International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Investigation of Groundwater Potential Using Geophysical Electrical Resistivity Method in Dhobley District, Lower Jubba Region, Somalia

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Abstract: ***This study aims to investigate the groundwater potential in Dhobley District, Jubaland State, Somalia, using the geophysical electrical resistivity method. Groundwater is a vital resource in arid and semi-arid regions, such as Somalia, where access to clean water is limited. The electrical resistivity method is a widely used geophysical technique for assessing subsurface hydrogeological conditions and has the potential to identify areas with high groundwater yield. The study area is located within the sedimentary rocks with alluvial as common types of rocks. The data acquired from six (7) VES stations using ABEM terrameter (SAS 300) was tabulated in a table which shows the resistivity, the thicknesses and the number of layers for each VES station. The data was analyzed using computer software called IPI2win, which yield an automatic interpretation of the apparent resistivity. The VES result revealed that the study comprises the top soil, clay, sandy clay and weathered limestone. The first layer or top soil consists of sandy soil with resistivity range from 23Ωm to 266Ωm and thickness of range from 0.63m to 2.82m (VES1 to VES 7). The second layer composed of clay its value ranges from 3.57Ωm to 37.7Ωm with thickness varies from 0.898m to 58.5 m (VES1 to VES 7), and the third layer composed of sandy clay with resistivity ranges from 5.54Ωm to 121Ωm with thickness varies from 2.26m to 19.1m (VES1,VES 2, VES5 and VES7). And the fourth layer composed of clay its value ranges from 3.78Ωm to 54.3Ωm with thickness varies from 22.8m to 48.7m (VES2 and VES 5). The fifth layer of VES 2 indicates the presence of weathered limestone with a resistivity value of 355Ωm and a thickness of 31.7m. However by considering the result obtained it is an indication that the study area has a good land for boreholes and other engineering and architectural activities, due to the features that enhance groundwater permeability and storage. For safety measures, in the deep aquifers which are ranges from 250m to 270m, the random dumping of waste products such as solid and liquid materials must to be avoided in nearby boreholes area in order to prevent waste contaminate to aquifer replenishment.***

Keywords: Vertical Electrical Sounding (VES), Groundwater potential aquifers, topsoil, weathered limestone, Dhobley district

1. Introduction

One of the most basic components of human existence and socio-economic development is water. The earth's fresh water that is obtainable for man's use is about 4x106km3 and is mainly available in the ground. The problem of gaining an adequate supply of quality water is generally becoming more severe effect due to ever increasing of population, irrigation and industrialization. Due to this situation, surface water cannot be dependable throughout the year; hence another alternative is needed in order to supplement for surface water. (Fadele et al., 2013). The first alternative opened to man is ground water, which may be defined as "water in the zone of saturation and from which wells, springs and underground runoff are supplied".

This water is trapped by geological formations (Palacky et al., 1981). The groundwater can be in the sedimentary terrain where it is less difficult to exploit or in the basement complex terrain in which it can be a bit difficult to locate especially in areas underlined by crystalline rocks (Fadele et al., 2013). Hence, a systematic and scientific approach to the problem is therefore essential for the study area in order to overcome these problems. The quantity and disposition of ground water depends on the geological characteristics of the host rock formation. The search for ground water is faced with lots of uncertainties; to minimize or avoid failures altogether, it is pertinent that the right exploration techniques are utilized in the delineation of subsurface water-bearing formations (Coker et al., 2009). Nowadays the used of geophysical techniques for groundwater exploration and water quality evaluations has increases due to rapid advances in computer software and other numerical modelling techniques. The use of Vertical Electrical Sounding has become very popular with groundwater prospecting due to simplicity of the technique. The purpose of electrical geophysical survey method is to detect the surface effects that produce by the flow of electric current inside the earth. This technique have been used in a wide range of geophysical investigations such as mineral exploration, archaeological investigation, engineering studies, geothermal exploration, permafrost mapping and geological mapping (Fadele et al., 2013).

The objective of the present study is to assess the availability of groundwater within the selected areas, to recommend borehole drilling sites and comment on aspects of depth to potential aquifers, aquifer availability and type, possible yields and water quality. For this purpose all available hydrogeological information of the areas have been analyzed, and a geophysical surveys done. The investigations involved hydrogeological, geophysical field investigations and a detailed desk study in which the available relevant geological and hydrogeological data were collected, analyzed, collated and evaluated within the context of the client's requirements.

The data sources consulted were mainly in three categories:
1) Geological and hydrogeological reports and maps
2) SWALIM database
3) Technical reports of the area by various organizations

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A number of studies have laid down a good base for further hydrogeological works. Numerous NGOs have also worked in Juba region and supported urban centers and local rural and semi urban communities by drilling water wells or conducting geophysical surveys. However, although many water projects have been implemented or supported in the region, water well drilling has commonly been conducted without adequate project feasibility studies, and to date, no systematic data collection has been carried on groundwater exploitation, capacity, and especially on groundwater level fluctuations. However, during the last few years, the FAO-SWALIM project (Somalia Water and Land Information Management) has done extensive work relating to water resources, including preparing more accurate and adequate hydrogeological maps but mainly in the northern part of Somalia, which are essential for planning any groundwater exploration and exploitation.

2. Study Area

2.1. Site location

Dhoobley formerly known as Liboi – Somali is a strategic division administration of Afmadow district, located south-western Somali‘s Lower juba region and approximately 0.2km from the Kenya border. Dhoobley is a district in the lower Juba region near the Kenya border. The main economic activity for the population is livestock grazing. The population relies mainly on borehole, surface dams and earth pans as main water sources with very bad condition.

The access to the surface dams and earth pans is very difficult especially for women and children, who are normally responsible for collecting water for their families.

