



Geoelectric evaluation of groundwater potential: a case study at Omuma local government area, Rivers State, Nigeria

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Received: 13 July 2020 / Accepted: 3 September 2020 / Published online: 17 September 2020
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Abstract

Rivers State as the nomenclature depicts is a state richly blessed with both surface and subsurface water. As a result of this, there is less problem of water scarcity, especially in the elite cities of the state, but so many other communities due to one reason or the other still wallow in abject water scarcity. In this survey, a total of seven (7) vertical electric soundings were carried out using Schlumberger configuration at Obibi community in Omuma local government area, Rivers State, to ascertain the location and depths to aquifer. ABEM terrameter SAS 300 was used in the survey with electrode spacing AB/2 of 150 m, thus probing to a depth of about 200 m. Geoelectric software (IPI2WIN) was utilized in the plotting, iteration and interpretation of the resistivity data obtained. From the quantitative interpretation and the lithology of the areas, five different subsurface layers were delineated with their geoelectric curve given as AK, AKQ and AKH. Aquifer in these areas is highly prolific and mostly located at an average depth of 52 m.

Keywords VES · Geoelectric · Aquifer · Lithology · Unconsolidated

Introduction

Health they say is wealth according to one of the aged long adages. One out of the many ways of maintaining this good health is by keeping a very good hygienic approach to our daily consumptions, especially our drinking water. A potable drinking water is very essential to human life and its scarcity can be catastrophic to human existence. Scarcity or contamination of potable drinking water can lead to serious public health challenges such as outbreak of epidemics. It was for this reason that the United Nations at the World Summit on Sustainable Development held at Johannesburg 2002 called for proportion of people without clean water and proper sanitation to be halved by the 2015 as one of the Millennium Development Goals “MDGs” (United Nations 2002). The problem of obtaining adequate supply of quality water even in tropical region is increasingly becoming more

acute due to ever increasing urbanization, industrialization and coastline which bounded some of the communities.

The recent studies show that over half the world population depends on groundwater as main source of water supply. According to Mato (2002), about 30% of the public water supplies are derived from groundwater, in the USA, it is about 50%, while it is about 99% in Denmark. According to NPC (2004), the south–south region had about the worst water situation in the country in spite of its abundant water resources.

Majority of riverine obtains their water for household uses from vendors. Some also extract their water from private boreholes and wells, while several others receive their domestic water from rainwater catchment (Wikipedia 2005). Rivers State as part of the riverine has three main source of water: groundwater, surface water and precipitated water, but largely depend on groundwater for its consumption.

In recent time, a noninvasive geophysical method (vertical electrical sounding) has been tested and proved to be useful in the search for groundwater due to its simplicity, better depth penetration and rapid advancement in computer software used in the analysis (Olawuyi and Abolarin 2013; Oladunjoye and Jekayinfa 2015). This method involves injecting an electric current into the ground with a pair of steel or copper electrodes and measuring the resulting

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potential difference within the subsurface using a second pair of electrodes. The resistance data collected in this way are converted to apparent resistivity reading which is later remodeled using iterative software to provide information about the depth, thickness and layers of the subsurface. This study area (Fig. 1) is carefully selected in Omuma local government area in Rivers State as a result of continuous influx of people in this area due to urbanization and search for greener pasture; hence, the demand for potable water has skyrocketed. The aim of this research work is to investigate the locations and depth of aquifer(s) at Obibi town in Rivers State, Nigeria. The result of this research work will go a long way in creating more awareness, providing necessary

information to the inhabitants for subsequent citing of their boreholes.

