⁰53’35.2”	732	165.33	QH
10	Quarters	011⁰19’15.9”	08⁰54’08.6”	657	165.33	QH
11	New Labotory	011⁰18’57.2”	08⁰54’05.6”	676	296.00	H
12	Boys Hostel	011⁰18’39.2”	08⁰53’40.2”	750	164.06	A
13	Adjacent Siwes Office	011⁰18’58.9”	08⁰53’51.2”	691	144.22	H
14	Central Library	011⁰18’57.9”	08⁰54’03.3”	667	312.33	H
15	Girls Hostel	011⁰18’59.3”	08⁰54’14.2”	666	126.94	QH

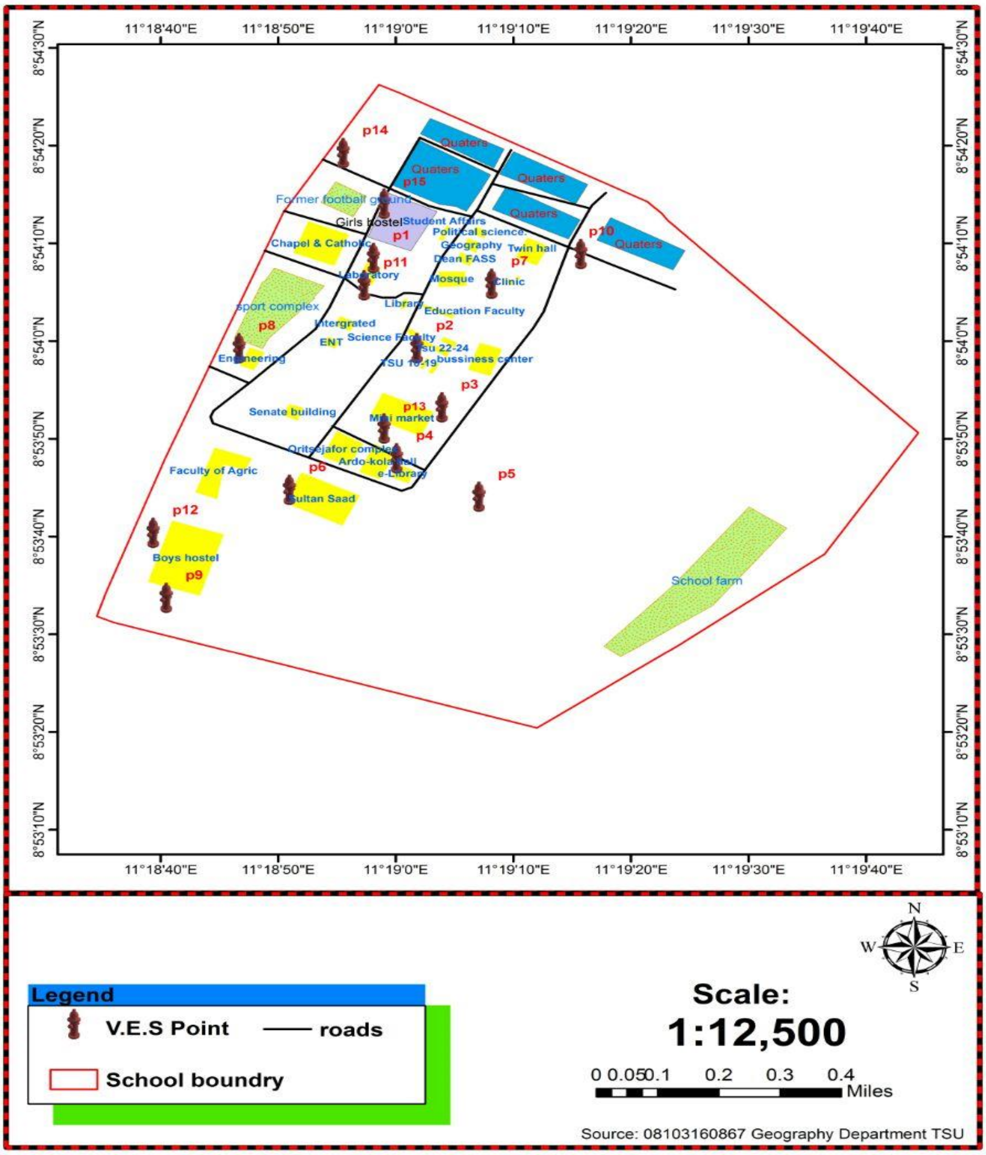

Fig. 2. Map showing the location of the VES point in the study area

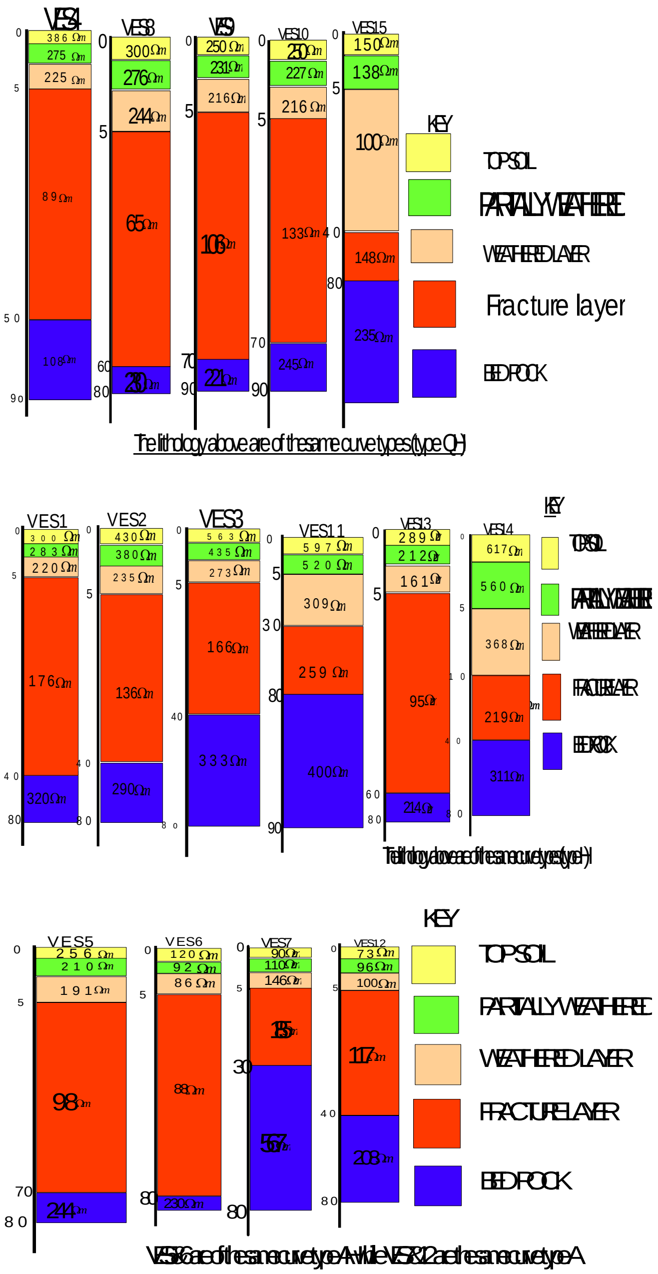

Fig. 3 Lithology of the VES points

The fracture zones are difficult to detect geophysical, unless it is of greater thickness. Where the fractured zone is saturated, a high groundwater can be obtained from borehole penetrating such a sequence. If depth of weathering is sufficiently thick as exhibited of most of the VES points in the study area, the weathered mantle could contain water in storage large enough to produce a successful borehole. Therefore, based on thickness and resistivity of weathered layer, the following VES point subsurface lithology and aquifer zones use vertical electrical sounding.

Bed rock

This is fresh basement layer ordinarily; it has a very high resistivity with infinite thickness. But where it is fractured and saturated the resistivity reduced, it is not a source of ground water unless fractured. However, when the shape of the VES curves approaches a very steep gradient of about 450 (steady increase in resistivity), it may indicate a fresh basement rock without fracture.