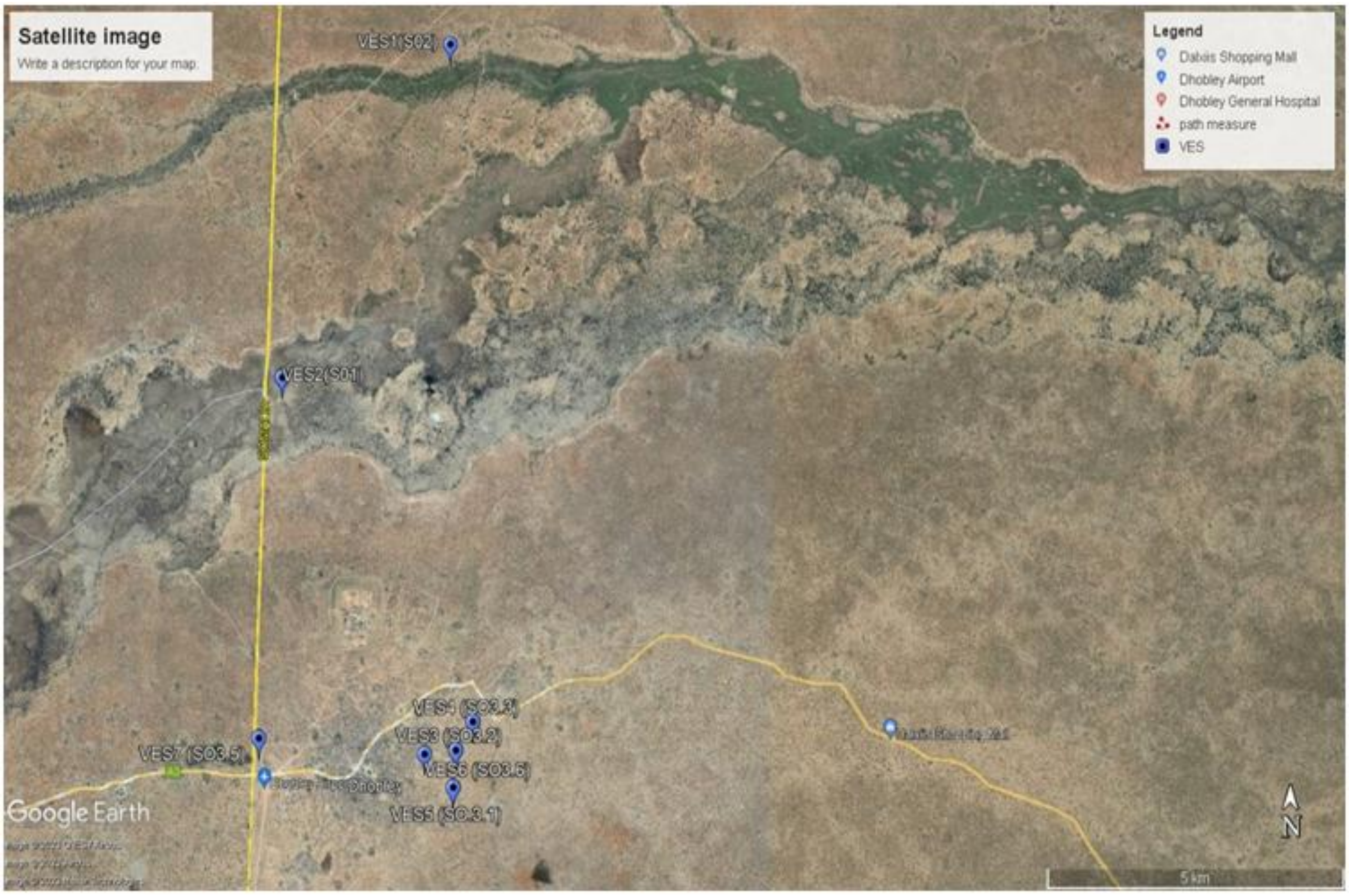

Figure 1: Satellite image Show the VES's Location in project area

2.2. Geology of study area

Several investigations have been undertaken and discussed the various aspects of geological hydrological and hydrogeological developments in the target area e.g.: Faillace and Faillace (1964 - 1987), UNDP/FAO (1968), Hunting Service (1969), V. N. Kozerenko (1972), Johnson (1978), Henry (1979), Pozzi, et al (1985), Hutchinson and Polishchouk (1988), Kammer (1989), MacDonald (1990), SWALIM (2007). The geology of the study area covered by this report is shown in the 1:500,000 scale geological map of Somalia, this map was compiled from various sources and was published by Abbate, et al in (1994) from University of Florence.

Geologically, the South- western Somali part of Somalia is covered by sediment dating from Cretaceous to Recent. The area has been described by Kozerenko (1972) and Pozzi, et al (1985), and several geological maps by Florence University (1973). Faillace and Faillace Hydrogeology and Water Quality Reports (1986) were based on the above mentioned works. The area covered by Cenozoic sediments and Limestone of Tertiary age, unconformably overlying the Cretaceous Sandstone and Limestone.

