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Exploration of Drinking Water Using Vertical Electrical Sounding Method in Behsud District, Nangarhar Province, Afghanistan

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Abstract

Water is a vital resource that sustains life on Earth, and its availability is critical to the well-being of living organisms. Groundwater, an important component of the global water supply, is stored in the porous layers of the earth's crust. Most areas in Afghanistan nowadays are facing drought and are searching for groundwater, and Khanakai village is one such area. For the exploration of groundwater, the electrical vertical sounding method is very effective in Khanakai village, Behsud district of Nangarhar, Afghanistan. Vertical Electrical Sounding (VES) investigations were carried out in Khanakai Returnees and Internal Displacement People (IDPs) Settlement in Behsud District, in order to study the aquifer characteristics with a view to determining the depth and thickness of sediments layers and recommend a suitable site to drill wells for safe drinking water. Five VES profiles were conducted in this area and the Schlumberger electrode configuration was used for the field data acquisition. Interpretations of VESs profile data results confirm the similarities between the subsurface geological sequence and lithology. The subsurface geology lies within the Quaternary-Neogene Clastic sedimentary deposits (clay, silt clay, silt sand, sand, gravel, people, coble, boulder, conglomerate, and sandstone) and it is underlain by fundamental Rocks (early Proterozoic gneiss, shiest, amphibolite and quartzite). The maximum depth of study range is between 140 m and 200 m. The aquifers' average apparent resistivity range is between 6.87 and 471 Ohm.m and the groundwater is characterized by fresh water. The depth of the water table is prospected between 75 and 95 m. The study area has fracture and sediments aquifers, but the sedimentary aquifer is not potential. This area is problematic for well drilling due to having a deep water table and hard strata, possibly bedrock. The groundwater table in the village is located at a depth of 75-95 m. The aquifer is composed of sand, gravel, sandstone, mud, and silt, and it is underlain by bedrock. The characterized groundwater is suitable for the drinking purposes of local people.

Keywords: Groundwater Exploration; Vertical Electrical Sounding (VES); Apparent Electrical Resistivity; Behsud Nangrahar-Afghanistan.

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1. Introduction

Water is vital for all living things Groundwater, found in the earth's porous layers, is a key water source used by 50% of the world's population [1]. Surface water seeps into the permeable environment due to gravity and moves downwards. Lithology of the crust particularly sedimentary layers varies greatly in composition, affecting the ability to collect water underground. Factors such as rock particle size, porosity, compaction, and cracks all play a role [2]. Access to clean water is crucial for drinking, but many people and factories in Nangarhar, Afghanistan use a significant amount of contaminated water daily. The electrical vertical method in Khanakai village of Behsud District, Nangarhar, Afghanistan can help address this issue. The data were collected from research conducted by DACAAR in 2016. This research article aims to analyze field data to determine a suitable location for drilling a water well and to assess clean groundwater in Khanakai village using the vertical electrical sounding method.

2. Research Goals

The primary goal of this scientific research is to explore groundwater and identify the best location for drilling a well based on geological and technical conditions. The study also involves calculating the apparent electrical resistivity, estimating the depth and thickness of the sediment layer, determining groundwater levels, and assessing the quality of underground aquifers.

3. Research Gaps

This research paper aims to address the following gaps:

- Studying the general climate, hydrogeology, and geology of the study area.
- Explaining the basic concepts of vertical electrical sounding and identifying the specific locations for geophysical survey.
- Providing and modeling vertical electrical sounding data using IX1D and ArcMap 10.5 software.
- Determining the depth of the aquifer and the water table.

4. Research Methodology

The methodology for this study involves reviewing prior works of literature using the library research method, along with collecting field data and interpreting it using IX1D and ArcMap 10.5 software. This study combines fieldwork, library research, and the use of computer software.

5. An overview of groundwater research in Nangarhar Province

Since 1962, numerous hydrological studies have been carried out in Afghanistan with support from various governmental and foreign institutions, mainly focusing on the capital Kabul. [3, 4, 5]. Limited hydrological studies have been conducted in Jalalabad sedimentary basin, located in eastern Afghanistan. In the past, the area had a small population and rare droughts, with water needs being met by abundant resources from rivers like Kabul and Kunar [6]. However, in recent years, the population in the Jalalabad

Basin has grown due to internal displacement and the return of immigrants, while climate change has led to more frequent droughts. This has created a higher demand for water, but the water levels in rivers and local sources have fallen significantly, and in some cases have even dried up completely [2, 3]. As a result, national and international institutions are actively working to find solutions to the water problems in this area.

