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Geoelectrical Investigations and their Correlation with Groundwater Depth and Quality in Kaithal District of Haryana

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Abstract : The present study was carried out to investigate broad hydrogeological conditions by identification and characterization of the aquifer formations in terms of expanse and depth in Kaithal district of Haryana state. Vertical electrical soundings (Schlumberger array) were performed with maximum current electrode spreading of 400 m. Two layer curve matching method and IPI2WIN software were used to interpret and correlate the field data with some existing borehole columns. Thickness and resistivity values of various subsurface layers were determined. Geoelectrical sections were prepared from apparent resistivity sections and interpreted quantitatively. Further, spatial distribution of average resistivity up to a depth of 200 m in the district was mapped in Geographic Information System (GIS) environment using ILWIS 3.6. The results were correlated with spatial distribution of depth to water level below ground level (bgl) and electrical conductivity of groundwater. The overall resistivity values were found to be directly proportional to depth to water level and inversely proportional to electrical conductivity (EC) of groundwater. A high average resistivity zone (65-130 ohm-m) was prominent in Gulha, and Siwan blocks – the fresh quality area with very deep water table (30-45m). Medium resistivity zone (30-65 ohm-m) was found to cover Ghaggar area of Gulha block and parts of Siwan, Kaithal and Pundri blocks where depth to water table was in deep category (20-30m). Again, low resistivity zone (15- 30 ohm-m) was found in parts of the district at shallow depths. In the remaining low lying part in southern region having shallow groundwater depth in 3-10 m range and a high EC in 2500-9000 μS/cm range respectively, the average resistivity was found to vary in 0-15 ohm m range. Entire Pundri block along with a part of the adjoining Kaithal block (about 32% of total area) can be identified as the zone of good groundwater prospects. Western part in Siwan block (about 8% of total area) was found critical due to fast depleting levels.

Keywords: Groundwater · Electrical Resistivity · Depth to water level · Kaithal · GIS · Aquifer · Spatial Distribution

INTRODUCTION

The conventional approaches for groundwater investigation are time consuming, difficult, uneconomical and introduce manual error (Prasad et al., 2008). However, there are a number of geophysical exploration techniques such as geoelectrical, electromagnetic, seismic and geophysical borehole logging, which enable an insight to the nature of water bearing layers. The choice of a particular method is governed by the nature of the terrain and cost considerations (Emenike, 2001). A planned geoelectrical investigation is capable of mapping an aquifer system, clay layers, the depth and thickness of aquifers and qualitatively estimating local groundwater flow (Steinich and Marín, 1996; Israil et al., 2006). The technique is suitable for such applications because of low cost, simple interpretation, high speed and non-invasive technology and also relative success in practice (Ariyo, and Gabriel, 2009). The vertical electrical sounding (VES) method is usually considered more suitable for the subsurface investigation of geologic environments consisting of horizontal or nearly horizontal layers, such as occurring in unconsolidated sedimentary sequences. Recently, the resistivity survey has also become popular for the investigation of subsurface pollution and groundwater quality problems (National Research Council, 2000).

The technique is based on the response of the earth to the flow of electrical current in form of variations in ground resistivity. In most earth materials, electricity is conducted electrolytically by the interstitial fluid. The resistivity is controlled mostly by porosity, water content and water quality than by the resistivities of the matrix (Ayer, 1989). In the shallow subsurface, the presence of water controls much of the resistivity variation. In general, measurement of resistivity is a measure of water saturation, its quality and connectivity of pore space. Thus, the identification of horizontal and vertical variations in lithology (including water type in pores), can lead to clarify the structural picture of the subsurface. The electrical resistivity contrasts existing between lithological sequences (Dodds and Ivic, 1998; Lashkaripour, 2003) in the subsurface are often adequate to enable the delineation of geoelectric layers and identification of aquiferous or non-aquiferous layers (Schwarz, 1988).

Electrical resistivity methods have been used successfully for groundwater prospecting in various terrains (Zohdy et al., 1989; Stewart, 1986; Ballukraya, 2001; Shrivastava and Bhattacharya, 2006). In a number of applications, geo-electrical method and groundwater quality studies have been integrated together (Keller and Frischknecht, 1966; Todd and Mays, 2005; Telford et al, 1988; Al-Sayed and El-Qady, 2007).