Paper ID: SR231220123451 DOI: https://dx.doi.org/10.21275/SR231220123451

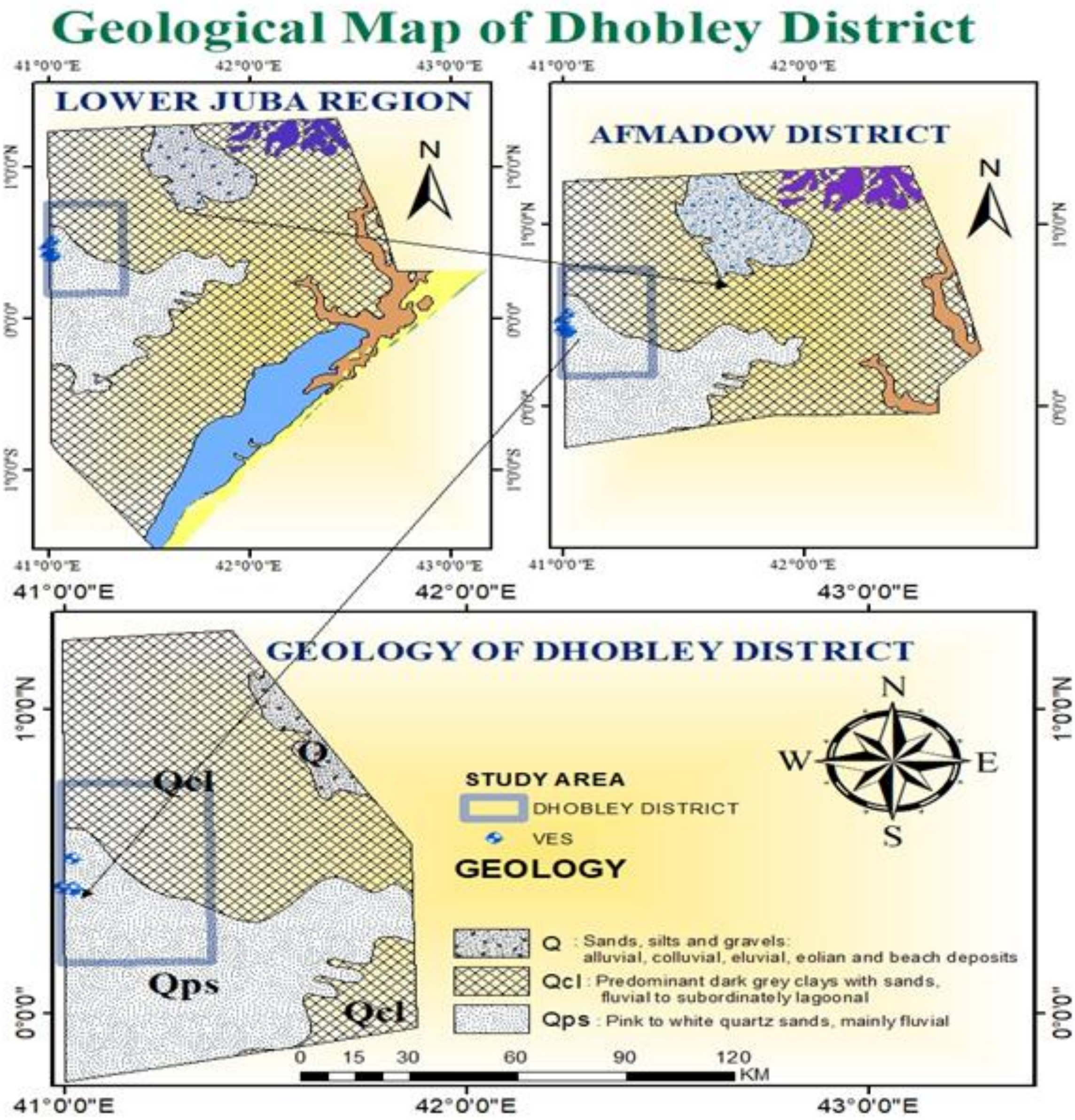

Figure 2: Geological map of Dhobley district

Table 1: Summarizes the Stratigraphic successions of the region. Table 5: Summarizes the Stratigraphic column of the study area as follows:

No	Type of rock	Age
1	Superficial deposits consist of alluvial, colluvial, sand-dunes and Coral limestone.	Quaternary
2	Consists of Limestone, evaporitic rocks and thick extensive series of sedimentary rocks. Karkar Formation Undifferentiated sediment (Oli-Mio) Tertiary Basalt	Tertiary
3	Limestone, Gypsum, Sandstone and Marls. Main Gypsum Formation Mustaxiil Formation Beled Weyne Formation Fer Fer Formation Yasooman Formation	Cretaceous

The area characterized by gently micro relief with sand cover and hard caliche patches. Sloping gently towards the east, the area is covered by whitish sand, gypsum, and caliche sand. The area covered by gypsiferous clay soils and gypsum; calcrete and caliche are common at the termination of the ancestral drainage systems. The bottom of these valleys is often covered by concretionary limestone. Large parts of the area covered by varying thicknesses of whitish and pink sands overlying limestone, gypsiferous limestone and caliche. The oldest sediments outcropping in Central Somalia are the Cretaceous formations. The lithological characteristics of these formations indicate a shallow sea with extensive lagunal environments where evaporates were deposited. Wadajir- Dhoobley area is predominately erosion plain covered by red sand, caliches, gypsiferous clay, hard limestone; concretionary rocks are quite common and are often covered by a thin veneer of aeolian red sands and terra rossa (red clay soil produced by the weathering of limestone).

Limestone often massive and karstified, water quality in wells in this formation is good to fair. In large part of the study area the thick sequences of sub-surface basalt is a geological marker indicating that the sediments above the basalt are of Quaternary age. The geology of the area is poorly mapped and published interpretations of the stratigraphic sequence are not always in agreement and the main rock groups occurs as low laying outcrops within the intervening alluvial sediment covered plains and valleys deposits cover most of the area. The main source of Groundwater aquifers recharged is the precipitation and run off in the Ogden region (Fig. 3).

2.3. Hydrogeology of the study area

Detailed studies of the hydrological and hydrogeological condition have carried out in the three sites include information about lithology, surface water runoff and infiltration rates, well construction and hydraulics, water quality and all other data necessary to assess the groundwater conditions in these districts. Surface water is limited in the target areas. Wars (also called bailey, water pan, ponds or dams) and berkads for rain water harvesting are more common in Dhoobley areas, Wars are large ground natural or mechanically scooped water catchments for surface water collection and storage, mostly unlined, also called bailey or water pan, ponds, dams. The main reason for this is the favorable soil type (clayey) for the construction of wars. War refers to unlined dug-out, mainly 2–3 m deep with a surface area of hundreds to thousands of square meters, built on clayey soils that retain water for approximately 3-4 months.

