VERTICAL ELECTRICAL SOUNDING FOR GROUNDWATER ASSESSMENT IN BALKH NEW UNIVERSITY, NAHR-I SHAHI DISTRICT OF BALKH PROVINCE

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ABSTRACT.

Vertical Electrical Sounding (VES) investigation were carried out in Balkh University, Nahr-I Shahi District of Balkh Province, in order to study the aquifer characteristic with a view of determining the depth and thickness of sediments layers and recommend suitable site to drill the well. Three VES stations were conducted at inside and outside of Balkh University compound and the Schlumberger electrodes configuration was used for the field data acquisition.

The length of current electrode spacing (AB/2) ranged from 400-500 m. The field data obtained was analyzed using IX1D computer software which gives an automatic interpretation of the apparent resistivity.

Interpretation of VES stations data results reviled the similarities of the subsurface geologic sequence (litho-logic layers). The expected layers of aquifer made of clay, silt clay, silt sand, sandy clay sand. The maximum depth of study range is between 108 m and 200 m. The aquifers apparent resistivity range is between 2.009 and 10.151 Ohom.m and the layers of aquifers characterized by saline and brackish water. The depth of water table is prospected between 13 and 17 m.
Key word: VES, Groundwater, Geo-electrical characteristic of sediments and Schlumberger array

List of Abbreviation and Technical Terms

Roh:	Apparent Resistivity (ohm.m)
Sp:	Self Potential (mV)
Vp:	Voltage Potential (mV)
In:	Current (m A)
VES:	Vertical Electrical Sounding
DACAAR:	Danish Committee for Aid to Afghan Refugee
WASH:	Water Sanitation and Hygiene

1. Introduction

On December 01, 2016, the geo-electrical survey was carried out in Balkh University, Nahr-I Shahi District of Balkh Province which was requested by Balkh University director and Balkh provincial Authority. Vertical Electrical Sounding (VES) using Schlumberger array [1] was carried out at three VES stations. SYSCAL Pro Standard & *Switch* (48 - 72 or 96) Version [2] was used for the data acquisition.

Vertical electric sounding (VES) employs collinear arrays designed to output a 1-D vertical apparent resistivity versus depth model of the subsurface at a specific observation point [3]. In this method a series of potential differences are acquired at successively greater electrode spacing while maintaining a fixed central reference point. The induced current passes through progressively deeper layers at greater electrode spacing [4]. The potential difference measurements are directly proportional to the changes in the deeper subsurface. Apparent resistivity values calculated from measured potential differences can be interpreted in terms of overburden thickness, water table depth, and the depths and thicknesses of subsurface strata.
In this study, the resistivity measurements were made by injecting current into the ground through two current electrodes (C1 and C2), and measuring the resulting voltage difference at two potential electrodes (P1 and P2).

2. Objectives of the survey

The overall objective of this survey was to assess the feasibility of drilling wells in the target area. The following are the specific objectives of the survey:

- Determine depth and thickness of sediments layers.
- Identify the depth of groundwater table of the area.
- Identify aquifers qualitative status of aquifers
- Conclusion of result.

3. Rationale to carry out investigation

In the compound of the University three tube wells were drilled and constructed. The water supply systems were constructed and the water from the constructed tube wells distributed to the university buildings. The water supply system blocked inside of buildings due to high salinity and very high hardness of distributed water. The water of tube wells is saline and brackish and the salinity value is higher than the National Drinking Water Quality Standard (NDWQS). The water of tube wells is not suitable for drinking, construction purposes and irrigation purposes. The University has drinking water problems in terms of quality for drinking, construction of new building and irrigation. There is needed to carry out study for the determination of groundwater (aquifers) quantitative and qualitative status. We tried to get the drilled and constructed wells data, but we couldn't get the data.'

4. Surface Geological setting of area

- **The surface geological formations of the area are:**
  - Recent Quaternary: Shingly and detritus sediments (gravel, sand, clay ,sand, loess)
  - Late Quaternary and Recent: Shingly and detritus sediments, gravel, sand, clay, clay sand, loess, travertine

- Middle Quaternary: Shingly and detritus sediments (gravel, sand, clay, sand, loess, loam, and travertine.
- Late Quaternary: Shingly and detrital sediments, gravel, sand, clay, clay sand, loam, and lose.
- Early Miocene: Read clay, sandstone, siltstone, conglomerate, and limestone.
- Middle Miocene: Brown clay, siltstone, sandstone, conglomerate and limestone.
- Paleocene: Limestone, marl, dolomite, sandstone, siltstone and conglomerate
- Early Cretaceous: Red sandstone, conglomerate, siltstone, gypsum and clay.
- Late Cretaceous: Sandstone, siltstone, clay, limestone, marl, conglomerate and gypsum.