Kaithal district of Haryana is an agriculture dominated area which has been facing the problems of depleting groundwater levels in its fresh groundwater quality belt. At the same time, rising water table and salinity conditions are prevailing in certain pockets in southern parts of the district (Goyal et al., 2010). Due to heavy dependence to meet its huge irrigation needs, the sustainability of the groundwater resource is of major concern. In view of this, the present study was undertaken to determine the geoelectrical characteristics of the aquifer present in the study area, to examine correlation of VES results with observations from groundwater depth and quality data, and to establish the usefulness of the electrical resistivity method as a potential tool in solving the complex geohydrological problems associated with groundwater occurrence and its development in a typical alluvial region.

STUDY AREA

The Kaithal district is constituted of six administrative blocks (Gulha, Siwan, Kaithal, Pundri, Rajaund and Kalayat) located between 29° 32' to 30° 12'N latitude and 76° 08' to 76° 45' E longitude (Fig.1). It forms a part of the upper Ghaggar basin in the vast Indo-Gangetic plain, covering 2284 km^2 of area and appears monotonous. The region is entirely covered by alluvial deposits of Quaternary to Recent age consisting of clay and sand. Kankar, gravel, cemented and unconsolidated sand are also found in the beds. The ground elevation varies from 217 m to 252 m from mean sea level with a gentle slope from north-east to south-west. Physiographically, the district may be divided in two units: the upland plain and the low lying areas. The upland plain is spread along the north-eastern boundary of the district, while the low lying area covers the southern part of the district.

The study area, in general, is suitable for exploitation of the groundwater resources, as the plains constitute thick columns of alluvium and serve as vast source of recharge like seepage from extensive canal system and moderate rainfall. The groundwater in the plains occurs under water table conditions in the zone of saturation. The aquifers occur in unconfined and semi confined conditions. The depth to water table in the study area, varied from 4 to 45 m below ground level (Goyal et al., 2010).