2.4. Groundwater Occurrence:

The study area depends totally on the groundwater as main source for the water and they are only two types of groundwater recourses; shallow wells and deep boreholes. Due to that the survey curried out to assess the groundwater conditions of the area surrounding the towns. Little was known about the subsurface geology of target areas, to this end, integrated methods for field studies were used in selected areas around the villages with the primary goal of identify potentials of groundwater occurrence in the area, including traditional hydrogeological methods, remote sensing investigations (Landsat ETM+7 images and DEM images) and lineament mapping, structural analysis and geophysical studies through Vertical Electrical Sounding (VES techniques) with a moisture algorithm. most of the areas is covered by a variety of continental quaternary deposits consisting of clay sand, sandy clay, clay, caliche, gypsiferous clay, Aeolian red sands.

3. Methodology

Vertical Electrical Sounding was carried out using Schlumberger array with a maximum current electrode spacing (AB) of 400 m and potential electrode spacing (MN) of 100 m during this survey. The instruments used to measure and record the resistance of the subsurface for the survey are: ABEM SAS 1000, four steel electrodes, field hammers, measuring tape and reels of wire, and global positioning system (GPS). Current was injected into the earth through a pair of current electrodes and the potential difference was measured between a pair of potential electrodes. The current and potential electrodes are normally arranged in a linear array. However, electrode spacing varies for each measurement and the center of the electrode array where the electrical potential is measured remains constant. The electrodes are distributed along a line, placed at a midpoint of each profile which was taken as the center of the sounding. Furthermore, the two current electrodes and the two potential electrodes are placed in line with one another.

The current electrodes were at the same distances from the center of the sounding (AB/2 = 1.5m). The potential electrodes were also at the same distances from the center of the sounding; however, this distance (MN/2 = 0.5 m) is much less than the distance AB/2. Most of the available interpretation software assumes that the spacing of the potential electrode is negligible compared to the current electrode spacing. When the distance between the current electrodes is larger, then the distance between the potential electrodes was increased to have a measurable potential difference and electrode configuration are arranged in the number of ways of setting up of current and potential electrodes.

The AB/2 was increased in steps up to a maximum value of 400 m and MN/2 to 100m. The instrument was then transferred to the next VES point and the entire process was repeated. During this resistivity sounding surveys, 7 vertical electrical soundings were acquired across the study area. The coordinates of the center of VES points were also noted.

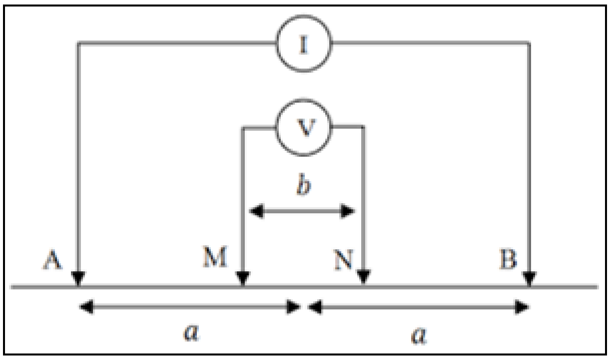

Figure 3: Schlumberger array and apparent resistivity diagram (Keller 1966)

AB: current electrodes
MN: potential electrodes

Table 2: Schlumberger electrode configuration (spacing)

Current electrode spacing (AB/2)	1-15	15-30	30-75	75-150	150-300	300-1000
Potential electrode spacing (MN/2)	0.5	5	10	25	50	100

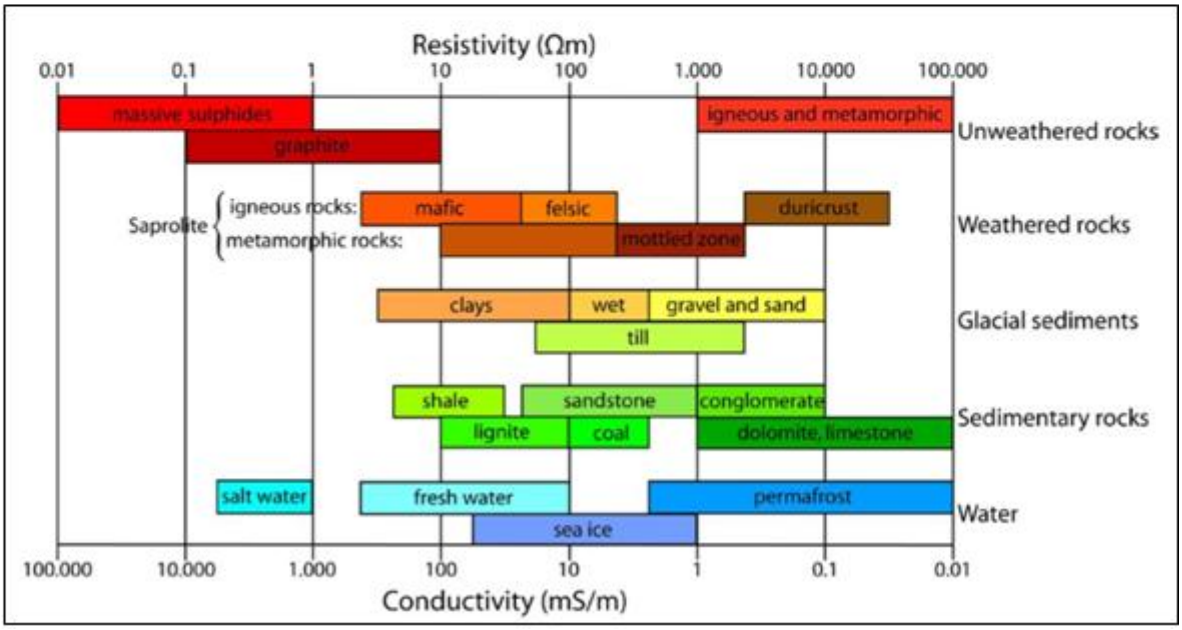

Figure 4: Electrical resistivity and conductivity of earth materials (*Modified from Palacky, 1988*)

Figure 5: Photos shows the Author collecting the data during the geophysical survey

4. Result and discussion

The geometric factor, K, was first calculated for all the electrode spacing using the relation; K= π (L2/2b – b/2), for Schlumberger configuration in which MN=2b and AB/=L. The results obtained were multiplied with the resistance values to obtain the apparent resistivity, ρa values. By the use of computer inversion software called IPIWIN 1D in the present study, the result of apparent resistivity and electrode spacing was plotted in a log-log scale to obtain VES sounding curve.