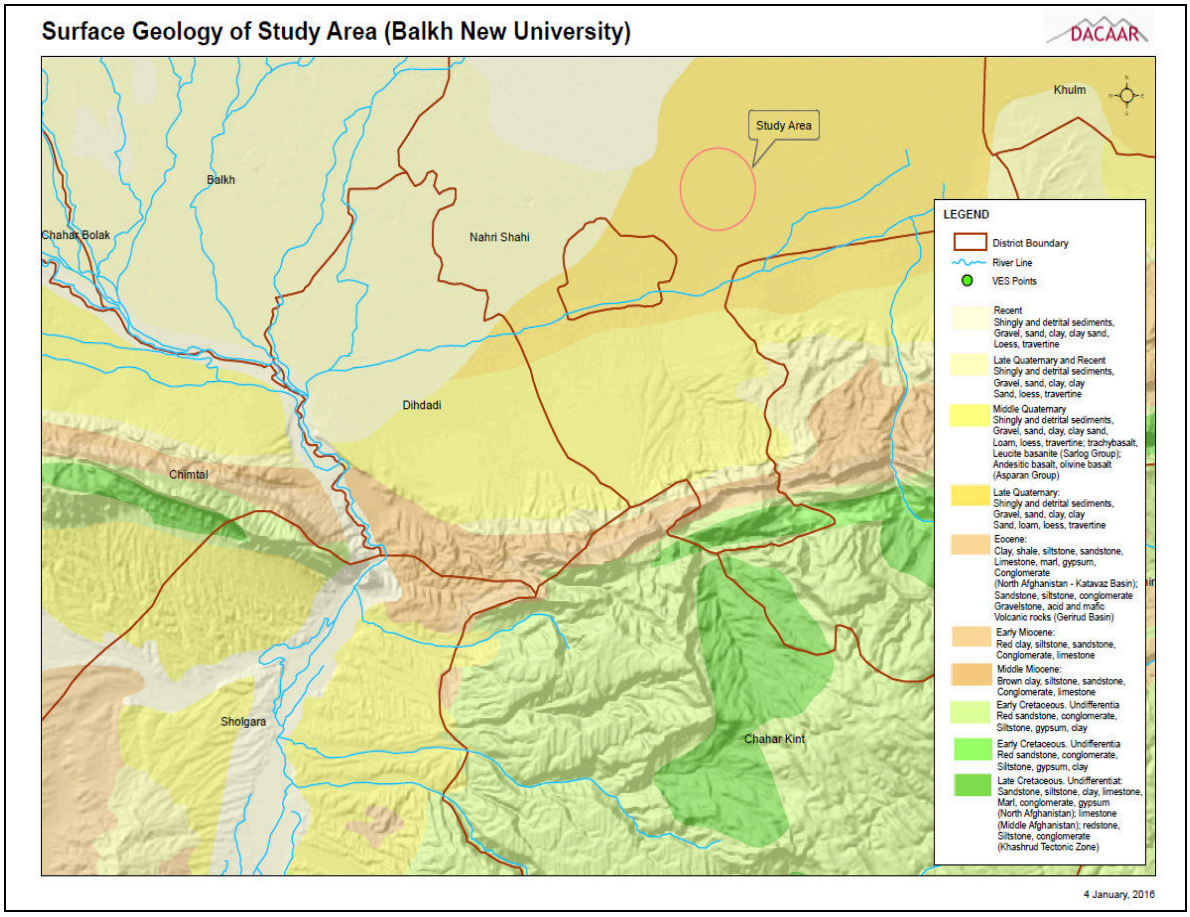

Figure 1 Surface Geological Setting of the Area

5. Materials and method

5.1 Description of study area

The study areas are located about 7.5 Km in the east direction of Mazar-i-Sharif and positioned at latitude of 36.72924 to 36.73101 and a longitude of 67.18911 to 67.19522. It has semi- arid climate with major fluctuation in day- and night-time fluctuations. The winter is characterized by low temperatures of less than -4 ºC while the summer is dominated by high temperatures of more than 45 ºC. The rainfall and snowfall are the main source of groundwater and surface water, and the area receives an average 150 mm rainfall. There are number of seasonal rivers and abandoned channels which are flowing water in rainy seasons. The study area shown in the figure 2