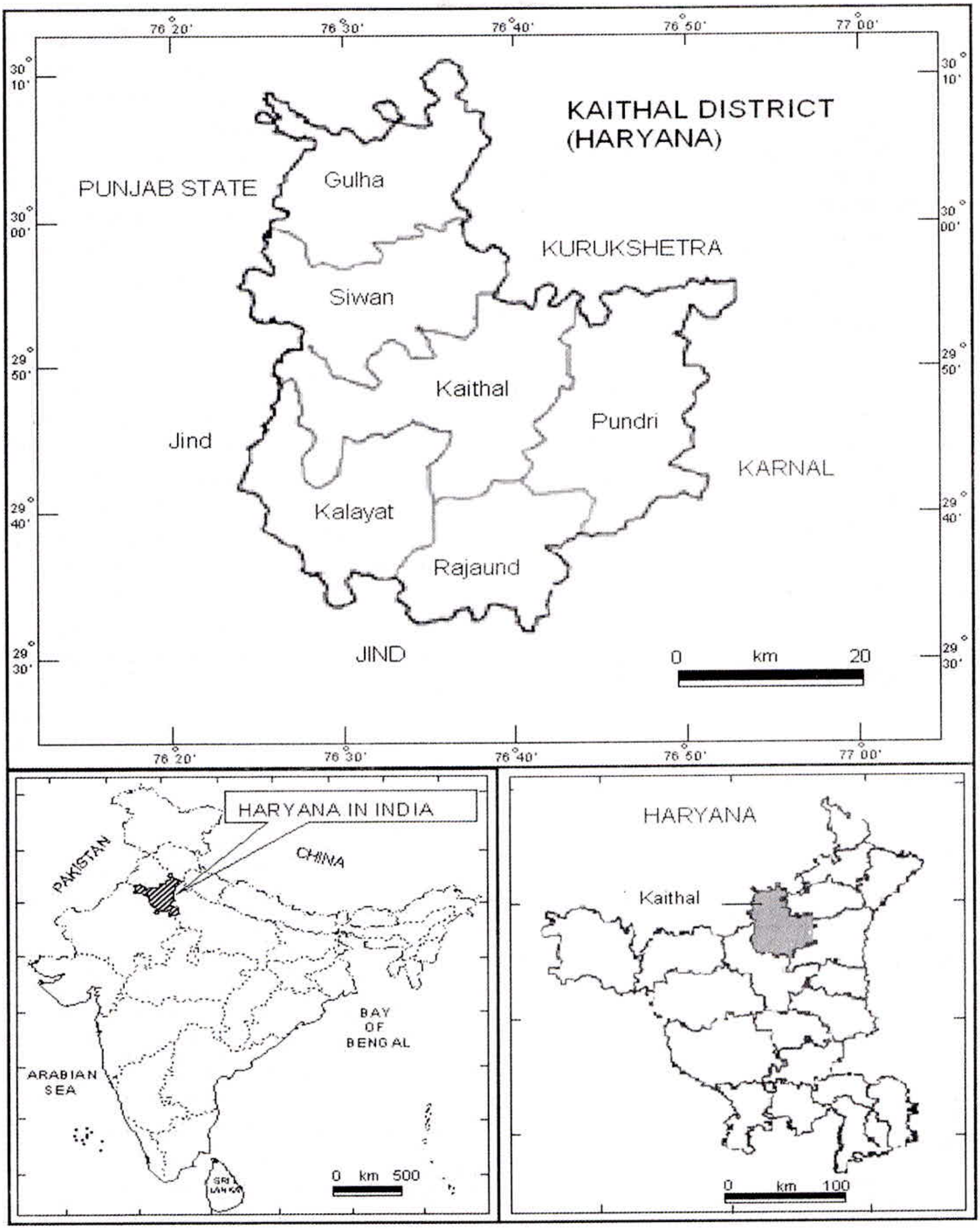


Fig. 1. Location map of the study area

MATERIALS AND METHODS

Vertical Electrical Sounding

An electrical current is passed through the ground by means of two electrodes (A and B) and the resultant potential difference developed between two potential electrodes (M and N) is recorded (Fig. 2). The electrical resistivity is then determined as a function of the value of the potential difference, the current applied and also the electrode separation. Apparent (bulk or effective) electrical resistivity (ñ$_a$) is then used to interpret subsurface anomalies. Resistivity measurements associated with varying depths relative to the distance between the current and potential electrodes in the survey can be interpreted qualitatively and quantitatively in terms of a lithological and geohydrological model of the subsurface.

The positions of current and potential electrodes are changed with respect to a fixed point (sounding point) and resistance values are measured at the surface which reflects the vertical distribution of resistivity values in a geological section. The variation of the apparent resistivity with change in electrode spacing and position gives information about the variation in subsurface layering. The apparent resistivity value is the product of the geometric factor (K) and the resistance (R) recorded in the resistivity meter (Eq. 1).

Apparent resistivity, ñ$_a$ = K R

$$\text{where, } K = \frac{\pi}{2}\,\frac{\left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2}{\left(\frac{MN}{2}\right)} \qquad (1)$$

Average resistivity at each point was calculated using (Eq. 2)

Average resistivity, ñ = “ ñ$_i$h$_i$ “ “ h$_i$ (2)

Because earth's subsurface is not homogeneous, the electrical properties of the ground (resistivity/ conductivity) alter the current density. The equipotential surfaces, perpendicular to the current flow, are modified by the deflection of the electrical current near inhomogeneities. The resistivity method measures the resulting variation in potential differences yielding information about