6. Climatic and hydrogeology of the study area

The study area is located at an average altitude of 600 m above sea level and is known for its mountain terrain. The climate of this area is semi-humid with varying temperatures between day and night. Summers, from March to August, are hot, with temperatures reaching up to 45 °C, while winter experiences temperatures drop below 4 °C [7]. Rain and snow, with an average annual precipitation of 150 mm, are the main sources of surface and groundwater [2, 6]. Local rivers and streams appear during the rainy season in certain parts of the province. The area is related to the deep east-south Hindu Kush basin from a hydrogeological perspective, with Neogene sediments covering the deeper parts of the region. These sediments have both layered and fractured characteristics, with small artesian wells in some areas. The Quaternary period contributed to the formation of water bodies along the rivers. Water is mainly found in the pores of the sand and gravel and flows through these layers.

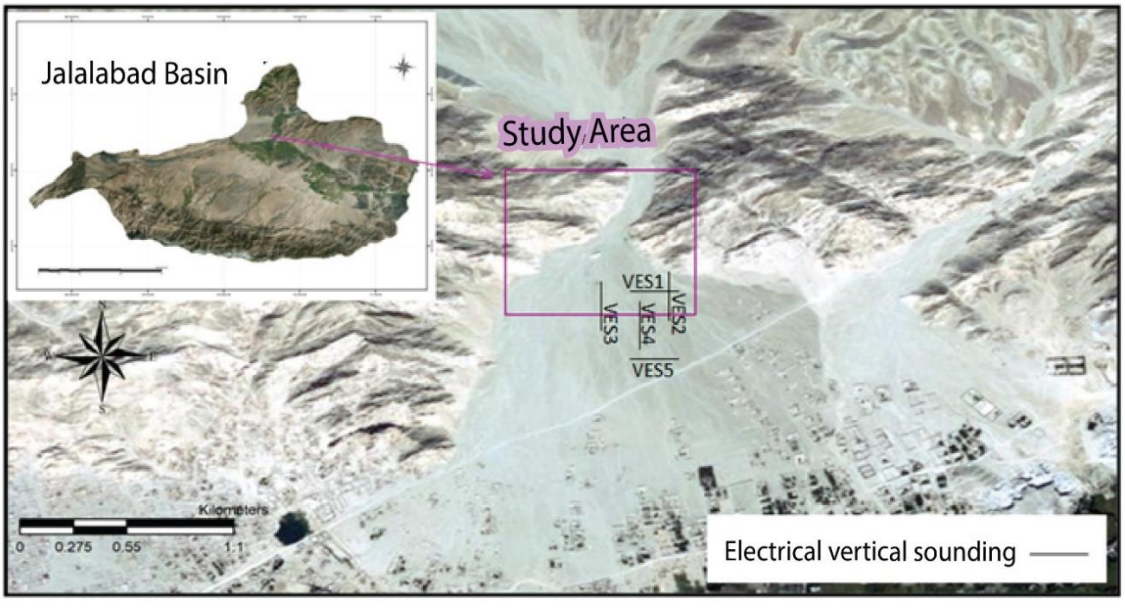


Fig. 1. Satellite image of the study area [8]

7. Geology of the study area

The Jalalabad Basin has a geological structure characterized by the presence of hard sedimentary rocks overlain by soft fractured and eroded sediments [9, 10]. The Jalalabad Basin is mainly covered by alluvial and colluvial fan debris consisting of shingly and detrital sediments, including gravel, sand, silts, clay, and loess in a range of fine to coarse

grains [6]. Throughout its history, the basin has undergone internal deformation, leading to localized uplift and subsidence [11]. The Jalalabad basin is also intersected by active and presumed active faults, resulting in different surface deformations [12]. This region was influenced by different geologic and tectonics processes, and rocks from different eras, including the Proterozoic, Paleozoic, Mesozoic, and Cenozoic, were involved in the formation of this region (Figure 2). The region's bedrocks belong to the Paleozoic and Mesozoic periods, and the deep bedrock is predominantly filled with soft, fractured sediments, mostly of Neogene and Quaternary age [9, 10, 11]. These sediments are alluvial-diluvian deposits and various lake sediments. The lithological composition of Nangarhar includes a range of rock types including gneiss, amphibolite, marble, gypsum, limestone, carbonate, gravel, sand, and others [9, 11] (Figure 2).

From a tectonic point of view, the study area is situated near the Spin Ghar Mountains, close to the Main Frontal Thrust system [6]. The tectonic activities in the region have shaped a basin and range-type topography, known as horst and graben [6, 12]. Eastern and north-eastern Afghanistan is intersected by several large active and potentially active faults, including the Chaman, Gardez, Paghman, Panjshir, Central Badakhshan, Sarobi, Spin Ghar, and Konar faults [9, 12, 13].