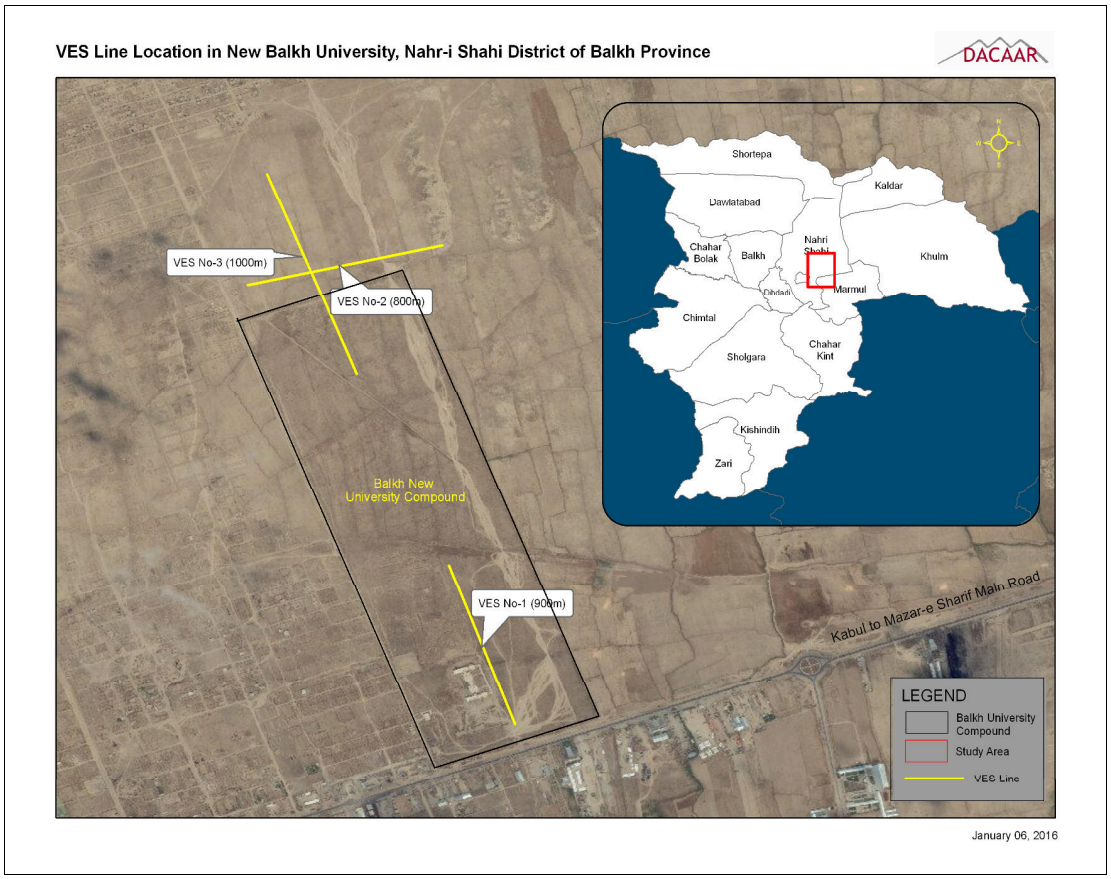

Figure 2 Location of Study Area

5.2 Data Acquisition

Vertical Electrical Sounding (VES) using Schlumberger array was carried out at three VES stations of Balkh University, Nahri Shahi district of Balkh province. SYSCAL Pro Standard & *Switch* (48 - 72 or 96) Version was used for the data acquisition. Figure 3 is shown the field data acquisition processes onsite.

Figure 3 Measured Field Data By SYSCAL Pro Resistivity Meter

The Applied Schlumberger Techniques was used by transmitting electrical current into the ground from DC (direct current) or low frequency sources by two electrodes (C1 and C2). The potential difference between a second pair of electrodes (P1 and P2) was measured (Figure 4)

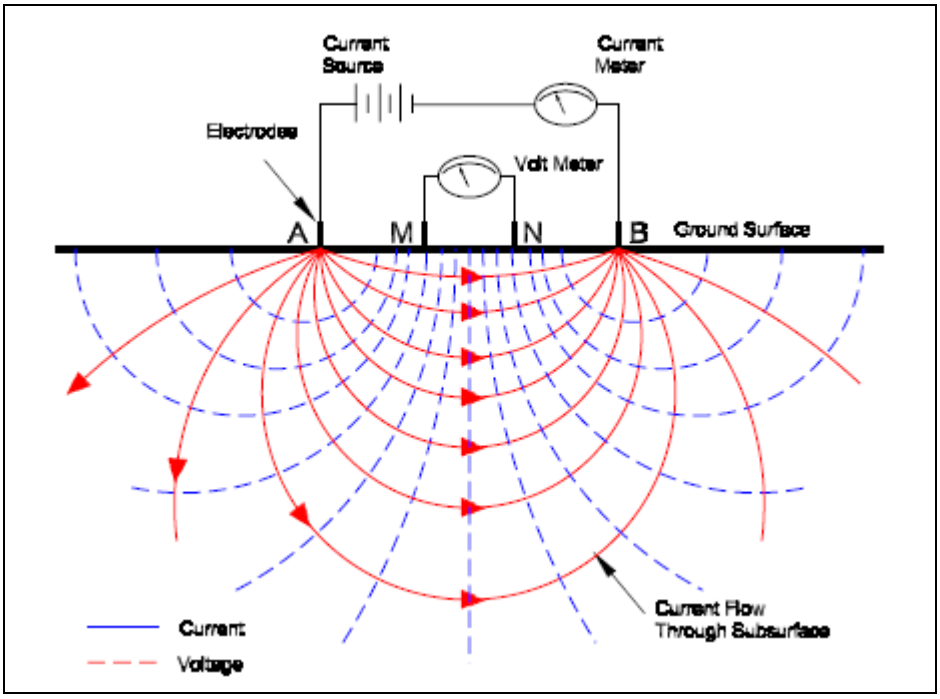

Figure 4 Schlumberger Applied Techniques Method

The field data were analyzed using IX1D software which gives an automatic interpretation of the apparent resistivity.