Study area

A geophysical survey was carried out at Obibi town in Omuma Local Government area in Rivers State, southeastern part of Nigeria, located within latitude $5^{\circ} 5' 59.406''$ N and longitude $7^{\circ} 11' 59.3556''$ E. Omuma local government area occupies a total area of 170 sq. km with an estimated population of 171,832 inhabitants with majority of the dwellers being members of Etche ethnic group (<https://www.manpower.com.ng/places/lga/737/omuma>). Basically,

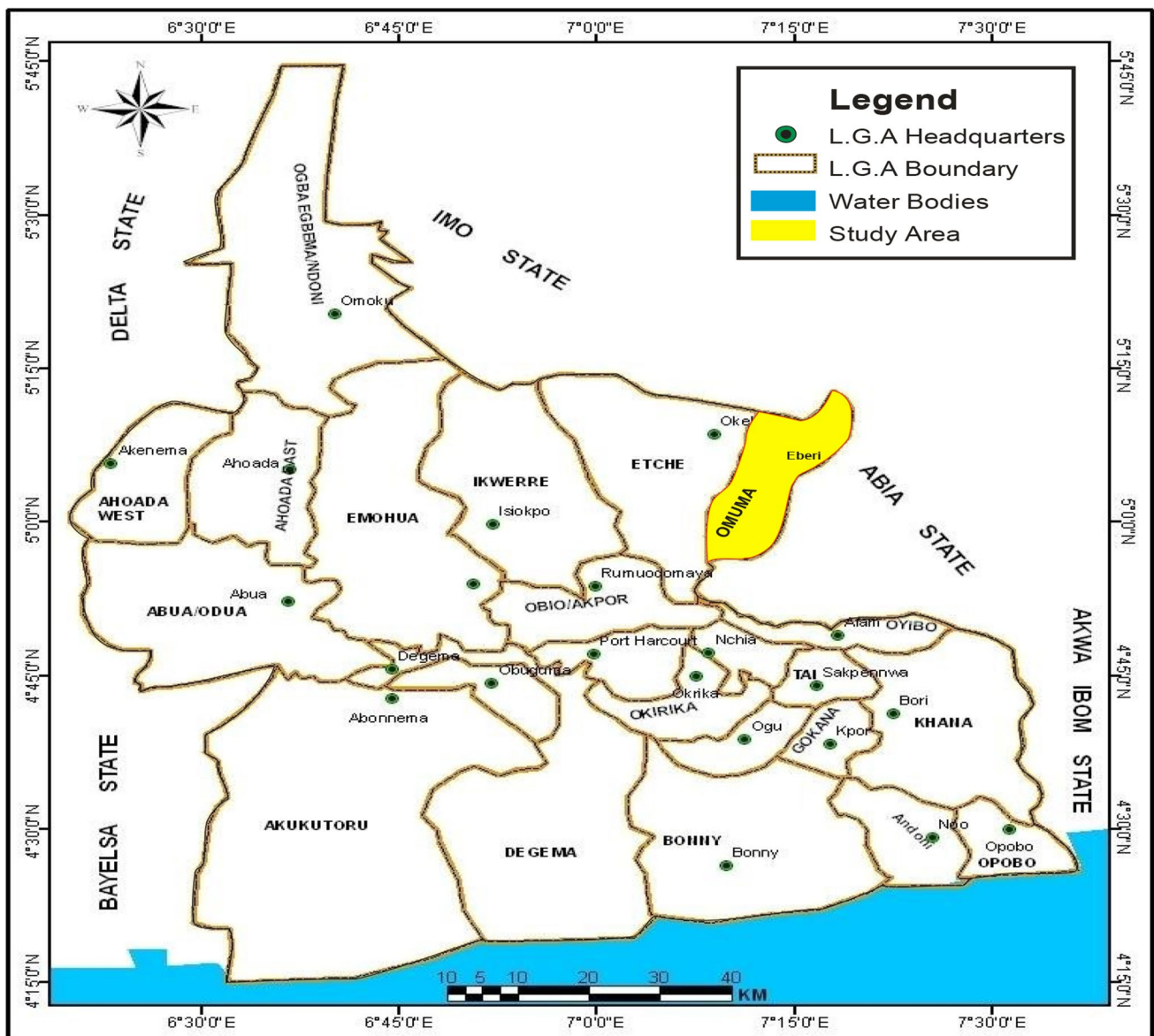


Fig. 1 Map of Rivers State showing the study area

the area consists of medium coarse to coarse unconsolidated sand and has a high groundwater potential due to its considerable aquifer thickness, high permeability and recharge potential (Offodile 1984). It is located in the Rivers south senatorial district and bounded by Etche on the west and south, while Abia state on the north and east (RSPHCMB). Other than fishing which is usually practiced by the riverine inhabitant, Omuma is also a hub of other agricultural crop like yam, maize, oil palm, etc. Stratigraphically, Omuma is situated on the coastal plain of the southeastern part of Nigeria, underlain by the sequence of the known Niger delta formation (Akata, Agbada and Benin) (Short and Stauble 1967). The geology of the Niger delta has been extensively documented by various researchers including Reymont (1965), Allen (1965), Short and Stauble (1967). The Benin formation which houses the aquifer (freshwater) in the Niger delta region consists of predominantly unconsolidated sand, gravel and occasionally intercalation of shales (Short and Stauble 1967). Underlain by the Benin formation is the oil-bearing zone of the Niger delta sedimentary basin (Agbada formation). It consists of predominantly upper sandy unit with minor shale intercalation and a lower shale unit which is thicker than the upper sandy unit (Merki 1970). It is estimated to be over 10,000 ft in thickness. The basal unit of the Niger delta basin comprising mainly of marine facies is the over pressure Akata formation. It is estimated to be over 4000 ft thick.

