JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452

Groundwater Potential Assessment Using Vertical Electrical Resistivity Method: A Case of Selam Bere Town, Gamo Gofa Zone Main Ethiopian Rift Valley

Mulugeta Markos Tediso[1], Lamessa Fekede Negero[2*]

[1,2*]Department of Physics, College of Natural and Computational Sciences, Dambi Dollo University, Dambi Dollo, Oromia Region, Ethiopia.

Authors E-Mail: [1]mulugetamarkos2022@gmail.com, [2*]lamefeke@gmail.com

Received 2022 March 25; **Revised** 2022 April 28; **Accepted** 2022 May 15.

Abstract

Electrical sounding method was supported to evaluate groundwater potential in Selam Ber catchment, Gamo Gofa district in southern Ethiopia. Records were collected after five sounding points via Schlumberger investigation arrays per maximum half-done current electrode separation (AB/2 =220). Qualitative analyses of Electrical resistivity data were described by means of curves, apparent resistivity, and pseudo depths. The numerical explanations of the electrical resistivity data were made by the data using IPI-Res3, IRIS, surfer software, building geo-electric unit near the survey line and geologic proof from the drill. The vertical electrical resistivity results of the data shown four geo-electric stratums which differ in range of cracking, enduring, and formation. Examining the potential aquifer of *Traverse Route SELATr1*, the fourth layer group with resistivity value of 45.76-50.66 Ωm. & infinite depth also reveals highly moderately weathered & fractured basalt. Geoelectric section obtained along Traverse Route SELTr1, the horizons of stratum four were enhanced potential aquifers such as the highly cracked and worn ignimbrite level of potential ground water depth could be realized if the fractured zone could be penetrated up to the fresh massive rock of the third depth layer group with estimated final depth of 250 meters. *And Traverse Route SELATr2* the resistivity soundings have identified five layers excluding BfVES-6; all are having similar curve types. The value of the true resistivity does not vary significantly found in the same geologic and hydro geologic pattern. Generally the possibility of striking water is undeniable starting from 45 meters (shallow aquifer) in all Vertical Electrical Resistivity.

Key Words: Ground Water, Vertical electrical sounding, Water resource, Traverse Route

1. Introduction

The accessibility of quality water resources has all the time been the primary worry of societies live in any region. It is one of basic need to sustain life. Our bodies want to ingest water every day to carry on working. Societies can occur without housing and foodstuff in certain period but they cannot be deprived of water and provision for extra than a few days, because of close connection between water and life. It plays a vigorous character in growth of societies since consistent source of water is vigorous privilege for formation of stable societies. Around two third of entire space in the world is enclosed by the water. It is occurred in numerous systems such as ice caps, glaciers, ocean water, surface water and ground water [1].

The major quantity of water on the earth [97.2%] is existed in the oceans and seas as brackish water but only lesser quantity of it [2.8%] occur as fresh water on terrestrial. This fresh exist on land is spread as ice caps and glaciers (76.43%), ground water and soil humidity [21.96%], fresh-water lakes [0.32%], saline lakes (0.29%) and very lesser quantity of it as rivers passages (0. 004%) .Surface water causes are forms of water on the earth's surface, such as rivers, lakes and basins [2].

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452

The present water source of **Selam bere Town** is steam, river and tradition hole. Since the data general well log history did not find, it is impossible to decide about the groundwater potentials of the area from the well. Therefore, in order to assess the groundwater potential at **Selam Bere** town vertical electrical resistivity method were applied to investigate and define the position of preferred bore hole points and the deepness, at which aquifers were situated.

2. MATERIALS AND METHODOLOY

2.1. Study area

Selam Bere town is found in Kucha Woreda of Gamo Gofa zone of Southern Ethiopian. It is located at 6.46933430 latitude and 37.45142700 longitudes in the axis and 583.0 Kilometers from Addis Ababa. The location and accessibility map of investigated sites is presented in Fig. 1