However, the surface geological sediments can be divided into different categories [9, 10]:

1. Fresh Quaternary sediments consisting of loess, clay, sand, and gravel.
2. Middle Quaternary consists of clay, silty clay, and conglomerates.
3. Early Quaternary sediments consisted of red clay, clay with organic matter, sand, and gravel.
4. Early Miocene sediments were characterized by sandstones, siltstones, conglomerates, and limestones.
5. Eocene sediments, which include clay, shale, and conglomerates.
6. Paleocene sediments, which include siltstones, conglomerates, and limestones.
7. Late Cretaceous sediments consisting of limestone and marl.
8. Old Cretaceous sediments consisting of limestone, dolomite, and gypsum [10, 11] (Figure 2)

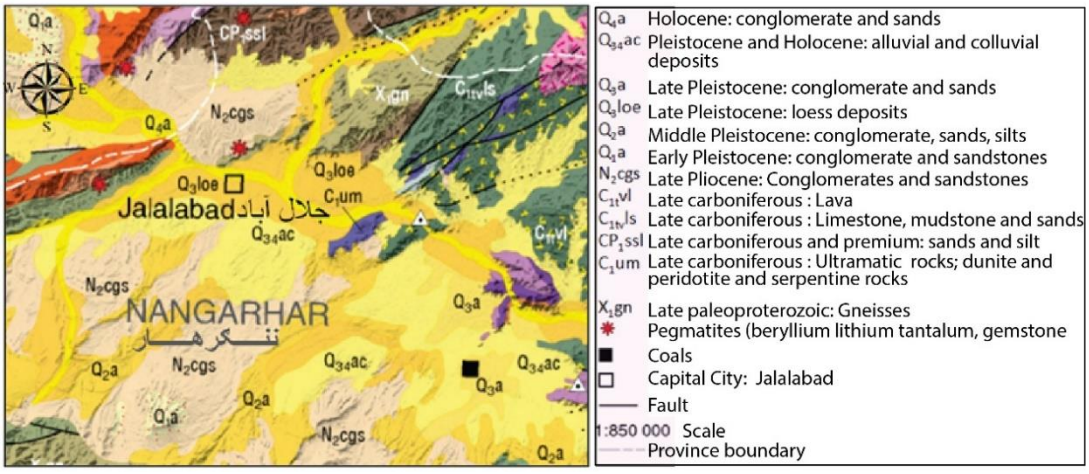


Fig. 2. Geological map of Jalalabad Basin [9, 10, and 11].

8. Geophysical survey in the study area and its purposes

The Khanakai village, previously uninhabitable due to its desert and mountainous terrain, is located in the northern part of Behsud District of Nangarhar Province, Afghanistan, with a latitude between 34.485572 and 34.491456, and longitude between 70.496714 to 70.496714 degrees. The study area is a semi-desert and the surrounding areas have mountainous terrain, which was previously uninhabitable. The Jalalabad Basin is wide, with altitudes ranging from 500-1800 m above sea level [6, 14]. The geophysical survey was done by DACAAR in Khanakai village to help relocate refugees and displaced families affected by drought and other challenges. The main issue hindering the resettlement plan is the lack of confirmed groundwater depth and location. No work has been done to determine groundwater location in the area. Therefore, it was important to conduct a geophysical survey using the vertical electrical sounding method to confirm the presence of groundwater and choose a suitable drilling site based on geological and hydrological conditions [14]. The location of the vertical electrical sounding is shown in Figure 2.

A geophysical survey using the Profiling and Vertical Electrical Sounding method was conducted on November 15-16, 2016, with the support of the (DAACAR), a Danish non-governmental and developmental humanitarian organization [14, 15, 16, 17] (Figures 1, 3).

The Sycle Pro Resistivity Meter was used for field measurements, and the data was interpreted using IX1D and ArcGIS software (Figure 3). In the Schlumberger method, direct current (DC) is applied to the ground with the help of two current electrodes labeled A and B, while the potential difference is measured by two receiving electrodes, M and N [17, 18].