Materials and methods

In search of a good location and depth of fresh water, a non-invasive geophysical technique, vertical electrical sounding, was carried out using Schlumberger array (Fig. 2). This method was preferred due to its better probing depth and high resolution. A total of seven vertical electrical soundings were conducted at Obibi town in Omuma L.G.A, south-eastern part of Nigeria, with maximum electrode spacing of 300 m between the current electrodes. The VES data were collected with a signal averaging system instrument (ABEM SAS 300) terrameter with a display screen and an automatic signal averaging microprocessor. The results obtained were plotted to get a curve on a bi-log graph, and

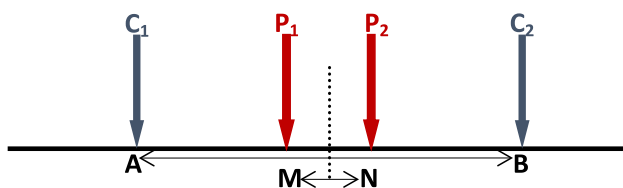


Fig. 2 A schematic illustration of Schlumberger configuration

the depth sounding curves were interpreted quantitatively to determine the location and depth of aquifer in the area. In VES, the depth of probe is proportional to the horizontal electrode spacing. According to Vingoe (1972), the vertical depth of penetration is usually two-third of longest electrode spacing. In this survey, the procedure involves injecting current via two current electrodes (C_1 and C_2) into the subsurface and measuring the resistivity through the corresponding potential electrodes (P_1 and P_2).

The apparent resistivity (ρ_a) of the subsurface is calculated using the formula:

$$\rho_a = \pi R \left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right]$$

$$\left[\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{MN} \right] \text{ is the geometric factor}$$