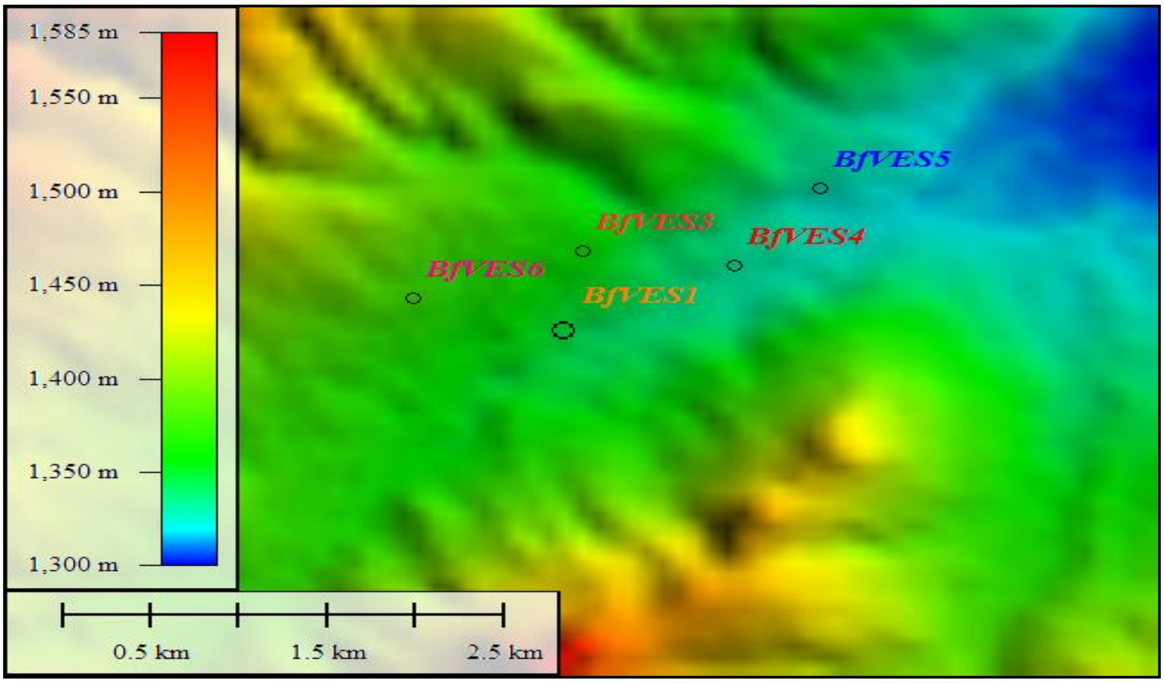


Figure 1. Digital map of the Selam Bere catchment found in Kucha Woreda of Gamo Gofa zone in southern Ethiopia.

2.2. METHODOLOGY

2.2.1. Electrical Resistivity Methods

Electrical resistivity is geophysical method that measure subsurface electrical resistivity structures using direct or low frequency interchanging current with a series of electrodes introduced into the earth. The probe consists of both current and potential for inserting the present and calculating the potential change in turn [3].

Electrical resistivities are broadly used in the exploration of appropriate groundwater sources; in engineering study to find subsurface hollows, faults and cracks; in archaeology for plotting the areal degree of leftovers of buried basis of the early buildings, among many other uses [4].

Method implemented during current survey is Vertical Electrical Sounding (VES) providing the subsurface information regarding the nature of rocks, their degree of weathering and/or fracturing, which are important and useful in identifying favorable areas of groundwater development [5].

Vertical electrical sounding (VES) is used to find subsurface horizontal and vertical variants of resistivity [7]. The ABEM Terrameter SAS 1000 [7,8]. Schlumberger electrode configuration was used for VES reading in all examined points with the maximum current electrode parting range used (half - the maximum current electrode separation, $\frac{AB}{2}$=220 for this work).

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452

2.2.2. Apparent resistivity

The apparent resistivity values ρ_a were determined as $\rho_a = k\frac{\Delta V}{I}$, where *k* is the geometric element, which relays on the mutual arrangement of potential and current probes, i.e. $k = 2\pi \frac{r_{AM} r_{AN}}{r_{MN}}$, whereas $\frac{\Delta V}{I}$ is obtained automatically from the resistivity meter display, A and B are Current probes ,M and N are Potential probes.