The fig. 4-11 are arrange best on the different types of curve, there are Q, H, A and K. From the above curves, fig. 7,8 and 9 are the same curve types QH, and fig. 4,5 and 6 are H curve type,fig. 10 is AH curve types and lastly fig. 11 is A curve type.

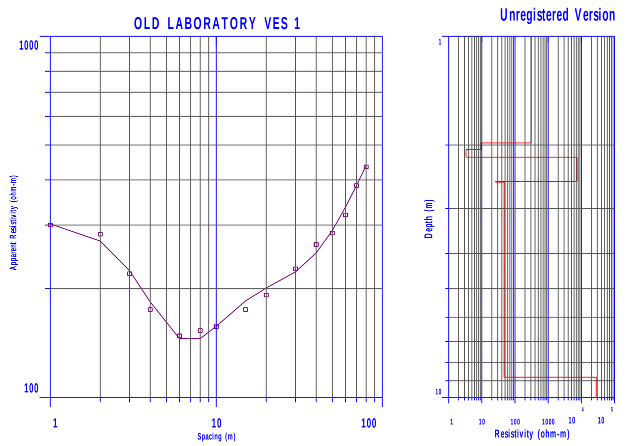

Fig 4. H curve type from VES 1 and 2

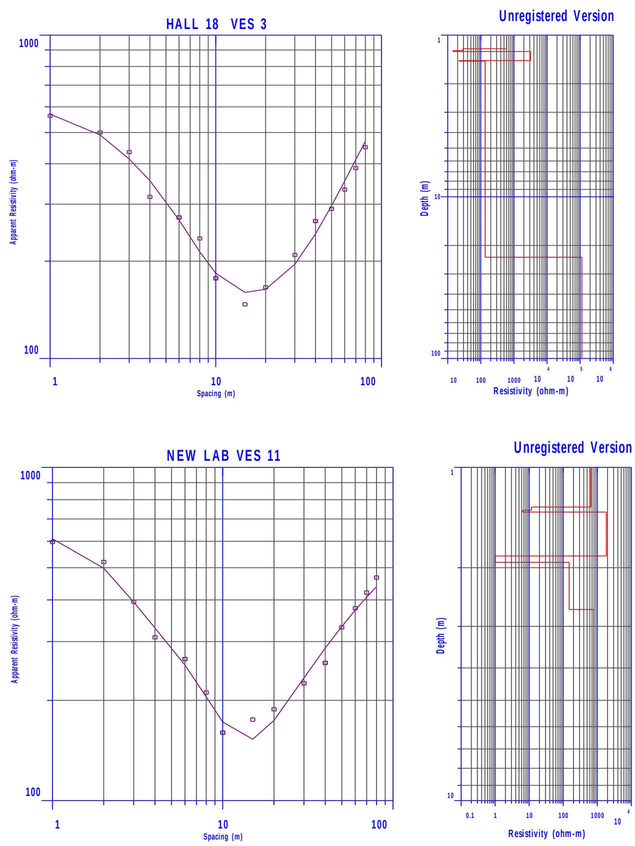

Fig. 5. H curve type from VES 3 and 11

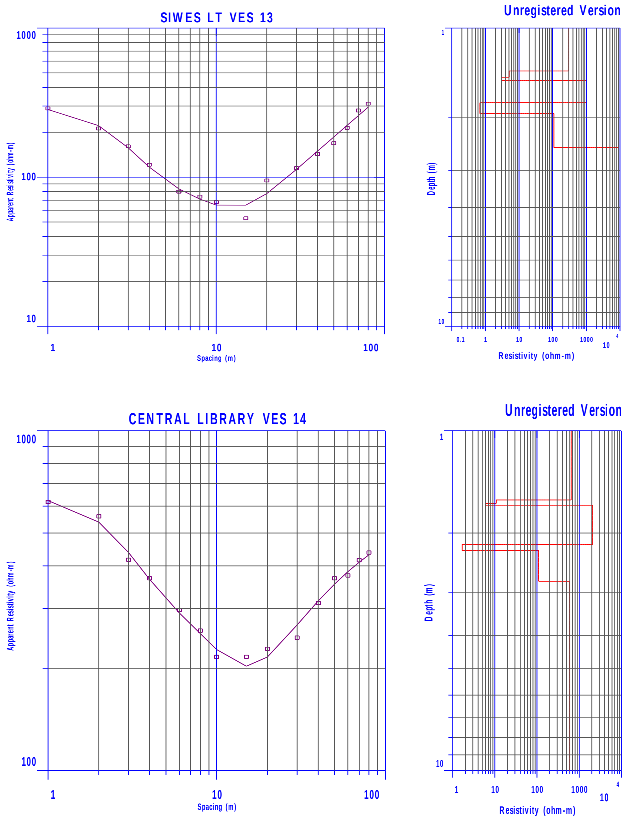

Fig. 6 H curve type from VES 13 and 14

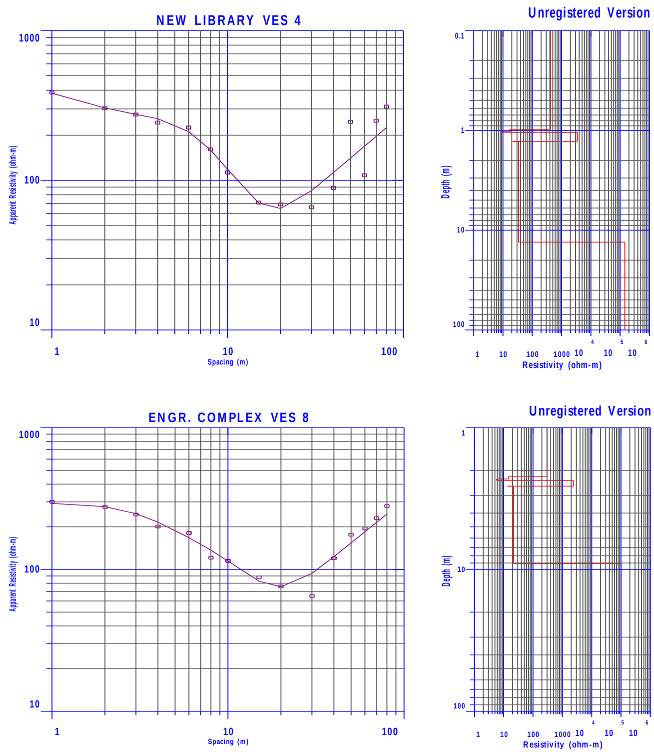