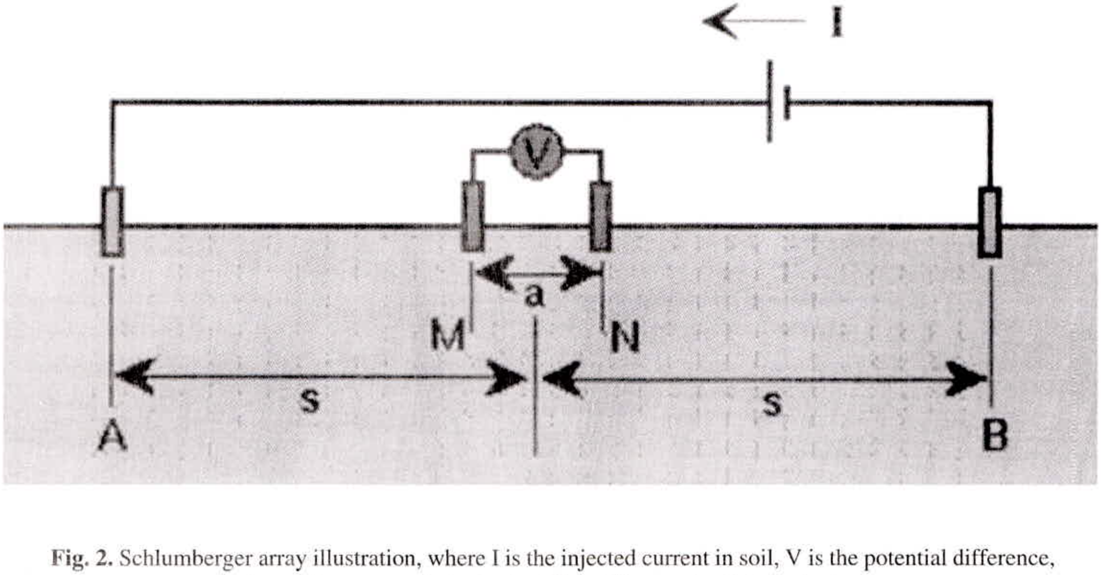


Fig. 2. Schlumberger array illustration, where I is the injected current in soil, V is the potential difference, A and B are current electrodes, M and N are potential electrodes.