$\Delta V = V_C - V_D$ **(2)**

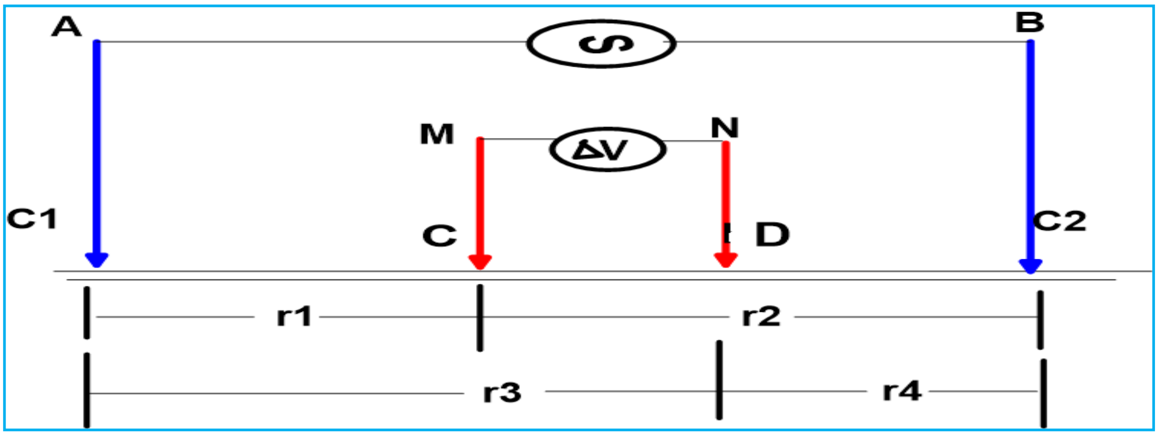


Figure 2. The Schlumberger array used in the survey [Two current (C1 and C2) and two potential (M and N) electrodes (Telford et al., 1990).

Consider the case where the electrode layout is placed over a homogeneous earth, the potential alteration measured relays on the applied current, the resistivity of the subsurface medium and the geometric element (k) obtained by the distance between electrodes.

Mathematically it is expressed as:

$$\Delta V = V_C - V_D = \frac{I\rho}{2\pi}\left(\frac{1}{r_1} - \frac{1}{r_2} - \frac{1}{r_3} + \frac{1}{r_4}\right) \quad (2.1)$$

$$\rho_a = k\frac{\Delta V}{I} \quad (2.2)$$

Standard electrode configurations used for 2 dimensional electrical resistivity tomography (2D-ERT) surveys are Wenner, dipole dipole, Wenner-Schlumberger, pole-pole, pole-dipole, and equatorial dipole-dipole [Telford et al., 1990; 9, 10, 11, 12, 13]

2.2.3. Electrical Resistivity Data Acquisition.

The instrument used in resistivity reading contained of a portable integrated resistivity meter IRIS instrument /SYSCAL Junior Switch 72 Model 5 powered by internal Tx 12v battery organized with other equipment such as connecting cables with reels and electrodes.

Stainless steel electrodes and reels with cables were used to inject electric current in to ground. The *GARMIN* GPS72H has served for navigating and locating the observation stations \ points.

The Schlumberger electrode configuration was used for VES measurements in all explored sites with the maximum current probe parting array used 220 m (half - the maximum current electrode separation) and was conducted along two lines which are about 400 m apart. The VES were worked with maximum current probe laying (AB/2) of 220 meters by

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452

smearing electrical current into the earth by means of two current electrodes, and the resulting potential difference was measured by the pair of potential electrodes found in the center. The current electrode arrangement designated for these surveys was AB/2 (1.5, 2.1, 3, 4.2, 6, 9, 13.5, 20, 30, 45, 66, 100, 150, and 220) meters and the spacing of the potential electrodes was MN/2 (0.5, 6, and 45) meters. The repeated measurements are taken at (20, 30 150 and 220) meters in order to eliminate the uncertainty.

3. Result and Discussion

3.1. Traverse Route SELATr1 (along BfVES-1, BfVES-4 & BfVES-5)

Table 1. Location of VES location on traverse route SELATr1

No	VES type	Longitude (UTM) (X)	Latitude (UTM) (Y)	Altitude (Z)
1	Bf VES-1	331151	716834	1348
2	Bf VES-4	332092	717328	1331
3	BfVES-5	332584	717881	1329

Geo electric Resistivity Section obtained along Traverse Route SELAMBERE Tr1 (Figures 4,5 and 6) with the **NE -SW** headings exposes four main resistivity groups in geoelectric section**.** The natures of curves obtained from BfVES-1, BfVES-4 & VES-5 are also very similar.

So the first layer group with a calculated true resistivity of 6.58- 324.7 Ωm and to the depth of 12.46 meter is a clay soil intercalated with dry alluvial deposit profile forming the upper stratography of in the study area.