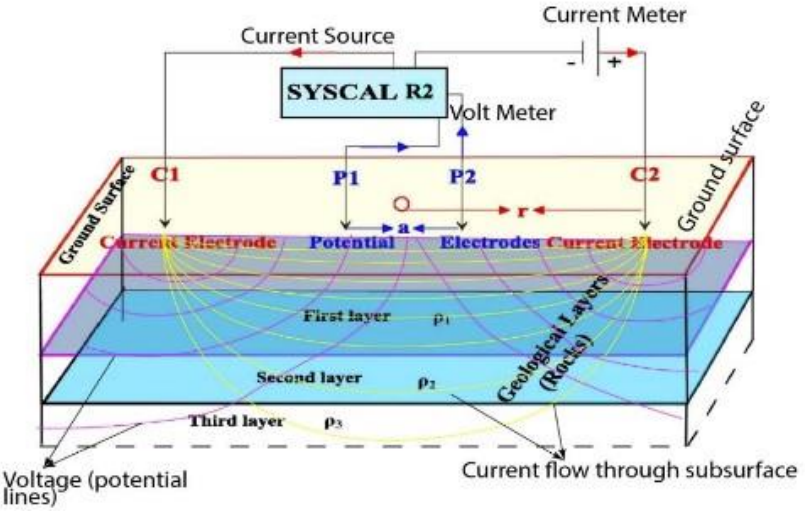


Fig. 3. Schematic of Schlumberger Applied Techniques Method, modified from [4, 17].

The Vertical Electric Sounding (VES) method aims to provide a vertical profile of apparent resistivity along the Earth's vertical axis [19]. This method uses a sequence of different potentials, each spaced from a fixed reference point, and large electrodes to penetrate deeper layers of the subsurface. The measured potential difference is directly proportional to the depth and the differences in the subsurface layers. [20].

The apparent resistivity values are calculated from the measured potential difference and then interpreted to determine the thickness of sediment layers, the depth of the water table, and the depth and thickness of the subsurface layers [13].

During the fieldwork for this research, the resistivity was measured by transmitting electricity into the soil and simultaneously evaluating the potential difference between two sets of electrodes: the current electrodes are (C_1 and C_2) and the potential electrodes are (P_1 and P_2) as shown in figure 4 [19, 20].

First, the electric current (I_{AB}) and the potential difference (ΔU_{MN}) are calculated for a small distance and then for a large distance AB/2. The total difference is then calculated using the following formula [13, 14].

$$\Delta u = I.\rho.MN/\Pi.AM.AN \qquad (1)$$

The specific electrical resistance can be determined from the above formula as follows:

$$\rho = (\pi.\Delta u.\mathrm{AM}.\mathrm{AN})/(I.AM) => \quad \rho = \mathrm{K}\Delta\mathrm{u}/\mathrm{I} \qquad (2)$$

Here: ρ-specific apparent electrical resistance, K- is the geophysical factor or device coefficient, Δu - is the potential difference between M and N electrodes, and I- indicates the intensity of the electric current. The potential difference is measured in millivolts (mV). Current in milliamperes (mA) and apparent electrical resistance in ohmmeter (Ohm.m) [19, 20].

The apparent electrical resistivity values for water and some rocks are as follows (Figure 4).

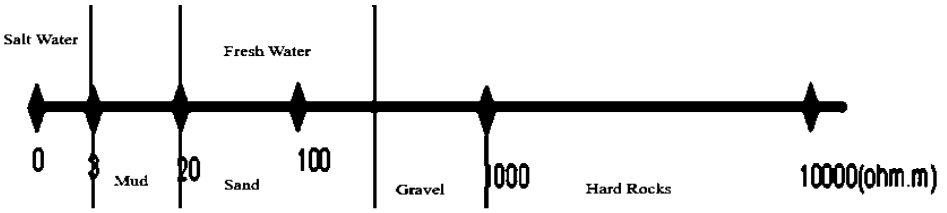


Fig. 4. Apparent electrical resistivity values for water and some rocks [19].

The location of the survey (as shown in Figure 1) and the length of the Vertical Electronical Sounding (VES) are listed in the table below (Table 1).

Table 1. Location and length of Vertical Electrical Sounding (VES) and Profile Sounding methods

Number	Location	VES Station	Latitude	Longitude	Absolute Elevation	Length
1	Khanakai	VES1	34.48690°	70.49968°	625 m	700 m
2	Khanakai	VES2	34.48696°	70.49963°	625 m	700 m
3	Khanakai	VES3	34.48797°	70.49893°	627 m	1000 m
4	Khanakai	VES4	34.49044°	70.49730°	634 m	1000 m
5	Khanakai	VES5	34.48779°	70.49873°	633 m	700 m

Five VES locations were selected in the area, as indicated in the first figure and table. The specific numbers for each VES are as follows:

Table 2. Electrical vertical sounding values along geophysical profile number 1

Distance between current electrodes AB/2 (m)	**Distance between the receiving electrodes MN/2 (m)**	**Electrical apparent resistance ρ_k (Ohm.m)**	**Potential difference Vp (mV)**	**Magnitude of the electric current (mA)**	**Device factor K (m)**
1	0.5	3.437	943.698	645.231	2.35
2	0.5	568.0269	171.082	3.554	11.8
3	0.5	291.2639	21.956	2.073	27.5
4	0.5	152.2768	12.499	4.063	49.5
5	0.5	178.4241	10.795	4.701	77.7
6	0.5	103.684	1.945	2.101	112
8	0.5	33.3696	0.614	3.68	200
10	0.5	23.7985	1.69	22.227	313
15	0.5	18.3188	0.87	33.482	705
15	5	22.1303	12.061	34.226	62.8
20	5	16.7402	8.424	59.38	118
20	0.5	18.6098	0.888	59.646	1250

25	0.5	47.1768	2.365	98.256	1960
25	5	16.8217	8.89	99.355	188
30	5	17.0446	8.686	140.141	275
35	5	18.4432	3.935	80.436	377
40	5	2.8769	3.669	79.388	495
50	5	13.1907	1.357	80.243	780
60	5	25.2989	0.861	38.117	1120
70	5	16.001	0.467	44.654	1530
80	5	54.2096	1.375	50.729	2000
80	30	22.8746	4.082	51.394	288
100	30	31.7311	2.002	29.969	475
100	5	114.3831	1.178	32.235	3130
125	5	133.5364	1.226	44.987	4900
125	30	35.9862	2.186	46.774	770
150	30	42.8652	0.716	18.875	1130
175	30	80.8317	1.54	29.721	1560
200	30	20.3772	0.938	93.905	2040
250	30	11.7366	0.145	39.905	3230
300	30	62.9884	0.276	20.419	4660
350	30	409.6	0.421	6.5377	6360

Table 3. Vertical electrical sounding data along geophysical profile No. 2

Distance between current electrodes AB/2 (m)	**Distance between the receiving electrodes MN/2 (m)**	**Electrical apparent resistance ρ_k (Ohm.m)**	**Potential difference Vp (mV)**	**Magnitude of the electric current (mA)**	**Device factor K (m)**
1	0.5	1088.359	6036.916	13.035	2.35
2	0.5	594.5482	816.748	16.21	11.8
3	0.5	264.3851	111.907	11.64	27.5
4	0.5	136.8535	40.81	14.761	49.5
5	0.5	89.0845	27.466	23.956	77.7
6	0.5	64.623	12.684	21.983	112
8	0.5	42.8306	4.267	19.925	200
10	0.5	34.0859	1.998	18.347	313
15	0.5	49.9616	1.624	22.916	705
15	5	23.076	8.537	23.233	62.8
20	5	23.3918	3.978	20.067	118
20	0.5	109.34	1.756	20.075	1250
25	0.5	34.2528	0.167	9.556	1960
25	5	11.3488	0.571	9.459	188

30	5	7.5383	0.799	29.148	275
35	5	21.1967	2.656	47.239	377
40	5	17.0557	1.422	41.27	495
50	5	15.4135	0.901	45.595	780
60	5	12.673	2.029	179.316	1120
70	5	21.0753	0.856	62.143	1530
80	5	11.2379	0.458	81.51	2000
80	30	19.5868	5.567	81.856	288
100	30	21.3735	1.984	44.092	475
100	5	48.1441	0.757	49.215	3130
125	5	36.0347	0.251	34.131	4900
125	30	22.1897	1.133	39.316	770
150	30	31.673	1.44	51.375	1130
175	30	30.6546	0.915	46.564	1560
200	30	39.2012	0.893	46.471	2040
250	30	62.0569	2.406	125.23	3230
300	30	53.9426	0.791	68.333	4660
350	30	140.9938	0.406	18.314	6360

Table 4. Vertical Electrical Sounding data along geophysical profile No. 2

Distance between current electrodes AB/2 (m)	**Distance between the receiving electrodes MN/2 (m)**	**Electrical apparent resistance ρ_k (Ohm.m)**	**Potential difference Vp (mV)**	**Magnitude of the electric current (mA)**	**Device factor K (m)**
1	0.5	415.8397	15019.42	84.878	2.35
2	0.5	768.2498	3490.328	53.61	11.8
3	0.5	472.5785	938.558	54.616	27.5
4	0.5	303.4802	448.697	73.186	49.5
5	0.5	239.2278	241.577	78.463	77.7
6	0.5	199.7818	133.11	74.623	112
8	0.5	150.0105	35.779	47.702	200
10	0.5	122.2439	19.659	50.336	313
15	0.5	68.5541	3.072	31.592	705
15	5	76.7595	38.744	31.698	62.8
20	5	43.2774	13.16	35.882	118
20	0.5	43.1339	1.271	36.833	1250
25	0.5	29.517	1.67	110.892	1960
25	5	28.0701	16.709	111.909	188
30	5	17.2005	4.809	76.886	275
35	5	19.972	4.523	85.378	377
40	5	17.5292	1.425	40.24	495