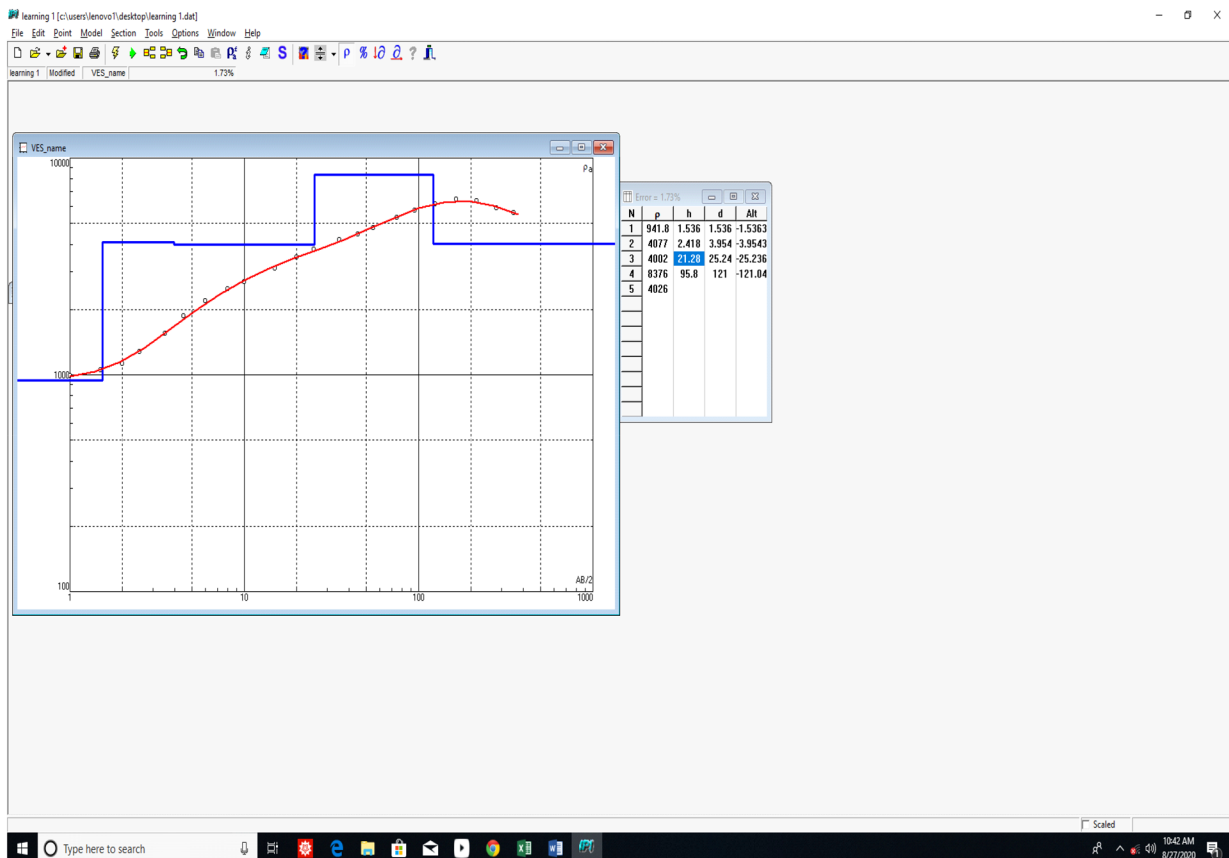
where ρ_a = apparent resistivity (Ωm), R = resistance (Ohm), AB = distance between current electrodes and MN = distance between potential electrodes. The field data was processed using IPI2WIN resistivity sounding interpretation software version 3.0 (2003), to determine the true resistivity and depths of subsurface formations. This computer program automatically generates model curves using initial layer parameters (resistivities and thickness) derived from partial curve matching of the field curves with standard curves, and calculates the true layer parameters of the geo-electric section.

Results and discussion

For a successful exploration of groundwater in sedimentary terrain, a good knowledge of the area geology is necessary. Omuma as a sedimentary terrain has proven less difficult in the exploration of groundwater. This research work was conducted to corroborate the principle of VES in differentiating lithologies and further predicting the depth to aquifer and its locations. The summarized result of the interpreted computer iteration field data is shown in Table 1. A total of seven (7) VESs were randomly carried out at Obibi with AK, AKQ and AKH geoelectric curve discovered (Figs. 3, 4 and 5). The geologic sediments delineated comprises of topsoil, clay, medium fine sand and medium coarse sand (Fig. 6), which is in line with the lithology of Omuma L.G.A and other Benin formation of the Niger Delta (Akpoborie and Aweto 2012; Idehai and Egai 2014; Nwokocho 2018). AKQ-type curve is the most prevalent and accounted for 42.857%