5.3 Location of VES stations

In the study area were perfrmed three EVS stations inside (north and south direction) and outside (north part of compound) of Balkh University compound. The stations location were georefrenced. The location and length of VES stations is shown in the table 1

Table 1 Location and Length of VES Stations

NO	Village	VES Stations	Latitude	Longitude	Elevation (m)	VES Distance (m)
1	Inside of Balkh University	VES_1	36.73454	67.19024	358	900
2	Outside of Balkh University	VES_2	36.74804	67.18584	341	800
3	Inside and outside Balkh University	VES_3	36.74853	67.18375	342	1000

5.4 Measured VES stations data

The field measured data are shown in Table 2, 3 and Table 4.

Table 2 VES_1 Measured Field Data

VES_1
Latitude: 36.73454 Longitude:67.19024 Elevation (m):358

AB/2	MN	Pa (Ωm)	ΔV (mV)	I (mA)	K
1	1	291.1546	4424.558	35.712	2.35
2	1	107.8117	298.62	32.684	11.8
3	1	38.06075	43.637	31.529	27.5
4	1	23.40072	21.965	46.463	49.5
5	1	21.78779	17.79	63.443	77.7
6	1	21.04795	10.041	53.43	112
8	1	18.71696	3.488	37.271	200
10	1	17.81011	1.898	33.356	313
15	1	15.62124	0.917	41.385	705
15	10	14.93223	9.812	41.266	62.8
20	10	10.93443	5.192	56.03	118
20	1	11.58886	1.067	115.089	1250
25	1	11.07494	1.339	236.971	1960
25	10	10.40884	13.206	238.521	188
30	10	9.661168	10.793	307.217	275
35	10	8.57239	11.158	490.711	377
40	10	7.836786	6.245	394.457	495
50	10	7.478129	6.789	708.121	780
60	10	7.186917	4.39	684.132	1120
70	10	6.457842	1.346	318.896	1530
80	10	6.725627	1.089	323.836	2000
80	60	7.453211	8.358	322.962	288
100	60	7.49382	5.278	334.549	475
100	10	6.773989	1.332	615.466	3130
125	10	7.222046	1.232	835.885	4900
125	60	8.033282	8.752	838.89	770
150	60	8.175426	6.618	914.734	1130
175	60	8.423021	5.099	944.369	1560
200	60	8.617607	4.075	964.653	2040
250	60	9.386791	0.358	123.188	3230
300	60	9.389848	2.786	1382.638	4660
350	60	9.443067	1.053	709.206	6360
350	100	9.446086	3.796	709.684	1766

400	100	9.397913	4.591	1152.89	2360
400	60	9.31812	1.296	1154.396	8300
450	60	8.969754	0.666	779.62	10500
450	100	9.064033	2.371	784.75	3000
500	100				3760

Table 3 VES_2 Measured Field Data

VES_2 Latitude: 36.74804 Longitude:67.18584 Elevation (m):341					
AB/2	MN	ρa (Ωm)	ΔV (mV)	I (mA)	K
1	1	179.9927	2861.424	37.359	2.35
2	1	56.08688	196.556	41.353	11.8
3	1	24.92543	51.021	56.291	27.5
4	1	16.58577	13.536	40.398	49.5
5	1	11.76258	6.216	41.061	77.7
6	1	9.700975	5.715	65.981	112
8	1	8.61745	2.041	47.369	200
10	1	6.987045	1.139	51.024	313
15	1	4.784781	1.397	205.837	705
15	10	5.262688	17.196	205.201	62.8
20	10	3.927624	12.612	378.91	118
20	1	3.750226	1.146	381.977	1250
25	1	3.705492	1.246	659.065	1960
25	10	3.711467	13.106	663.869	188
30	10	3.575076	7.1069	546.673	275
35	10	3.435913	5.379	590.202	377
40	10	3.426203	2.005	289.672	495
50	10	3.494422	1.198	267.409	780
60	10	3.586117	1.103	344.484	1120
70	10	3.818739	1.418	568.13	1530
80	10	3.9961	1.461	731.213	2000
80	60	3.8456	9.797	733.705	288
100	60	4.160653	4.218	481.547	475
100	10	4.215473	0.752	558.362	3130
125	10	4.577363	0.48	513.833	4900
125	60	4.615583	3.072	512.49	770
150	60	5.048104	2.865	641.32	1130
175	60	5.441976	1.912	548.095	1560
200	60	5.770278	1.325	468.435	2040
250	60	6.207898	1.046	544.239	3230
300	60	6.544149	1.203	856.64	4660
350	60	6.729862	0.623	588.761	6360
350	100	7.247283	2.428	591.649	1766
400	100	7.203382	1.34	439.016	2360
400	60	7.324238	1.368	1550.25	8300
450	60				10500
450	100				3000
500	100				3760