Fig. 7. HQ curve type from VES 4 and 8

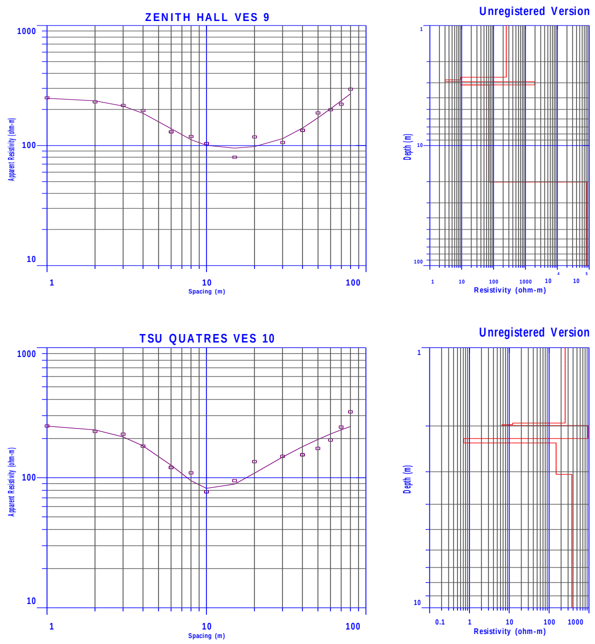

Fig. 8. HQ curve type from VES 9 and 10

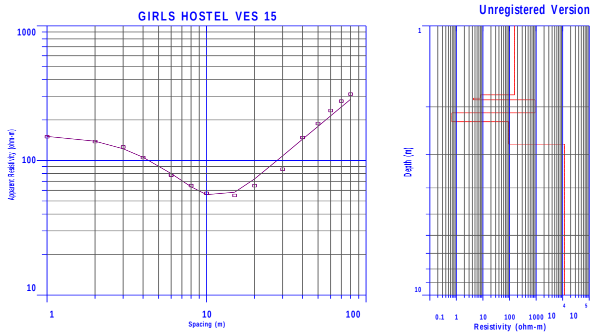

Fig. 9. HQ curve type is VES 15

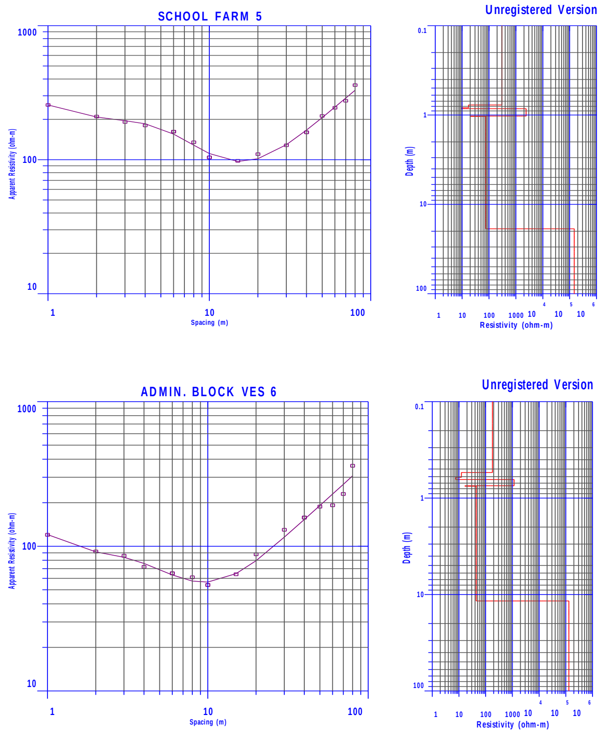

Fig. 10. AH curve type from VES 5 and 6

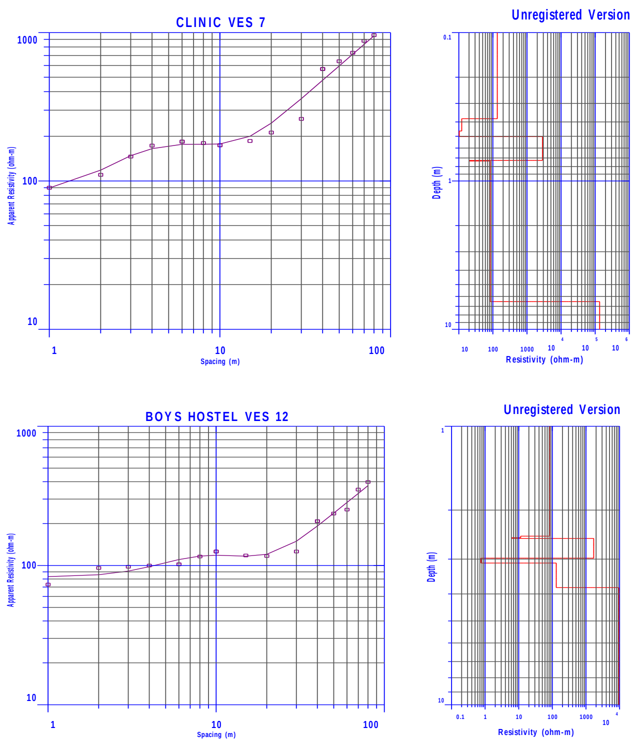

Fig. 11. A curve type from VES 7 and 12

Conclusions

Due to the pressing need for potable water in the university campus effort aimed at provision of this resource is worth undertaking. The use of geophysical methods in the groundwater investigation method will help to reduce if not alleviate completely the problem of borehole failure in the area. Hence boreholes drilled base on recommendation from this study will yield utmost results for water. Expedience of groundwater from boreholes will reduce, the spread of water related disease, promoting social economic activities there by contributing to poverty alleviation and further increasing life expectancy of the native.

Conflict of interest

The authors declare no conflict of interests.

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