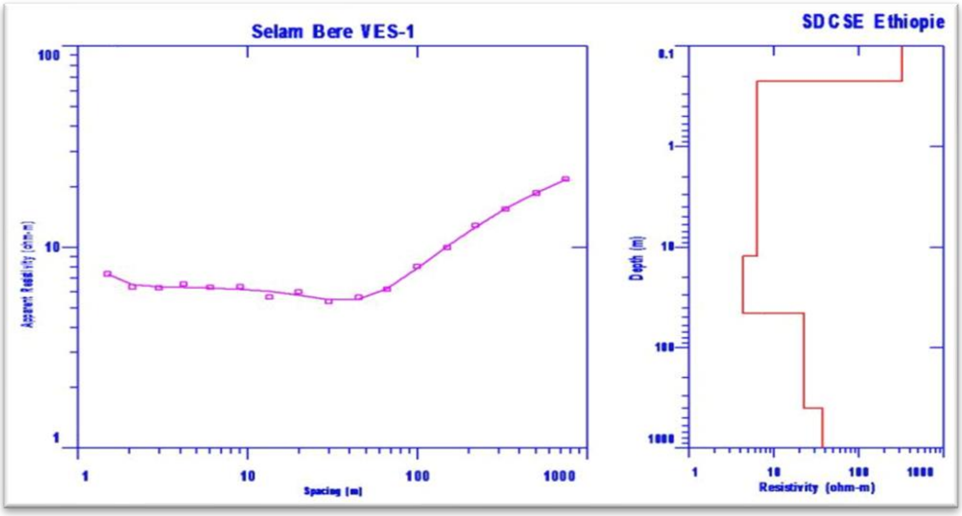
The second layer group with resistivity value 5.15 Ωm and with thickness 38.19mts is related to water saturated highly weathered volcanic ash, sand & tuff dominantly at BfVES-4 station area.

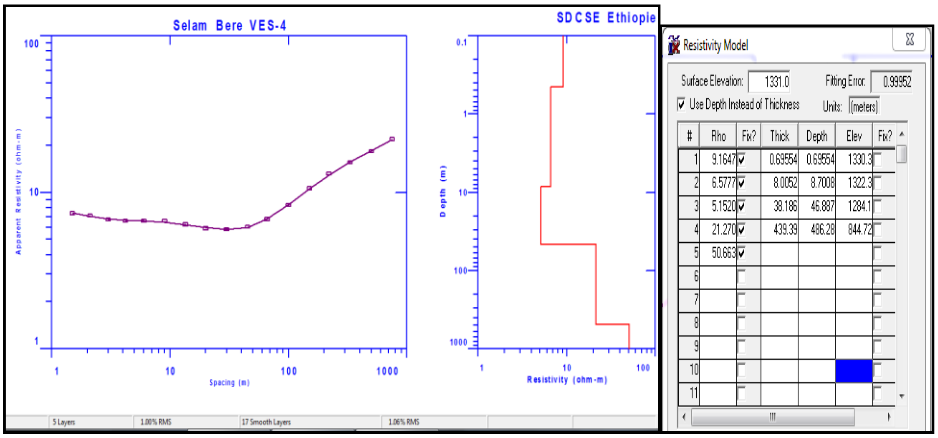
The third layer group with resistivity 13.89-21.27 Ωm having remarkable depth thickness of 45-250 meters where the major water saturated highly weathered and fractured basalt is expected.

The fourth layer group with resistivity value of 45.76-50.66 Ωm. & infinite depth also reveals highly moderately weathered &fractured basalt.

Potential ground water depth could be realized if the fractured zone could be penetrated up to the fresh massive rock of the third depth layer group with estimated final depth of 250 meters.

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452





RMS of Curve fitting error =1%

RMS of smmoth model= 1.06%

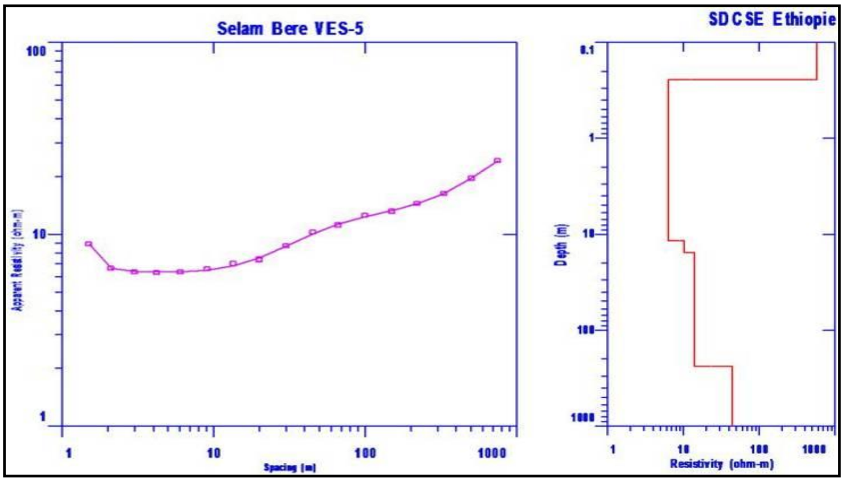


Figure 4.a) Resistivity graph of BfVES-1 .b) Resistivity graph of BfVES-4.