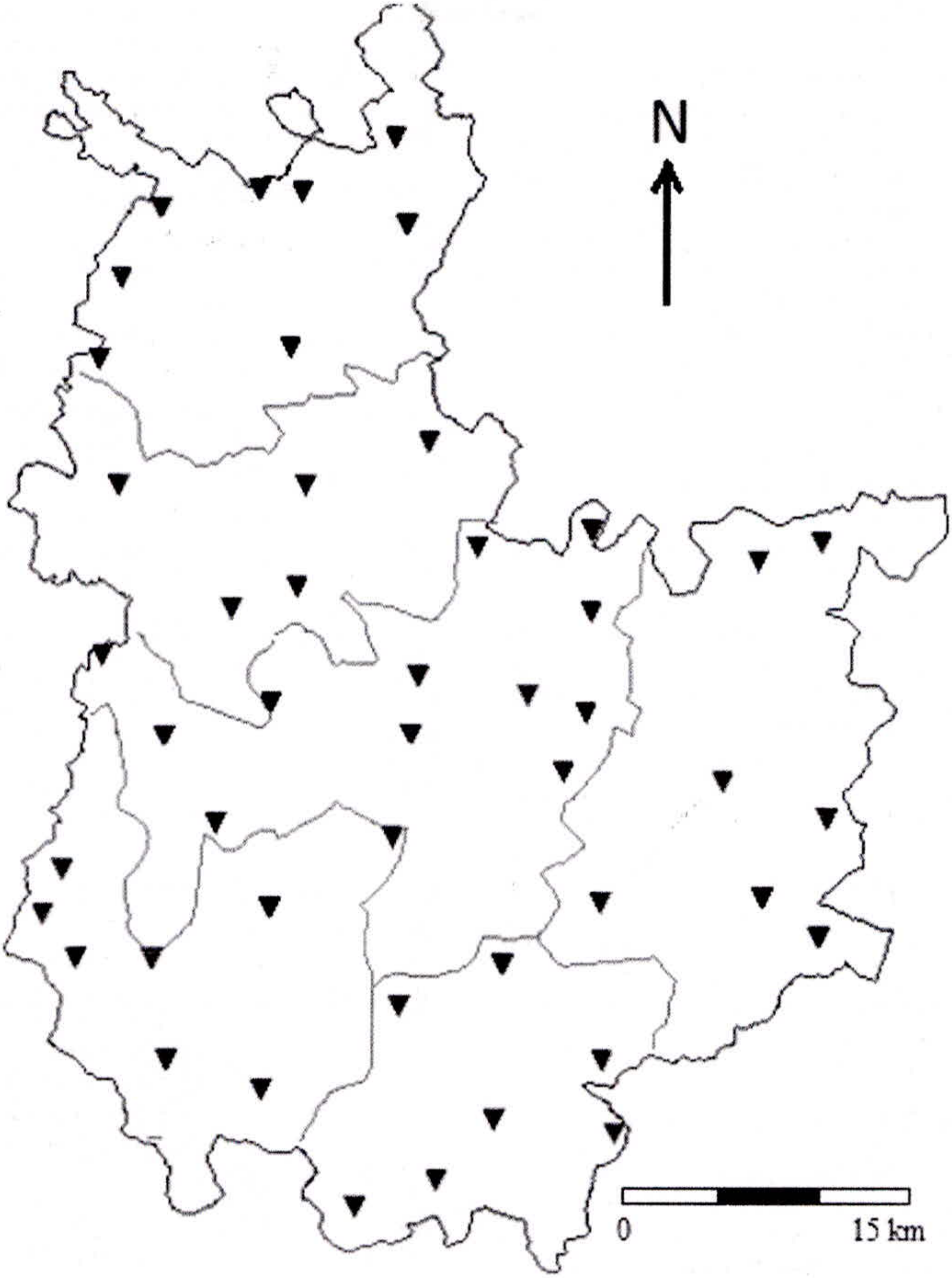


Fig. 3. Locations of sounding points in the study area

the subsurface inhomogeneity. The measured variations are primarily due to the subsurface material directly below the survey line (in the survey plane), although this is not completely true because the earth is not isotropic. Data are termed *apparent* resistivity because they are averages over a complex current path but are associated with a single depth point in the survey plane. The wide resistivity ranges of earth materials (Table 1) suggest that resistivity data may look noisy. Often data are plotted as the logarithm of the apparent resistivity.

Interpretation

The field curves were primarily interpreted by two layer curve matching method using Mooney and Orellana (1966) master curves. The curves derived from the field observations are interpreted by comparison with apparent resistivity curves computed for assumed models of the sub-surface stratification. In curve matching technique, the field curve is compared with theoretical curves computed for various layer parameters. When the field curve matches with a particular theoretical curve, the layer parameters of the theoretical curves are taken as the solution for the field sounding data. For a better estimation of resistivities and thicknesses of the subsurface layers, sounding curves were interpreted quantitatively using the IPI2WIN software program version 3.0.1.a7.01.03. This software helps in interactive semi-automated interpretation of the field data. Multiple iterations were tried to reach the best fit between the field curve and the calculated one (Bobachow, 2002).

Preparation of spatial distribution maps

Spatial distribution map was generated by carrying out point interpolations using moving average (inverse distance) method. Further, the map was classified into average resistivity ranges of 0-6, 6-16 and 16-128 for comparison with EC distribution map of the area (Goyal et al., 2010). Again, classification into 0-15, 15-30, 30-65 and 65- 130 was done to compare with spatial distribution map of groundwater depth of the district (Goyal et al., 2010). Areas under each depth and quality zone were determined from histograms generated by the software for these maps.

RESULTS AND DISCUSSION

Vertical electrical soundings, carried out, were analyzed qualitatively by preparing apparent resistivity sections and quantitatively by inferring layer parameters i.e. true resistivity and thickness of the formations using curve matching method.

Final results of the interpretation of all data in the 62 sounding curves are shown in Table 1. Examples of field curves are given in Fig 4.The visual inspection of the field data showed the presence of twelve types of curves. This large number of types reflects the horizontal variations that characterize the plain (Table 1). The combination of all type of curves recorded in the study area indicate the presence of multilayered inhomogenous formation. In the above classified curve types, A and H type curves indicate the presence of three layers followed by combination of curves (AK, HA, KH, QH) indicating the four layer sub-surface medium. The resistivity data confirm mainly of an alluvial aquifer.