Table 4 VES_3 Measured Field Data

VES # 03 Latitude: 36.74853 Longitude:66.18375 Elevation (m):342					
AB/2	MN	ρa (Ωm)	ΔV (mV)	I (mA)	K
1	1	54.43707	15018.73	648.345	2.35
2	1	111.7764	6519.028	688.2	11.8
3	1	83.39922	2153.477	710.086	27.5
4	1	48.86296	769.481	779.513	49.5
5	1	31.1925	323.349	805.457	77.7
6	1	21.4239	158.885	830.62	112
8	1	14.61523	71.095	972.889	200
10	1	11.84297	31.281	826.731	313
15	1	10.08231	9.16	640.508	705
15	10	9.32818	96.126	647.148	62.8
20	10	7.621596	42.849	663.402	118
20	1	8.134596	4.333	665.829	1250
25	1	6.127018	1.898	607.16	1960
25	10	5.681946	18.406	609.004	188
30	10	4.790016	10.363	594.951	275
35	10	4.375406	6.51	560.924	377
40	10	4.074943	4.942	600.325	495
50	10	3.992965	3.33	650.494	780
60	10	4.013914	2.414	673.577	1120
70	10	4.340157	1.74	613.388	1530
80	10	4.505363	1.289	572.207	2000
80	60	3.503961	7.011	576.253	288
100	60	3.880198	4.039	494.44	475
100	10	4.963493	0.781	492.502	3130
125	10	5.579599	1.325	1163.614	4900
125	60	4.425887	6.703	1166.164	770
150	60	4.931078	3.753	860.033	1130
175	60	5.326374	2.156	631.454	1560
200	60	5.53896	1.912	704.19	2040
250	60	5.855375	1.232	679.608	3230
300	60	6.171319	0.802	605.595	4660
350	60	6.565468	0.63	610.284	6360
350	100	6.787617	2.371	616.886	1766
400	100	7.120581	1.884	624.421	2360
400	60	6.849272	0.494	598.633	8300
450	60	6.747689	0.43	669.118	10500
450	100	7.32357	1.647	674.671	3000
500	100	7.551567	1.998	994.824	3760

6. Results and discussion

6.1 VES stations data interpretation

The VES stations field geo-electrical data versus electrode spacing (AB/2) were plotted on log-log scale to obtain VES Curve and layered model using IX1D software [5]. The 1D(one dimensional) VES stations Curve illustrates number of layers, computed and modeled apparent resistivity, thicknesses and depth of layers.

6.1.1 VES _1 Curve

- The VES_1 Curve (Figure 5) shows the following geo-electrical layers:
  - Top layer characterized by average apparent resistivity values of 432.03 Ohm.m with 0.6983 m thickness and the expected deposits made of dry loose and clayey sand.
  - The second layer characterized by average apparent resistivity values of 19.621 Ohm.m with 8.8470 m thickness. The apparent resistivity value highly decreased and the trend indicated the increasing of salinity layer. The expected litho-logy of layer probably made of silt clay.
  - The third layer characterized by average apparent resistivity values of 6.6899 Ohm.m with 38.385 m thickness. The decreasing trend of apparent resistivity indicated the high salinity of saturated layer (aquifer) and expected the aquifer has saline and brackish water. The expected litho-logy of layer probably made of clay and silt clay. The depth of this layer is expected 47.930 m.
  - Fourth layer described by average apparent resistivity values of 6.9519 Ohm.m with 33.656 m thickness. This layer indicated high salinity than the other layers. The expected litho-logy of layer may be consisting of clay, sandy clay. The depth of this layer is expected 81.586 m.
  - The fifth layer characterized by apparent resistivity value of 9.4736 Ohm.m with the expected thickness of more than 120 m.
  - The expected water table ranges between 14 m and 17 m. The VES_1 apparent resistivity curve and layered model is shown in the Figure 5.