c) Resistivity graph of BfVES-5

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452

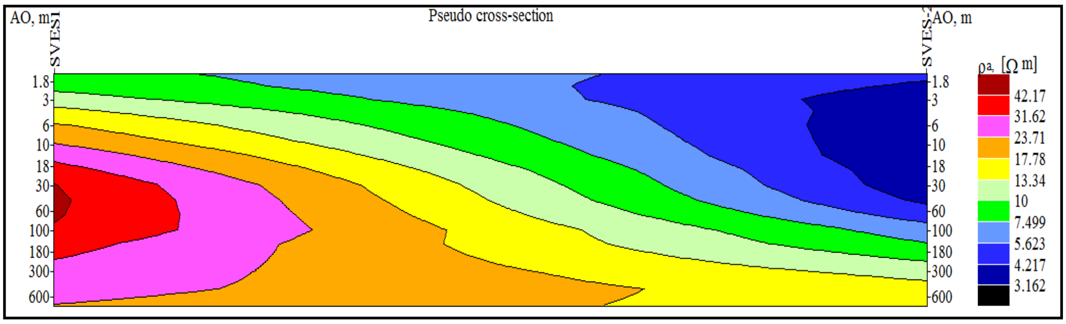


Figure 5.Pseudo-cross section obtained from apparent resistivity DVES-2 and DVES-3

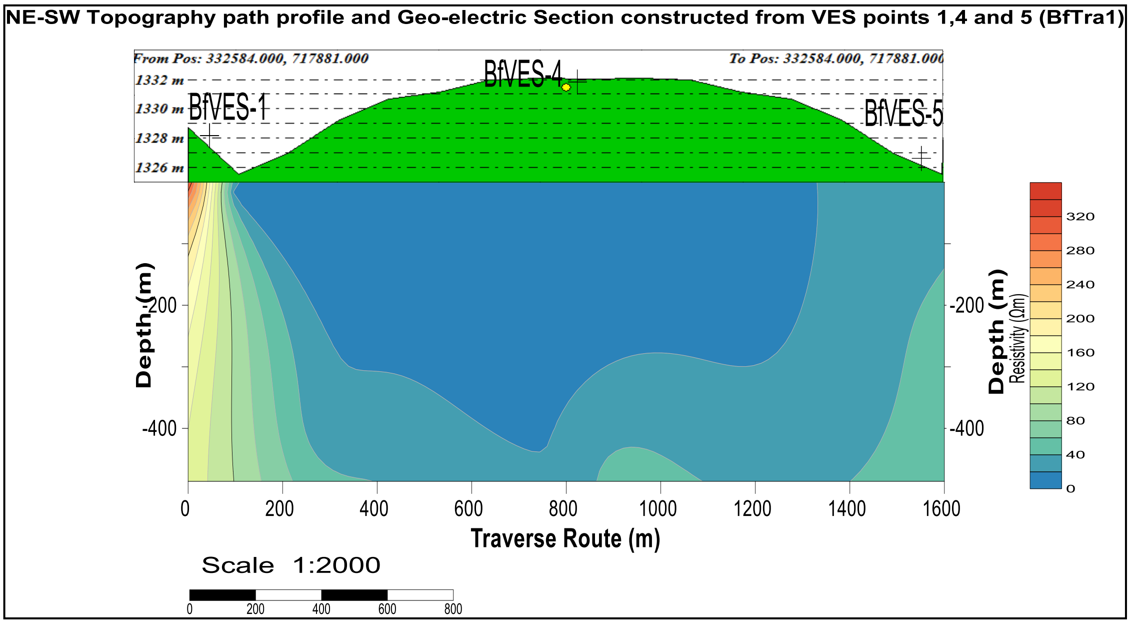


Figure 6.Topograpy path profile and Geoelectric Section obtained along Traverse Route SELTr1.

3.2. Traverse Route SELATr2 (along VES point BfVES-3 & BfVES-6)

Table 2. Location of VES location on traverse route SELATra2

No	VES type	Easting	Northing	Altitude
1	Bf VES-3	330759	717304	1361
2	Bf VES-6	330759	717304	1354

The geo electric model represents five geo electric resistivity layers (groups) (Figure 9.).