The interpretation revealed the presence of 3-5 geoelectric sub-surface layers. These geoelectric layers are topsoil and the weathered layer which can be sandy, clayey sand, or clay. It was found that out of the sixty two field curves, twenty four were three layer while thirty four were four layer and three were five layer curves. The top layer is predominantly clay/ clay with Kankar with resistivity varying from 6- 46 ohm-m and its thickness varying between 1.9 m to 10 m. The second and third layer had thicknesses ranging from 4.3m to 90m and 15m to 193.5m, respectively while the fourth layer had thickness ranging from 11m to 99m and fifth layer had thickness that extended beyond the

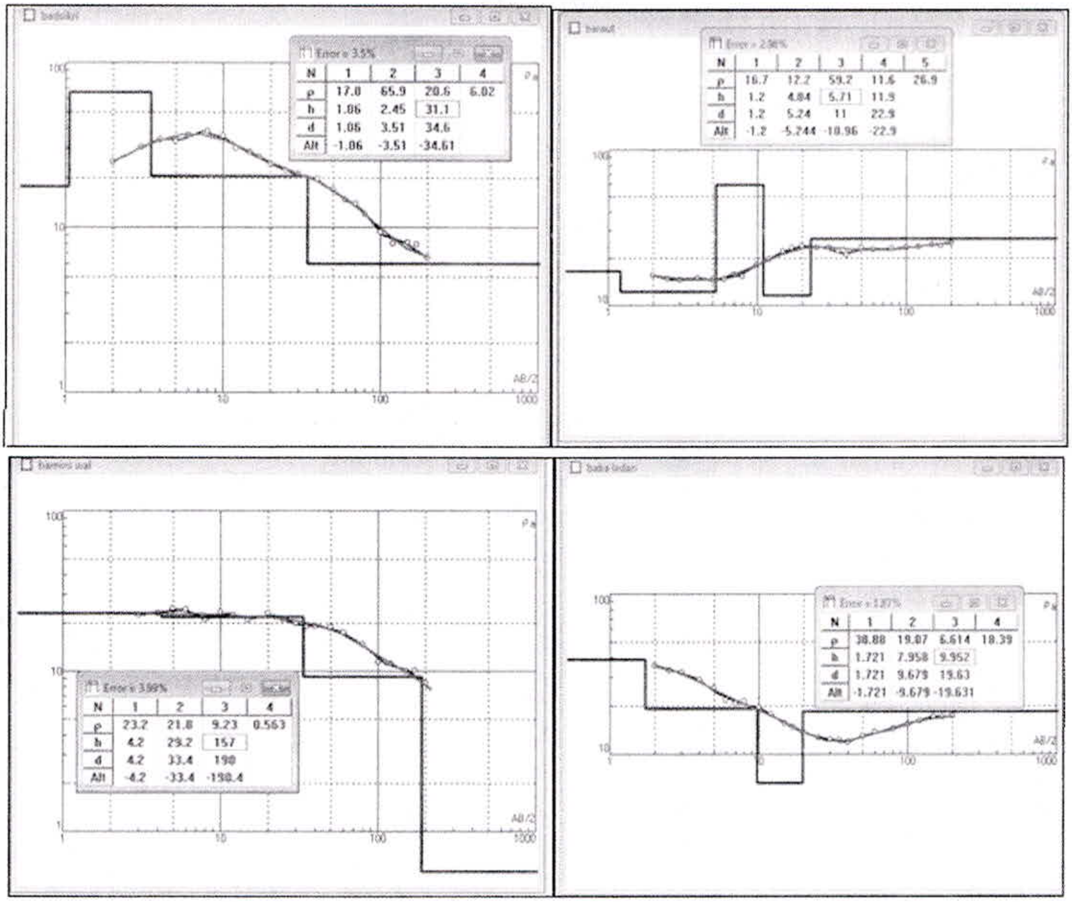
Table 1. True resistivity and thickness of different subsurface layers determined by curve matching method.