Table 1 Summary of VES result

VES	Geographic location	Layer resistivity $\rho_1/\rho_2/\dots/\rho_n$ (Ωm)	Thickness $h_1/h_2/\dots/h_n$ (m)	Depth $D_1/D_2/\dots/D_n$ (m)	Layer	Curve type
1	5° 5' 59.406" N 7° 11' 59.3556" E	20.6/153.7/223.7/95.9	2.8/8.3/49.8/ ∞	2.8/11.1/60.9/ ∞	4	AK
2	5° 6' 40.6476" N 7° 11' 3.12" E	425.7/663.0/1843.6/340.5/106.4	1.2/4.9/18.9/39.0/ ∞	1.2/6.1/25.0/64.0/ ∞	5	AKQ
3	5° 6' 31.878" N 7° 12' 2.1384" E	415.5/775.5/3142.4/524.2/163.8	1.0/11.5/19.9/19.3/ ∞	1.0/12.5/32.4/51.7/ ∞	5	AKQ
4	5° 6' 40.6476" N 7° 11' 14.0136" E	573.4/772.8/2705.4/1007.6	3.3/11.8/44.5/ ∞	3.3/15.1/59.6/ ∞	4	AK
5	5° 6' 15.642" N 7° 11' 14.244" E	29.3/1897.5/404.4/219.0/5153.4	1.3/10.9/12.7/40.0/ ∞	1.3/12.2/24.9/64.9/ ∞	5	AKQ
6	5° 6' 40.878" N 7° 10' 55.7832" E	58.4/8463.4/416.9/110.8/937.0	0.8/1.7/2.4/11.2/ ∞	0.8/2.5/4.9/16.1/ ∞	5	AKQ
7	5° 5' 59.2908" N 7° 11' 55.9572" E	204.3/1062.9/1870.0/1106.3/112.0	1.3/10.5/12.3/20.3/ ∞	1.3/11.8/24.1/44.4/ ∞	5	AKQ

**Fig. 3** AK-type curve for VES (1 and 4)

of the total curve, while AK and AKH curve accounted for 28.571% each. The topsoil which is composed of moist clay and sand is relatively thin with a varied resistivity

and thickness ranging from 20.6 to 573.4 Ωm and 0.8 to 3.3 m, respectively. The second layer has a resistivity values between 153.7 and 8463.4 Ωm and comprises mainly of