Geo electric Resistivity Section obtained along Traverse Route SELABERE Tr2 ((Figure7 a) and b)) with the **NE -SW** headings reveals four main resistivity groups in geoelectric section**.**

The first layer group with a calculated true resistivity of 2-29 Ωm and to the depth of 41 meter is a clay soil intercalated with dry alluvial deposit/ water saturated highly weathered volcanic ash, sand & tuff profile forming the upper stratigraphy of in the study area.

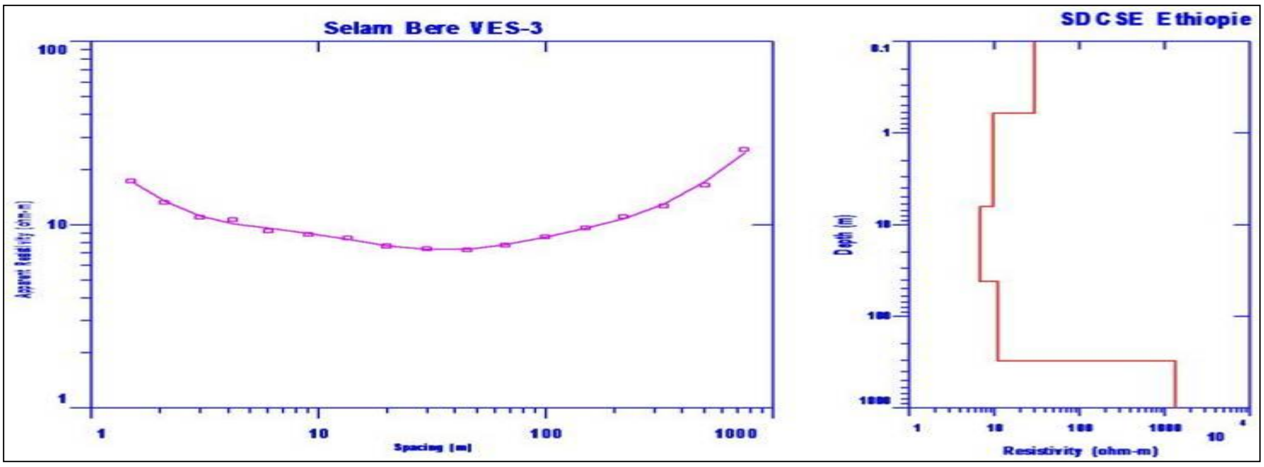
The second layer group with resistivity value 7-11 Ωm and with remarkable depth thickness 120 meters is related to the first major plausible water saturated highly weathered and fractured basaltic aquifer.

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452

The third layer group with resistivity 14 Ωm having remarkable depth thickness of up to 300-350 meters where the major water saturated highly weathered and fractured basalt is expected.

The fourth layer group with relatively high resistivity value of 1300-3847 Ωm. & infinite depth also reveals slightly to fresh basalt.

Potential ground water depth could be realized if the fractured zone could be penetrated up to the recommended final depth of 250 meter.