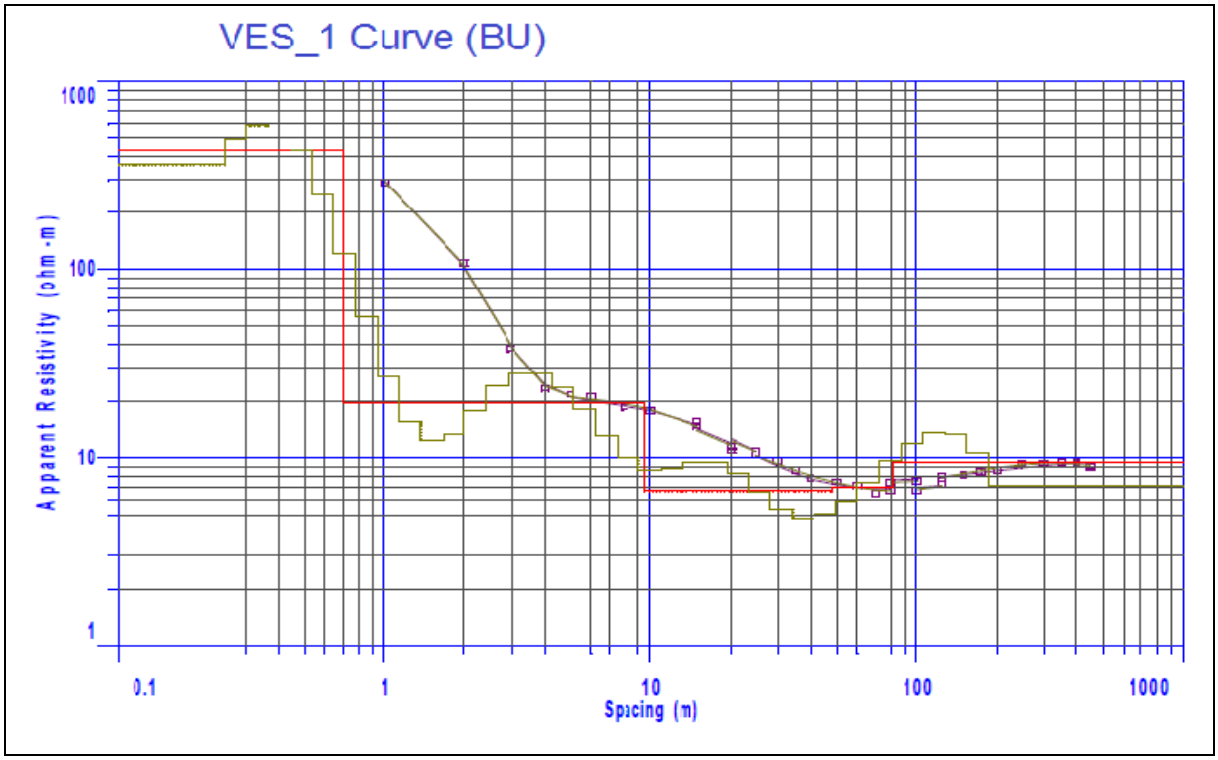

Figure 5 VES _1 Curve and Layered Model

6.1.2 VES 2 Curve

- The VES_2 Curve (Figure 6) shows the following geo-electrical layers:

- Top layer characterized by average apparent resistivity values of 275.64 Ohm.m with 0.7078 m thickness and the expected deposits made of looses and clayey sand.
- The second layer characterized by apparent resistivity values of 14.511 Ohm.m with 4.049 m thickness. The apparent resistivity values highly decreased. The decreasing trend of apparent resistivity may be due to increasing the salinity of layer. The expected litho-logy of layer probably made of silt cay.
- The third layer characterized by average apparent resistivity values of 3.466 Ohm.m with 55.525 m thickness. This layer indicated decreasing trend of apparent resistivity and saturated with saline and brackish water. The expected litho-logy of layer probably made of sand clay and silt cay. The depth of this layer is expected 60.282 m.
- Fourth layer described by average apparent resistivity values of 11.384 Ohm.m with 48.782 m thickness. This layer indicated increasing apparent resistivity and saturated with saline water. The expected litho-logy of layer probably made of sand clay and sand. The depth of this layer is 109.06 m.
- The fifth layer characterized by apparent resistivity value of 10.151 Ohm.m with 46.951 m thickness. This layer observed increasing of apparent resistivity and decreasing salinity of aquifer. The expected litho-logy of layer made of silt clay and silt. The depth of this layer is 156.01 m.

The expected water table ranges from 14 m and 16 m. The VES_2 apparent resistivity curve and layered model is shown in the Figure 6.