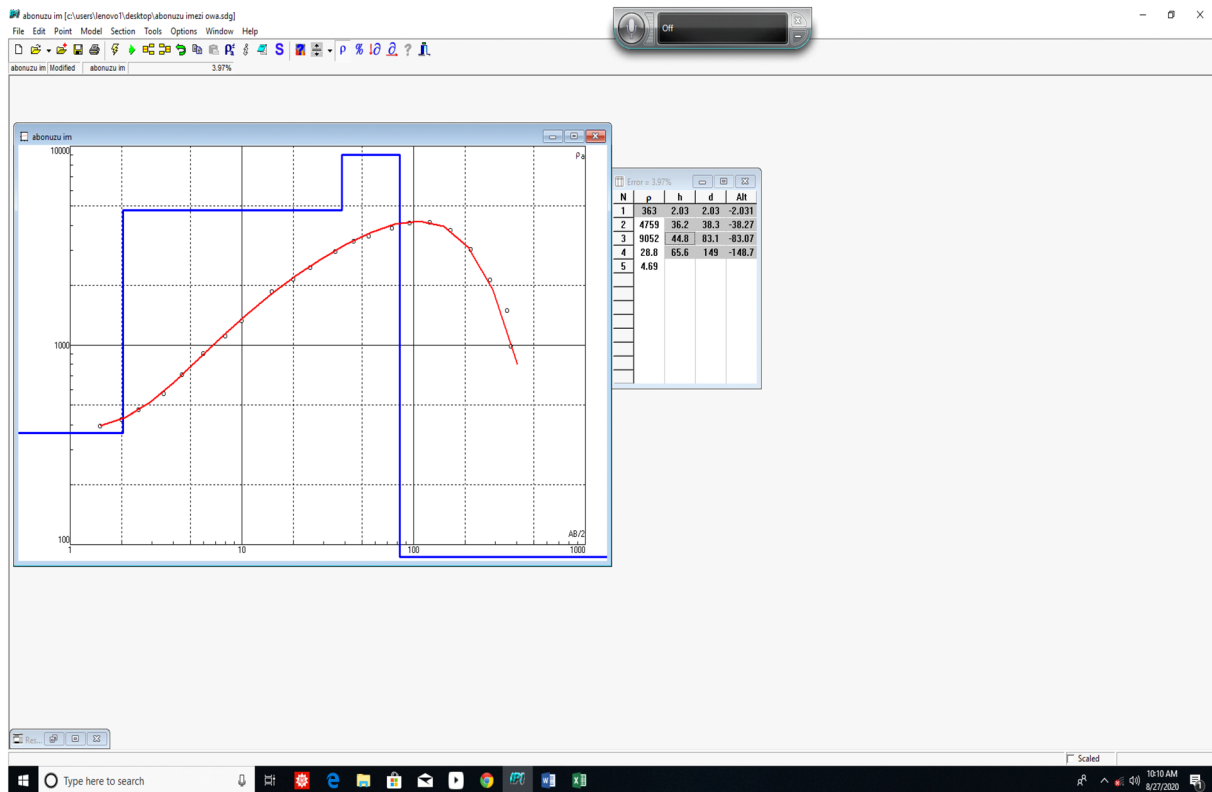


Fig. 4 AKQ-type curve for VES (2, 3 and 7)

fine sandy formations. The highest thickness of 11.8 m in this layer occurs at VES 4 and is considered to be a zone of shallow aquifer. Fine coarse sand is delineated at the third layer with characteristics of a good aquifer at VES 1 and 4 having thickness and depth ranging from 44.4 to 49.8 m and 59.6 to 60.9 m, respectively. The fourth layer is a medium coarse sand and also possesses a large amount of groundwater potentials almost in the entire zone with resistivity and thickness ranging from 95.9 to 1106.3 Ωm and 11.2 to 40.0 m, respectively. However, the fifth layer is presumably coarse grain sand with an infinite thickness.

Conclusion

The determination of the subsurface distribution of resistivity from measurement on the subsurface can yield useful information as resistivity is a fundamental electrical

property of rock material closely related to their lithology. Result of the geoelectrical investigation using D.C. electrical resistivity method around Obibi in Omuma L.G.A in Rivers state reveals precisely the aquiferous zones in the area. The field curves were interpreted using partial curve matching techniques. The layer resistivity, thickness and depth obtained were subjected to iteration software IPI2WIN which reduces the uncertainty/error to the barely minimum (Figs. 3, 4 and 5). From the value of resistivity, thickness and depth acquired in the survey, the third layer in VES 1 & 4 and the fourth layer in VES 2, 3, 5, 6 & 7 is best suited for groundwater exploration (Fig. 6). The result of this investigation showed that the aquifer in this study area is highly prolific and occur at average depth of 52m and having average thickness of 32 m. This study therefore recommends that for a good productive aquifer, a borehole in this area should be drill to a depth ≥ 52 m.