50	5	18.4937	1.586	66.892	780
60	5	19.5288	0.732	41.981	1120
70	5	26.1863	0.868	50.715	1530
80	5	17.1837	0.616	71.696	2000
80	30	22.4914	5.674	72.655	288
100	30	24.3496	3.452	67.34	475
100	5	33.3312	0.723	67.894	3130
125	5	22.0871	0.437	96.948	4900
125	30	25.0924	3.203	98.289	770
150	30	29.0683	1.658	64.453	1130
175	30	31.3344	1.511	75.226	1560
200	30	37.5466	1.459	79.271	2040
250	30	46.1461	0.813	56.906	3230
300	30	53.5801	0.584	50.792	4660
350	30	119.2151	0.748	39.905	6360
350	100	103.6078	2.353	40.107	1766
400	100	142.9254	2.064	34.081	2360
400	30	156.5851	0.634	33.606	8300
450	30	249.8997	0.593	24.916	10500
450	100	199.9466	1.747	26.212	3000
500	100	79.899	0.505	23.765	3760

Table 5. Vertical Electrical Sounding data along geophysical profile No. 4

Distance between current electrodes AB/2 (m)	**Distance between receiving electrodes MN/2 (m)**	**Electrical apparent resistance ρ_k (Ohm.m)**	**Potential difference Vp (mV)**	**Magnitude of the electric current (mA)**	**Device factor K (m)**
1	0.5	810.826	12237.26	35.467	2.35
2	0.5	111.65	627.965	66.368	11.8
3	0.5	34.53	71.088	56.615	27.5
4	0.5	22.713	29.53	64.357	49.5
5	0.5	22.502	12.256	42.321	77.7
6	0.5	27.425	10.925	44.616	112
8	0.5	31.522	6.909	43.836	200
10	0.5	30.253	8.197	84.807	313
15	0.5	37.415	2.517	47.427	705
15	5	35.76	27.258	47.869	62.8
20	5	39.14	17.763	53.552	118
20	0.5	45.701	1.955	53.472	1250
25	0.5	22.249	0.756	66.6	1960
25	5	40.054	14.254	66.904	188

30	5	43.21	7.883	50.17	275
35	5	43.485	4.623	40.08	377
40	5	47.496	4.823	50.265	495
50	5	46.867	2.623	43.654	780
60	5	51.971	2.014	43.403	1120
70	5	35.35	0.625	27.051	1530
80	5	46.487	0.648	27.879	2000
80	30	56.019	5.534	28.451	288
100	30	43.344	3.33	36.493	475
100	5	37.761	0.619	51.309	3130
125	5	61.928	0.508	40.195	4900
125	30	53.713	2.852	40.885	770
150	30	47.066	4.875	117.043	1130
175	30	59.158	1.687	44.486	1560
200	30	50.564	1.243	50.149	2040
250	30	129.673	1.239	30.862	3230
300	30	237.695	1.701	33.348	4660
350	30	102.325	1.69	105.042	6360
350	100	64.432	4.664	127.834	1766
400	100	181.591	1.336	17.363	2360
400	30	439.128	0.91	17.2	8300
450	30	81.116	0.372	48.153	10500
450	100	22.879	0.36	47.204	3000
500	100	29.023	0.29	37.57	3760

Table 6. Vertical Electrical Sounding data along geophysical profile No. 5

Distance between current electrodes AB/2 (m)	**Distance between receiving electrodes MN/2 (m)**	**Electrical apparent resistance ρ_k (Ohm.m)**	**Potential difference Vp (mV)**	**Magnitude of the electric current (mA)**	**Device factor K (m)**
1	0.5	785.779	15019.42	44.918	2.35
2	0.5	636.098	5224.956	96.926	11.8
3	0.5	381.081	675.04	48.713	27.5
4	0.5	193.815	213.647	54.565	49.5
5	0.5	97.556	54.679	43.55	77.7
6	0.5	51.119	8.012	17.554	112
8	0.5	33.535	5.907	35.229	200
10	0.5	28.101	4.797	53.43	313
15	0.5	4.549	0.956	148.157	705
15	5	22.947	17.733	48.53	62.8
20	5	17.983	6.748	44.278	118