The Vertical Electrical Sounding modeling carried out at six (7) VES stations was used to derive the geo-electric sections of various profile; which indicate the existence of mostly four geologic layers in the study area in each VES point were the survey was carried out.

This comprised the top soil, clay, sandy clay and weathered limestone. The first layer or top soil consists of sandy soil with resistivity range from 23Ωm to 266Ωm and thickness of range from 0.63m to 2.82m (VES1 to VES 7).

The second layer composed of clay its value ranges from 3.57Ωm to 37.7Ωm with thickness varies from 0.898m to 58.5 m (VES1 to VES 7), and the third layer composed of sandy clay with resistivity ranges from 5.54Ωm to 121Ωm with thickness varies from 2.26m to 19.1m (VES1,VES 2, VES5 and VES7).

And the fourth layer composed of clay its value ranges from 3.78Ωm to 54.3Ωm with thickness varies from 22.8m to 48.7m (VES2 and VES 5).

The fifth layer of VES 2 indicates the presence of weathered limestone with a resistivity value of 355Ωm and a thickness of 31.7m

The interpreted results of VES soundings have been summarized and presented in the following tables. Layer-specific resistivity ranges (presented in the tables) are determined lithological and geological background of the area.

VES's Interpretation:

Table 3: The results of electrical soundings interpretation:

Dhoobley VES 1 ((latitude 41.201944 , Longitude 0.5097222)			
Depth (m)	Thickness (m)	Resistivity (Ohm.m)	Interpretation
0.63	0.63	250	Alluvial deposit/ sandy(topsoil)
58.5	58.5	37.7	Clay
64	5.58	30.4	Clay
>>>>	<<<<	3.78	Clay

Dhoobley VES 2 ((latitude 40.996944 , Longitude 0.461111)			
Depth (m)	Thickness (m)	Resistivity (Ohm.m)	Interpretation
0.75	0.75	56.6	Sand(topsoil)
1.65	0.898	6.26	Clay
3.91	2.26	20	Clay
26.7	22.8	9.06	Clay
58.4	31.7	355	Basal limestone

Dhoobley VES 3 ((latitude 41.025278 , Longitude 0.4097222)			
Depth (m)	Thickness (m)	Resistivity (Ohm.m)	Interpretation
1.07	1.07	266	Sandy (topsoil)
22.7	21.8	25.3	clay
>>>>	<<<<	36.8	clay

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Dhoobley VES 4 ((latitude 41.027778 , Longitude 0.4136111)			
Depth (m)	Thickness (m)	Resistivity (Ohm.m)	Interpretation
2.81	2.81	23.4	Clay (topsoil)
8.74	5.93	3.57	Clay
>>>>	<<<<	30.4	clay

Dhoobley VES 6 (latitude 41.020556, Longitude 0.4091667)			
Depth (m)	Thickness (m)	Resistivity (Ohm.m)	Interpretation
2.82	2.82	46.6	Clay (topsoil)
14.2	11.4	5.97	clay
>>>>	<<<<	121	sandy clay

Dhoobley VES 5 ((latitude 41.025000 , Longitude 0.40472222)			
Depth (m)	Thickness (m)	Resistivity (Ohm.m)	Interpretation
0.75	0.75	190	Sandy clay (topsoil)
12.4	11.6	15.2	Clay
31.9	19.1	5.54	Clay
80.1	48.7	54.3	Clay
>>>>	<<<<	0.285	Clay

Dhoobley VES 7 ((latitude 40.992778 , Longitude 0.41111111)			
Depth (m)	Thickness (m)	Resistivity (Ohm.m)	Interpretation
1.7	1.7	239	Alluvial deposit/ sandy (topsoil)
16.1	14.4	19.8	Clay
>>>>	<<<<	255	Sand saturated with water