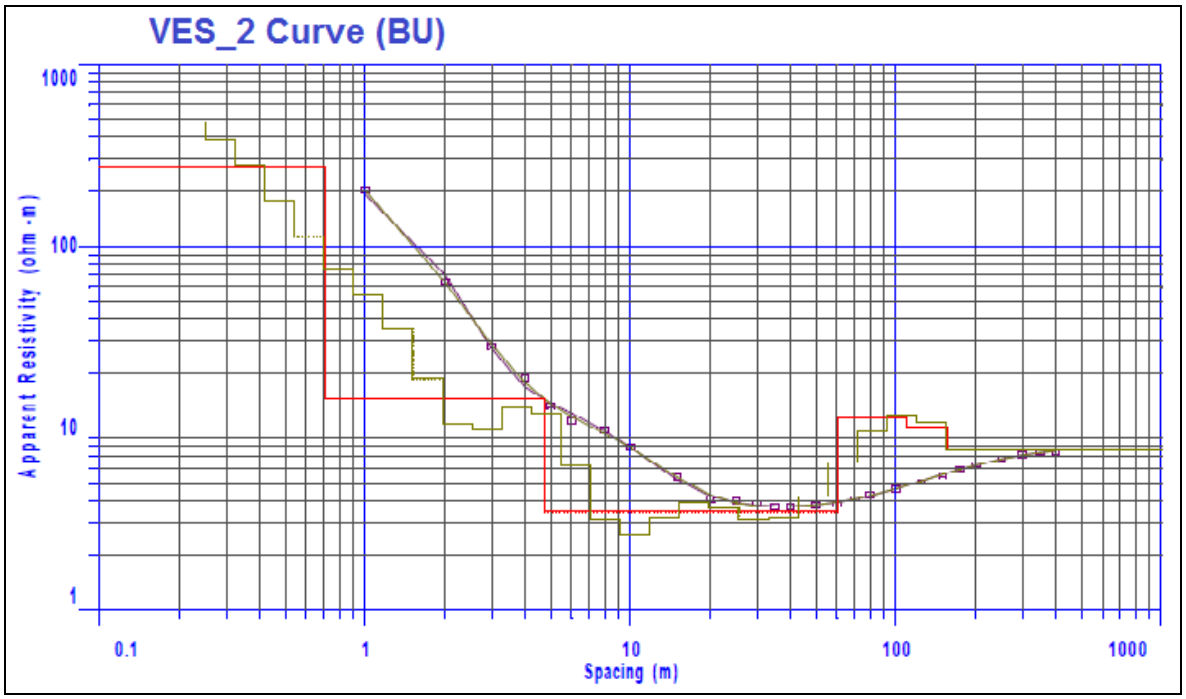

Figure 6 VES _2 Curve and Layered Model

6.1.3 VES _3 Curve

- The VES_3 Curve (Figure7) shows the following geo-electrical layers:
  - Top layer characterized by average apparent resistivity values of 107.20 Ohm.m with 1.5814 m thickness and the expected deposits made of dry looses and clayey sand.
  - The second layer characterized by apparent resistivity values of 9.0139 Ohm.m with 10.418 m thickness. The average apparent resistivity values highly decreased. The de-

creasing trend of apparent resistivity may be due to increasing the salinity of layer. The expected litho-logy made of silt and silt clay.

- The third layer characterized by apparent resistivity values of 2.0091 Ohm.m with 24.919 m thickness. The decreasing trend of apparent resistivity indicated the high salinity of saturated layer (aquifer) and expected the aquifer has saline and brackish water. The expected litho-logy of layer probably consist of clay and silt clay. The depth of this layer is 36.919 m.
- Fourth layer described by apparent resistivity value of 8.0904 Ohm.m with 56.026 m thickness. This layer increasing trend of apparent resistivity and salinity of aquifer. The expected litho-logy of layer made of silt clay and sand clay. The expected depth of this layer is 92.944 m.
- The fifth layer characterized by apparent resistivity value of 9.2652 Ohm.m and made of clay.

The expected water table ranges between 13 m and 15 m. The VES3 apparent resistivity curve and layered model is shown in the Figure7.