20	0.5	7.212	0.258	44.719	1250
25	0.5	12.863	0.276	42.056	1960
25	5	12.335	2.777	42.325	188
30	5	18.89	4.179	60.839	275
35	5	16.218	2.299	53.442	377
40	5	18.205	3.278	89.13	495
50	5	18.653	2.585	108.095	780
60	5	14.612	1.064	81.555	1120
70	5	26.955	1.289	73.164	1530
80	5	22.487	0.539	47.938	2000
80	30	22.179	3.758	48.799	288
100	30	21.344	2.686	59.775	475
100	5	13.446	0.32	74.489	3130
125	5	5.972	0.086	70.559	4900
125	30	20.087	1.844	70.685	770
150	30	20.629	1.137	62.281	1130
175	30	18.289	0.528	45.037	1560
200	30	54.588	2.546	95.147	2040
250	30	29.364	1.445	158.947	3230
300	30	32.117	0.299	43.383	4660
350	30	46.552	0.643	87.848	6360

9. Interpretation of measured data, and results

The field data of vertical electrical sounding was analyzed using the IX1D v2 software to interpret the measured data. The resulting apparent electrical resistivity values are then plotted on a graph against distance, revealing the number of layers, thickness, and depth calculated and modeled using apparent resistivity.

10. Interpretation of the results of vertical electrical sounding values

The interpretation of apparent resistivity helps determine the width, depth, and boundaries of soil layers, and the results can be found in Table 7.

Table 7: Results of interpretations of Vertical Electrical Sounding

No	VES Stations	Vertical Electrical Sounding data interpretation results					
		App-Resistivity *(Ohm-m)*	Number of Layers	Thickness *(m)*	Depth *(m)*	Elevation *(m)*	Fitting Error (%)
1	VES_1 LAT: 34.48690 LON: 70.49968	3847.2	1	0.25254	0.25254	-0.25254	15.213
		378.42	2	2.0665	2.3191	-2.3191	
		14.437	3	29.11	31.43	-31.43	
		49.242	4	119.02	150.45	-150.45	
		4297.9	5	?	?	?	
2	VES_2 LAT: 34.48696 LON: 70.49963	360.83	1	1.6486	1.6486	-1.6486	5.765
		30.752	2	7.7076	9.3562	-9.3562	
		17.736	3	81.034	90.39	-90.39	
		2398.1	4	?	?	?	
3	VES_3 LAT: 34.48797 LON: 70.49893	646.61	1	1.4831	1.4831	-1.4831	7.567
		162.92	2	5.7289	7.212	-7.212	
		16.434	3	81.512	88.724	-88.724	
		309.29	4	?	?	?	
4	VES_4 LAT: 34.49044 LON: 70.49730	166.65	1	0.90988	0.90988	-0.90988	12
		6.8703	2	1.06	1.9698	-1.9698	
		68.667	3	4.5746	6.5445	-6.5445	
		31.372	4	112.92	119.46	-119.46	
		757.6	5	?	?	?	
5	VES_5 LAT: 34.48779 LON: 70.49873	607.72	1	1.4395	1.4395	-1.4395	15.29
		41.484	2	3.7195	5.159	-5.159	
		5.5319	3	5.2153	10.374	-10.374	
		30.184	4	194.36	204.74	-204.74	
		2813.5	5	?	?	?	

11. Interpreting graphical values of Vertical Electrical Sounding

The IX1D v2 software was used to interpret the vertical electrical sounding field data, determining the thickness, depth, boundary of rock layers, and lithology from the apparent resistivity. The apparent resistance is generated and calculated in the same way for all VES using this software. Let's focus on VES-1 for now.

The diagrams (Figures. 5, 6) show that the upper layer is made of sand, gravel, and rocks with an apparent resistivity of 384.7 ohm-m and a diameter of 0.25 m. The second layer has a resistivity of 378.42 ohm-m, a width of 2,067 m, and is composed of sand, gravel, and coarse-grained rock. Its apparent resistivity is 14.33 ohm-m, with a width of 29.11 m. The lithology includes sand, mud-sand layers, and gravel, reaching a depth of up to 119 m. According to the data from the first VES, water is present in this layer at a depth of 75-85 m. The resistance versus distance variation is shown in Figures 5 and 6.