Figure 4: The sounding curves and their models

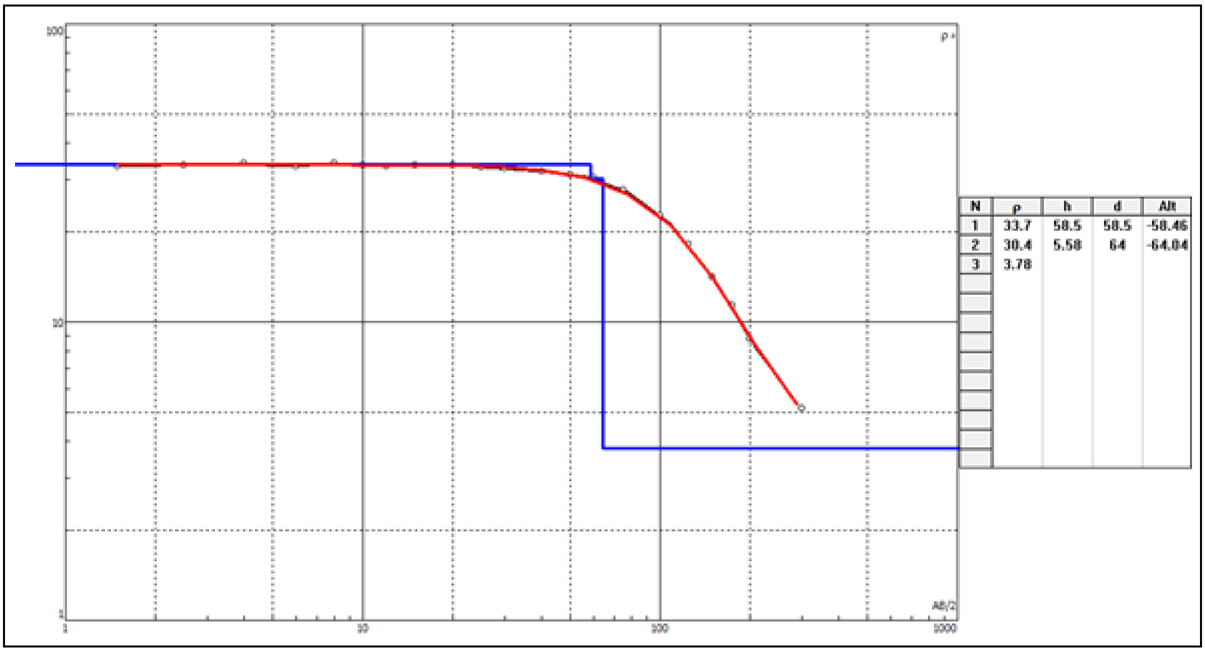

Figure 6: VES1 Graph

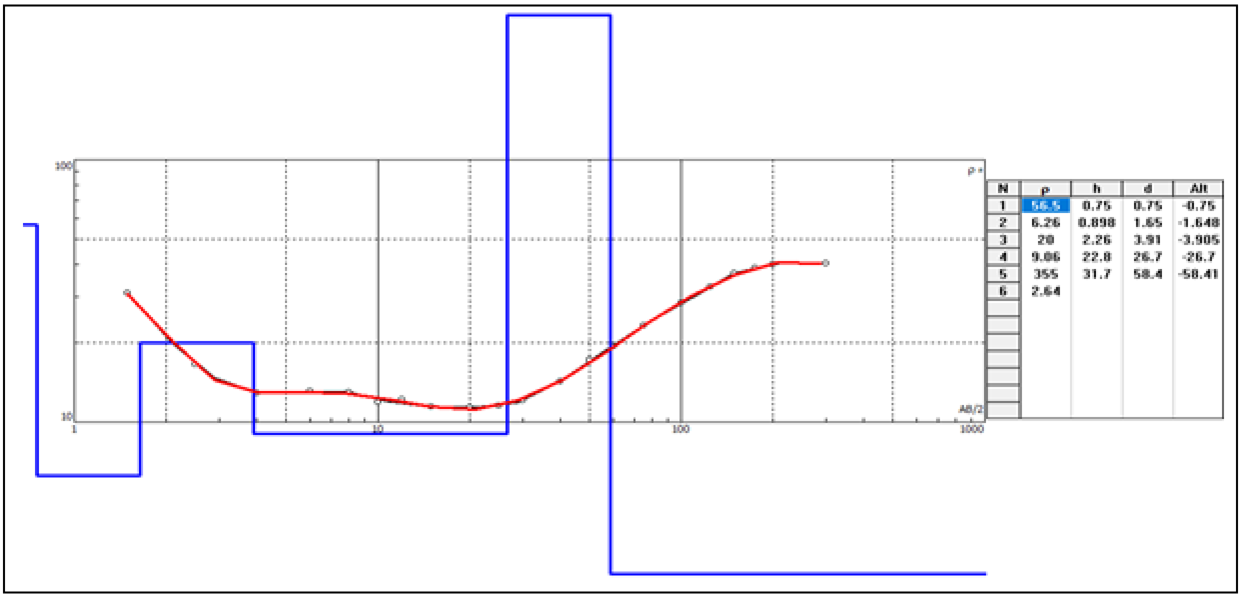

Figure 7: VES2 Graph

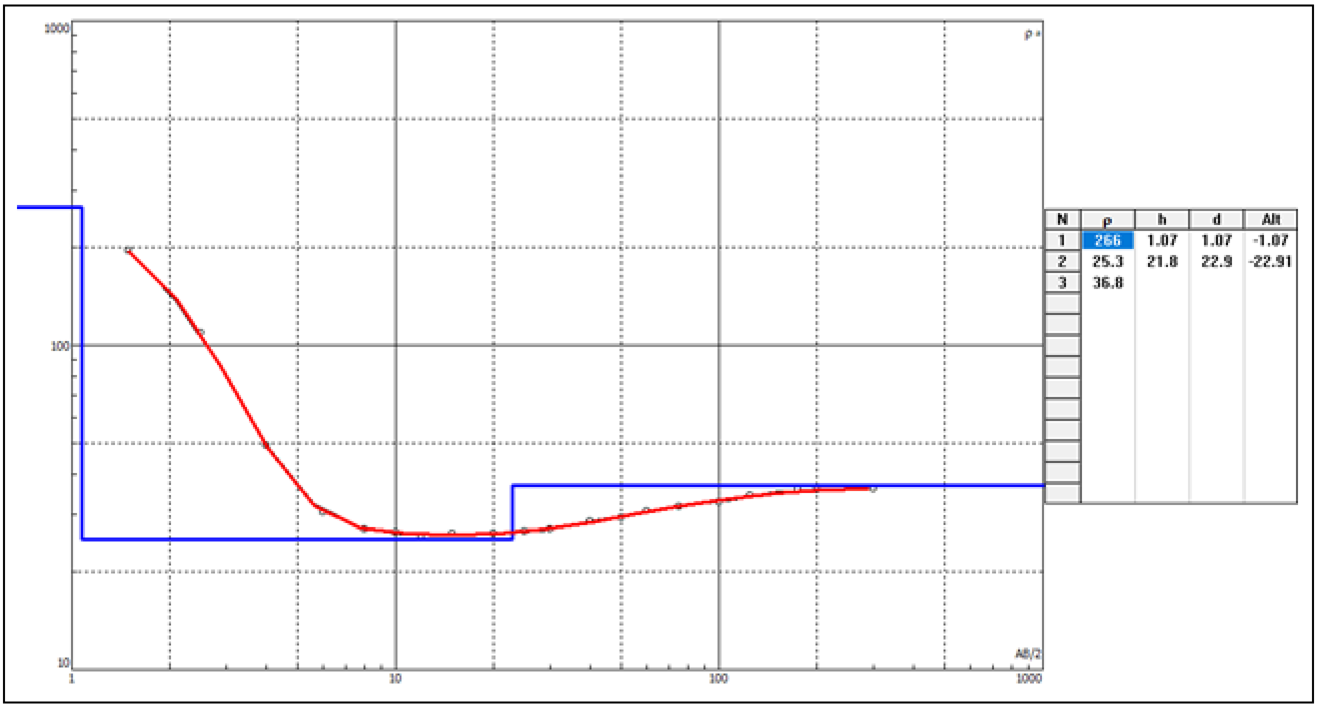

Figure 8: VES3 Graph

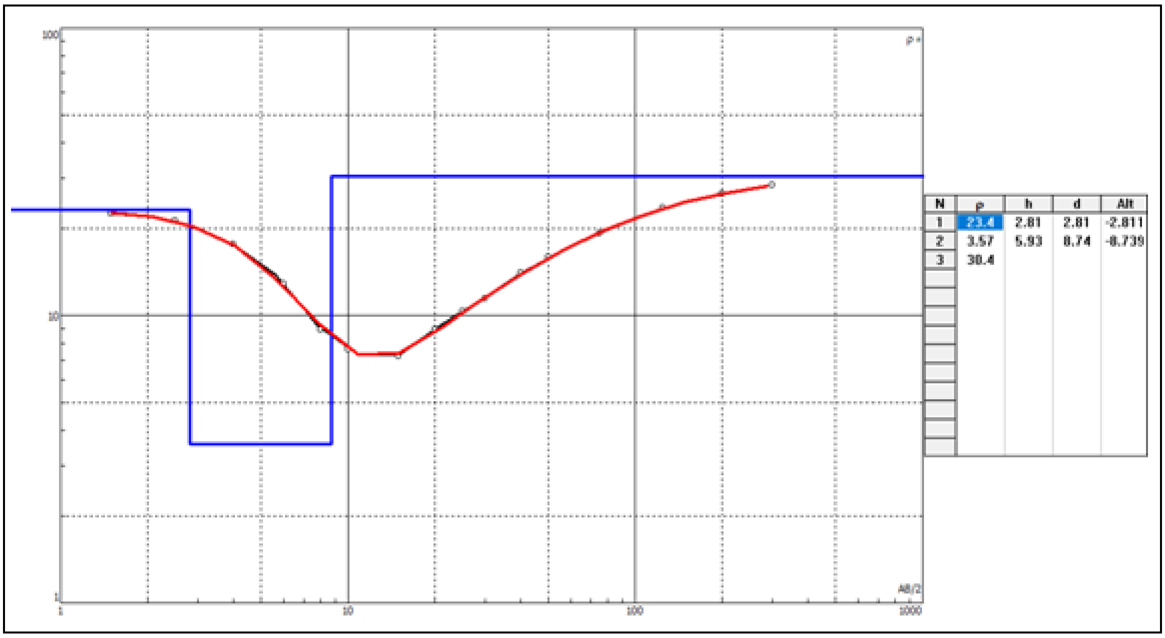

Figure 9: VES4 Graph

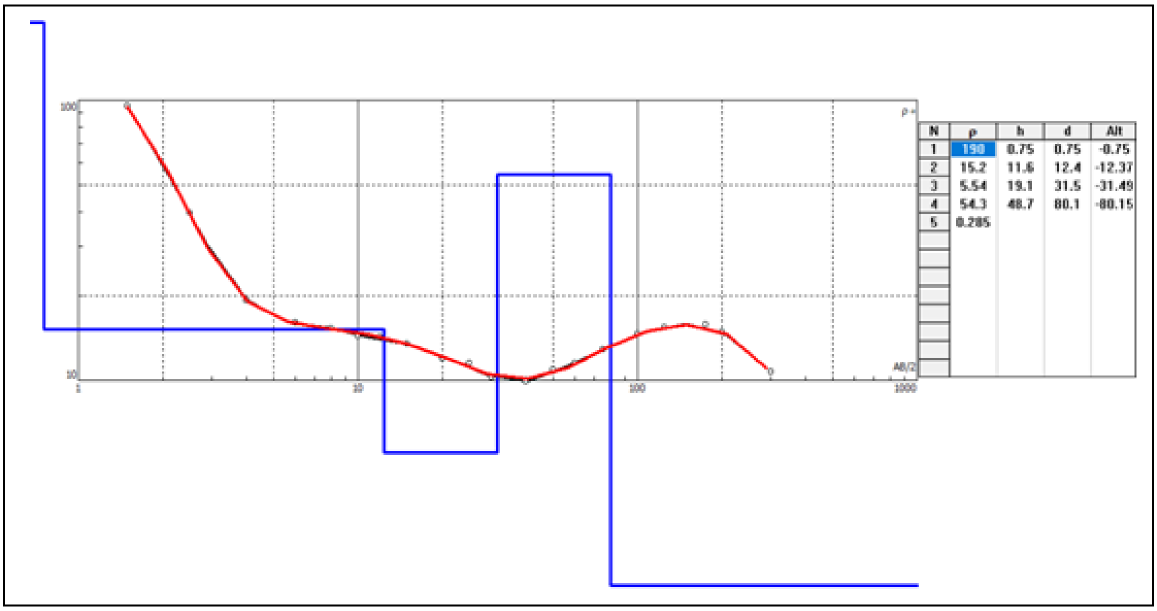

Figure 10: VES5 Graph

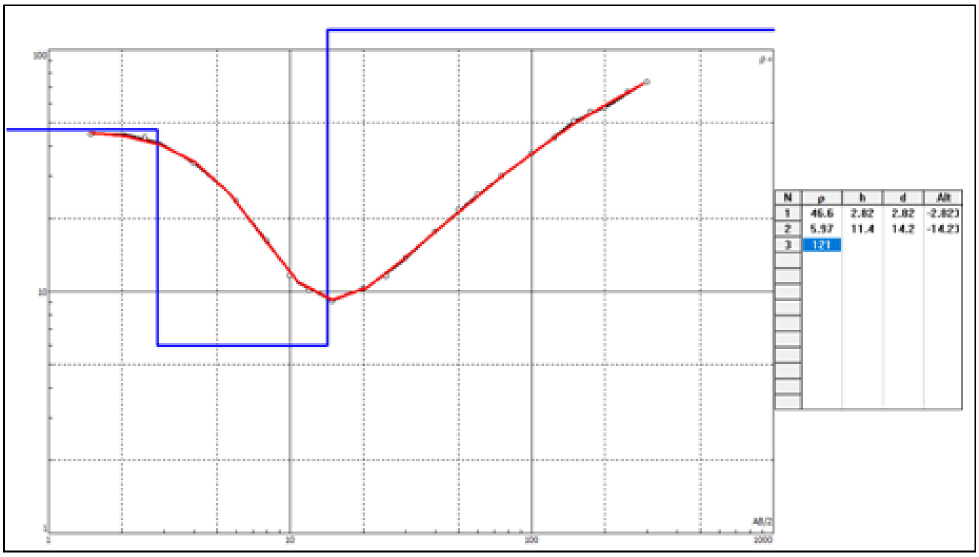

Figure 11: VES6 Graph

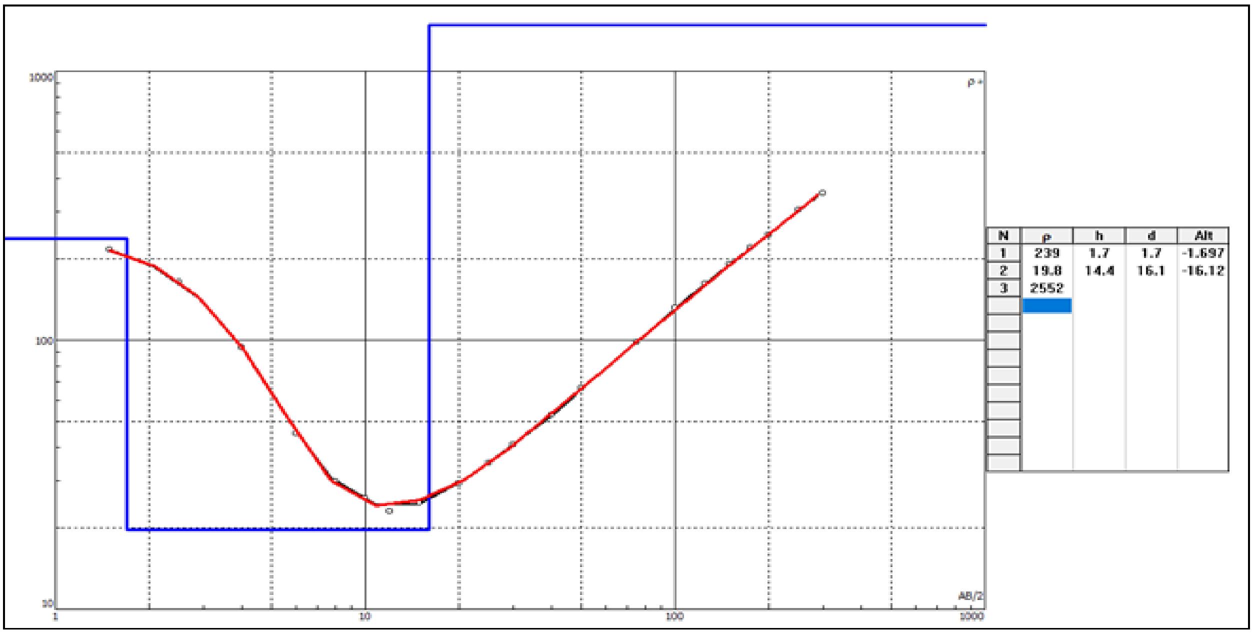

Figure 12: VES7 Graph

5. Conclusion

Vertical Electrical Sounding (VES) technique carried out at seven (7) VES stations in Dhobley district, Lower Jubba region, Somalia revealed that; there are four layers mostly in the area by which among the seven (7) VES stations only one station has five layers (station 2). It is also seen that the probable stations more suitable for making boreholes were station VES 2, 4. However by considering the result obtained it is an indication that the study area has a good land for boreholes and other engineering and architectural activities, due to the features that enhance groundwater permeability and storage. For safety measures, in the deep aquifers which are ranges from 250m to 270m, the random dumping of waste products such as solid and liquid materials must to be avoided in nearby boreholes area in order to prevent waste contaminate to aquifer replenishment.

Acknowledgement

Without the inspiring, comforting and refreshing presence of my wife Khadija Abdi this work would probably be worse. Thanks. The author thanks Mumtaaz Engineering and general services company for supporting this study by providing equipment and logistics. The data of this paper is a primary data, was obtained during the field work by the author. All data can be received upon request of the author.

Conflicts of interest

The author declares no conflict of interest.

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