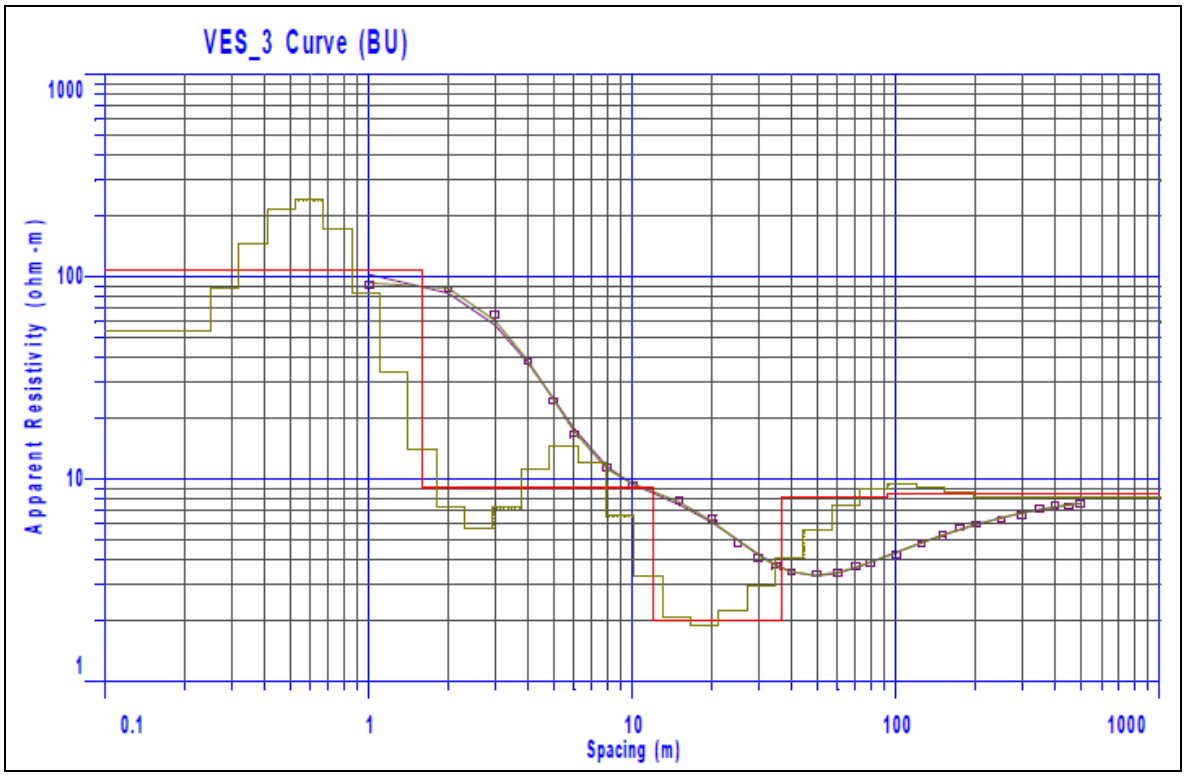

Figure 7 VES _3 Curve and Layered Model

6.2 Vertical Electrical sounding data interpretation results

The apparent resistivity, thicknesses, depth, the number of layers and expected litholog of VES stations is shown in the table 5.

Table 5 VES Stations Interpreted Data Summary

No	VES Stations	Vertical Electrical Sounding data interpretation results						Expected litho logy of layers
		App-Resistivity *(Ohm-m)*	Number of Layers	Thickness *(m)*	Depth *(m)*	Elevation *(m)*	Fitting Error (%)	
1	VES_1 LAT: 36.73454 LON: 67.19024	432.03	1	0.69832	0.69832	-0.69832	4.21	Loose and clayey sand
		19.621	2	8.847	9.5453	-9.5453		Silt clay
		6.6899	3	38.385	47.930	-47.930		Clay and silt clay
		6.9519	4	33.656	81.586	-81.5586		Sandy clay
		9.4736	5	?	?	?		
2	VES_2 LAT: 36.74804 LON: 67.18584	275.64	1	0.70785	0.7085	-0.7085	3.95	Dry loose and clayey sand
		14.511	2	4.0494	4.7572	-4.77572		Silt clay
		3.4666	3	55.525	60.282	-60.282		Clay and silt clay
		11.384	4	48.782	109.06	-109.06		Sandy clay and sand
		10.151	5	46.951	156.01	-156.01		Sand clay sand, sand
		7.529	?	?	?	?		Clay
3	VES_3 LAT: 36.74853 LON: 66.18375	107.20	1	1.5814	1.5814	-1.5814	4.15	Loose and clayey silt
		9.0139	2	10.418	12.00	-12.00		Silt clay.
		2.0091	3	24.919	36.918	-36.918		Clay and silt clay
		8.0904	4	56.026	92.944	-92.944		Sandy clay
		8.4325	5	?	?	?		?

7. Conclusion

The geo- electrical data plot of the different VES stations show significant similarities of litho-logic layers and the results are following:

- Dry loose, clayey sand and silt layer (first and second layers) characterized by average apparent resistivity values of ranging 9.0139 Ohm.m to 432.03 Ohm.m. The decreasing trend of apparent resistivity may be due to increasing the salinity of unsaturated layers (evaporative).
- The third and fourth layers of stations average apparent resistivity values range from 2.0091 Ohm.m to 11.384 Ohm.m. The expected litho-logy of layers made of silts clay, clayey sand silt and clay. These layers influenced by the salinity and brackish water. The salinity of groundwater increased from second layer to the third layer. The average depth of layers range from 36.98 m to 109.06 m.
- The fifth layers of stations average apparent resistivity values range from 8.432 Ohm.m to 10.51 Ohm.m. The expected litho-logy of layers made of sand, silt clay clayey and silt. These layers saturated with saline water. The salinity of groundwater is not suitable for drinking. The average depth of layers range from 109 m to 156 m.
- The lower part of station layers average resistivity value is lower than 8 Ohm.m. The expected litho-logy of layers may be consisting of silts clay, clayey sand silt and clay with saturation of saline water. The average depth of layers range from 115 m to 200 m.
- The expected depth of water table ranges between 13 and 17m

8. Recommendation

The study outcome confirms that there are no suitable aquifers to the depth of 200 m for groundwater development from the qualitative point of view. In this area which has been studied the drilling of well will be wastage of resources (time and money).

9.Reference

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