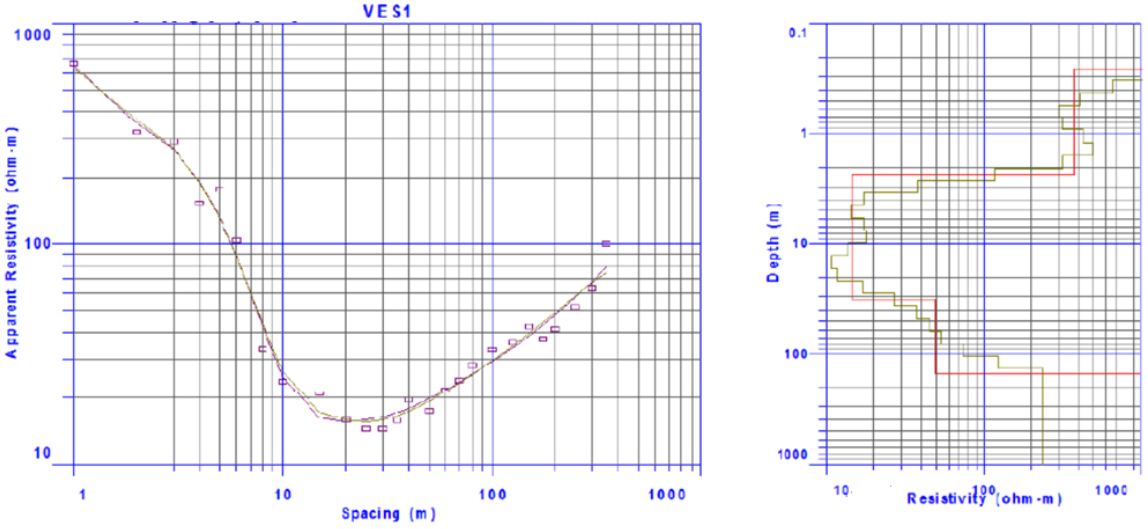


Fig. 5. Apparent resistivity versus distance and depth for VES-1

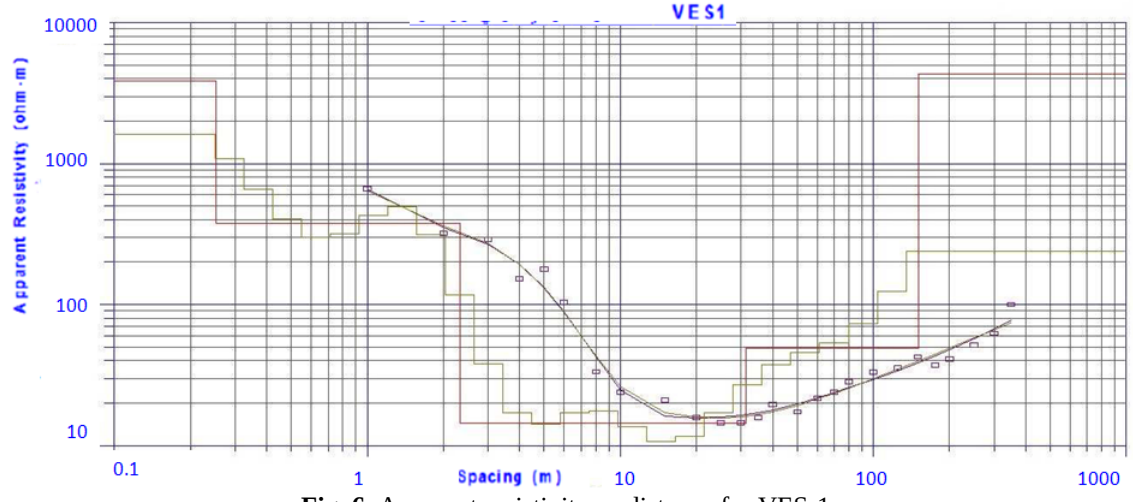


Fig. 6. Apparent resistivity vs distance for VES-1

12. Conclusions and Recommendations

1. From studying and interpreting the field data of the electrical vertical sounding method used in Khanakai village, Behsud district of Nangarhar, Afghanistan, we can obtain the following results:
    i. The groundwater table in the village is located at a depth of 75-95 m.
    ii. The aquifer is composed of sand, gravel, sandstone, mud, and silt, and it is underlain by bedrock.
    iii. The groundwater in this area is suitable for drinking purposes.
2. In To improve the application of vertical electrical surveying (VES) in the specified region, here are some suggestions:
    i. The research results mentioned are not sufficient in this area.
    ii. We should increase the number of VES to conduct a more comprehensive survey to explore aquifers in the area.
    iii. The research results mentioned may not be very accurate in some areas, so it's best to use them carefully and with caution in the future.
    iv. Since this method can play a significant role in groundwater exploration and rock diagnostics, it is recommended to also use this method in the surrounding areas.
    v. Because of the accuracy of the vertical electrical sounding results, it is recommended to carry out one or two exploratory drillings in this area to a depth of 100 m. Water samples should be taken from the wells mentioned and analyzed in the laboratory for quantity and quality.

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