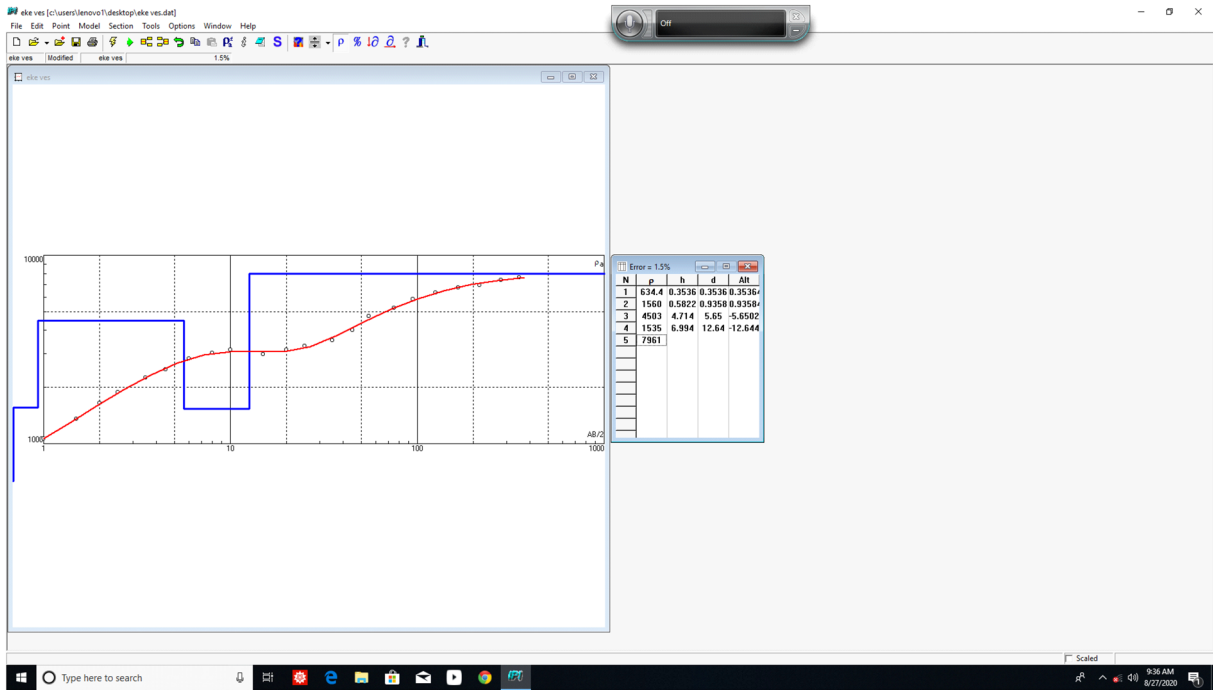


Fig. 5 AKQ-type curve for VES (2, 3 and 7)

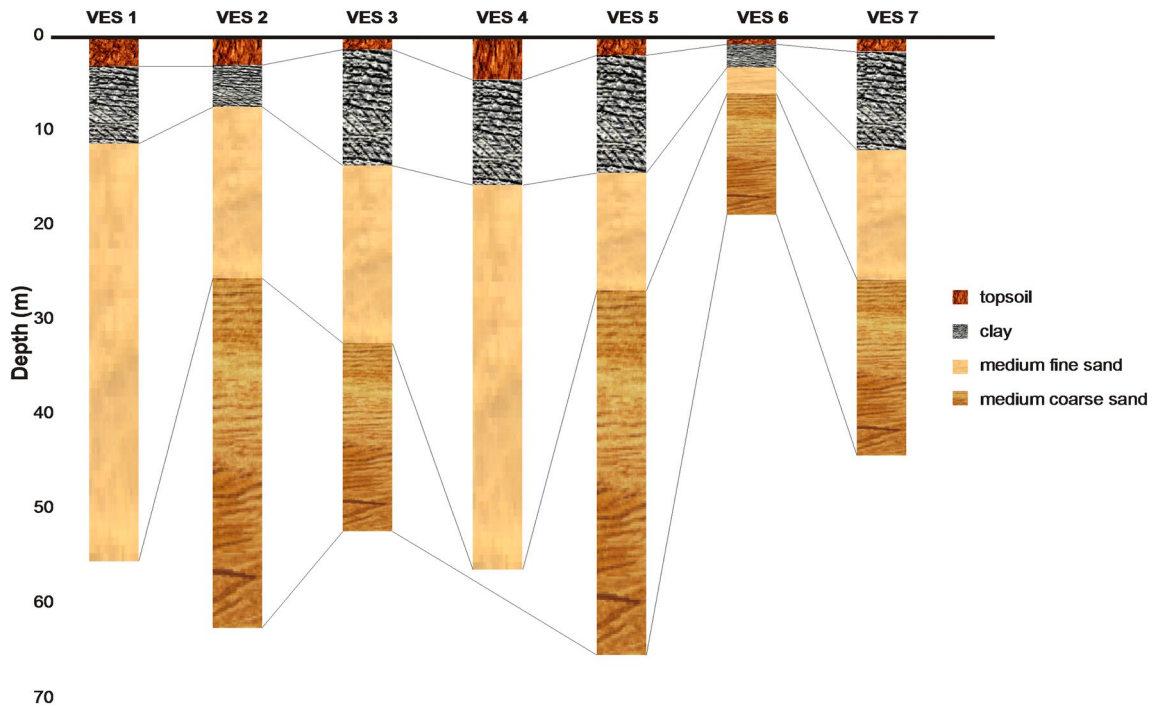


Fig. 6 Interpreted lithology with depth

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