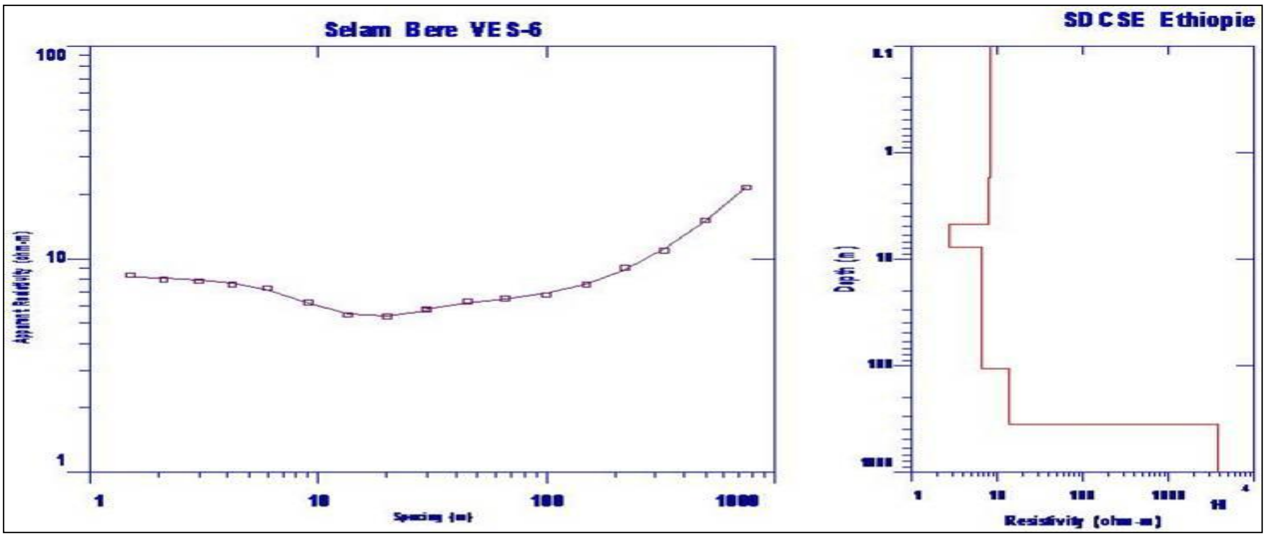


Figure 7.a) Resistivity graph of BfVES-3. b) Resistivity graph of BfVES-6

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452

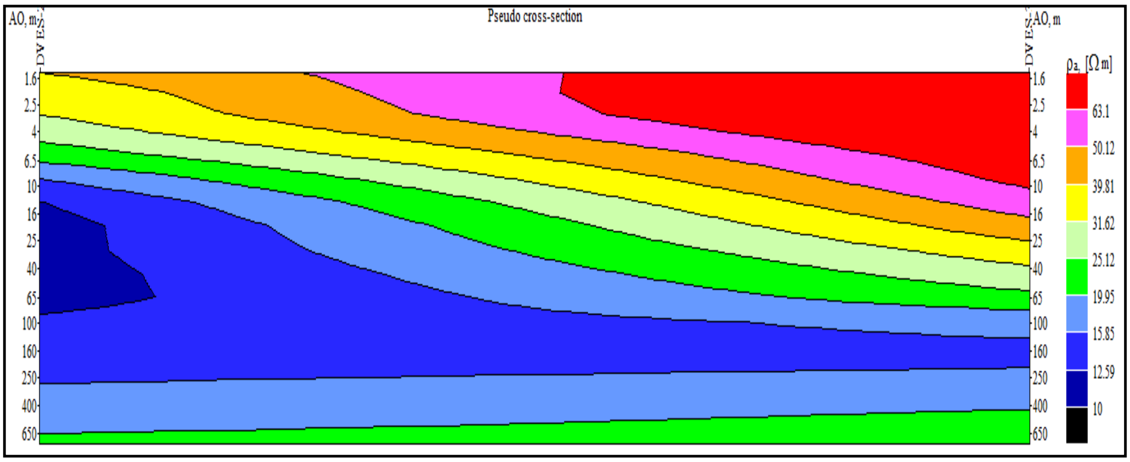


Figure 8.pseudosection of BfVES-3 and BfVES-6.

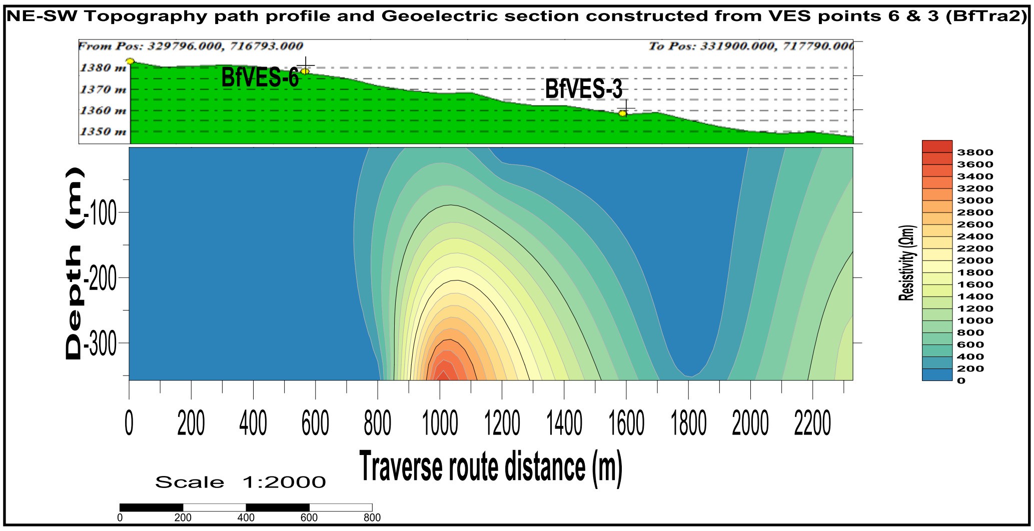


Figure 9.Topograpy path profile and Geoelectric Section obtained along Traverse Route SELATr2.

Table 3.Borehole data found from Selam Bere Hospital compound used to calibrate the resistivity result.

Borehole	Coordinates		Depth (m)
Layer	Depth Intervals (m)	Thickness (m)	General Lithological Description
1	0 – 4	4	Clay
2	4 – 8	4	Weathered Tuff
3	8 – 46	38	Volcanic Ash ,sand Tuff
4	46 – 60	14	Volcanic Ash ,sand Tuff
5	60 – 96	36	Basalt
6	96 – 145	6	Slightly fractured weathered basalt

Water has been struck at about 55meters & increased at 100 meters, however discharge at 145 meters is 2.5 L/sec, drilling should not have been stopped at this depth.

4. Conclusion and recommendation

4.1. Conclusion

Based on the interpretation of the resistivity sounding & inferred from the local geological & hydrogeological condition of the area, the following is concluded on the groundwater occurrence and possible exploitations.

All the resistivity soundings have identified five layers except BfVES-6; all are having similar curve types. The value of the true resistivity does not vary significantly found in the same geologic and hydro geologic pattern.

Generally the possibility of striking water is undeniable starting from 45 meters (shallow aquifer) in all VES area.

4.2. Recommendation

Therefore the recommended depth for borehole scheme is 250 meter to have sufficient water by full penetration of fractured and weathered basalt aquifer. Furthermore as stated above, the borehole data found to calibrate the interpretation reveals that drilling with depth of 145 meter having only 2.5 L/sec which shows that drilling stopped with no sufficient penetration of the aquifer.

5. References

[1] Shiklomanov, I. (1993).World Fresh Resources. In: Water in Criss: A Guide to the Worlds Telford, W.M., Geldart, L.P & Sheriff, R.E. 1990. Applied Geophysics, 2nd Edition, Cambridge University Press, New York, 1608p.
[2] Fetter, C.W. (2001).Applied Hydrogeology, 4thEdition.Prentice-Hall, Inc.London, UK. pp120.
[3] Kearey, P. and Brooks, M. 1984. An Introduction to Geophysical Exploration, Blackwell Science Publications, U.S.A.
[4] Reynolds, J.M. (1997).An Introduction to applied and Environmental Geophysics. John Wiley and Sons limited, England, UK.pp.116-209,415-522.
[5] Loke, M.H. and Barker, R.D. 1996. Practical techniques for 3D resistivity surveys and data Inversion. Geophysical Prospecting. 44, 499-523.
[6] Nabighian, M. N & Macnae, J. C. 1991. Time domain electromagnetic prospecting methods.Electromagnetic Methods. In: M. N. Nabighian (Ed.), Electromagnetic Methods in Applied Geophysics, Society of Exploration Geophysicists, 2: 427-509.
[7] ABEM. 1999. ABEM Terrameter SAS 4000/SAS 1000. Instruction Manual. ABEM Printed Matter 93101. ABEM, Sweden.
[8] ABEM. 2012. ABEM Terrameter LS.Instruction Manual. ABEM Printed Matter 20120109, ABEM, Sweden based on release 1.10.
[9] Loke, M.H. 2000. Electrical Imaging s Surveys for Environmental and Engineering Studies, a Practical guide to 2-d and 3-d surveys. Penang, Malaysia.
[10] Kearey, P. and Brooks, M. 2002. An Introduction to Geophysical Exploration, Blackwell Science Publications, U.S.A.
[11] Dahlin, T. and Zhou, B. 2004. A numerical comparison of 2D resistivity imaging with 10 Electrode arrays. Geophysical Prospecting. 52, 379-398.
[12] Loke, M.H. and Lane, J.W. 2004. Inversion of data from electrical resistivity imaging surveys in water covered areas. Exploration Geophysics. 35, 266-271.
[13] Loke, M.H. 2010. 2D and 3D Electric Imaging Surveys, Geotomo Software Sdn Bsd, Malaysia.
[14] Golden software Inc. (2010).Surfer®10, contouring 3D surface mapping for scientist and Engineers, Golden software, Inc. Colorado
[15] Loke, M.H. and Baker, R.D. 1995. Least-square DE convolution of apparent resistivity Pseudo sections. Geophysics. 60, 1682-1690.
[16] Loke, M.H. 2004. RES2DINV ver. 2.14, Geotomo Software Sdn Bsd, Malaysia.

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 3050-3059
https://publishoa.com
ISSN: 1309-3452

Annex

Photographic view of electrical resistivity data gathering