Point Id	Location	ρ1	h1	ρ2	h2	ρ3	h3	ρ4	h4	ρ5	h5
35	BadSikri	25	2	62	6	19	30	6.6	162		
36	Bamniwala	25	2	20	25	14	60	7	113		
3	Barot	15	6	30	30	21	164				
1	Batta 1	8	2. 3	12	6	3	110	7.5	82		
4	Begpur	34	2	85	7	45	45	70	146		
32	Bhagal	18	2	90	50	45	125	4.5	23		
44	Chandana	6.8	2	34	12	8	70	13	116		
17	Chhot	20	2	16	7	5.4	30	10.5	161		
46	Dadwana	30	2	105	70	15.1	128				
23	Dhons	40	2	100	4.5	21.6	194				
19	Dhundrehri	19	2.5	6	40	6.5	158				
15	Dilluwala	35	2	70	10	20	188				
39	Dundhwa	17	2.4	7	13	3	72	1	113		
62	Farshmajra	22	3	44	24	100	100	15	73		
16	Franswala	13	2	16	40	27	120	10	38		
40	Geong	10	2	35	125	15	73				
50	Habri	32	4	40	11	18.5	60	13	125		
25	Hansumajra	6	2	7.5	10	105	188				
6	Jaswanti	30	2	12	15	33	100	26	83		
9	Kaithal	13	2	26	13	17.6	31	32	64	15	90
60	Kakyurmajra	46	2	69	10	124	50	50	138		
38	Kalayat	26	2	8	8	3	120	6	70		
56	Kasan3	27	2	22	27	4.4	115	10	56		
30	Kasauli	10	3	100	50	47	147				
22	Kathwar	7.2	2	36	40	11	75	30	83		
5	Keorak	11	10	17	30	35	160				
33	Kharal	35	3	88	40	26	157				
28	KheriDabar	7.6	7.6	8	11	80	36	62	145		
10	KheriGulamali	28	3	14	16	24	181				
42	Khurana	20	8	30	90	13	102				
58	Kithana	11	2	9	14	3.6	184				
37	Kolekhan	22	2	33	7	19	28	3.3	160	5.4	3
53	Kukarkanda	17	2	34	40	10.5	158				
8	Kultaran	12	2.5	15	5	45	24	21	169		
34	Kurar	20	3	30	12	16	80	8.5	105		
13	Ladana Baba	34	2	17	11	6	30	20	157		
12	Manas	30	3.3	20	100	11.5	97				
55	Mandwal	17	2	26	7	15	70	8	121		
2	Mataur	18	3.3	5.4	22	12	50	3.6	125		
61	MeghaMajra	13	2	65	22	135	72	18	104		
21	Mundri	15	2	4.5	4.5	10	15	24	60	17	119
57	Narwal2	12	2	15	60	1	138				
48	Pabnawa	19	2	133	19	41	80	19	99		
47	Pai	26	3	52	12	21	70	6.6	115		
43	Patti Khot	8	2	29	6	23	20	10	100	17	72
26	Peedal	25	2	31	8	150	64	65	126		

Resistivity ρ (ohm-m), thickness of layer h (m)

Table 2. True resistivity and thickness of different subsurface layers determined by IPI2WIN

Point Id	Location	ρ_1	h_1	ρ_2	h_2	ρ_3	h_3	ρ_4	h_4	ρ_5	h_5	Curve type
35	BadSikri	19.5	1.3	94	2	21	31	6	166			KQ
36	Bamniwala	23	4	22	29	9.2	157	0.6	10			QQ
3	Barot	14	5	59	5.7	12	12	27	177			KH
1	Batta 1	4.4	11	10.6	44	17	146					A
4	Begpur	30	1.6	94	5	6	2.3	68	191			KH
32	Bhagal	13	0.4	68	5	12	3	62	64	9	128	KHK
44	Chandana	6	2	118	2	1.6	5	11	191			KH
17	Chhot	5	1	44	1	6	12	28	34	5	152	KHK
46	Dadwana	24	1.2	70	6	126	56	14	136			AK
23	Dhons	25	2.6	11	33	7	165					Q
19	Dhundrehri	41	3	141	3	23	55	17	139			KQ
15	Dilluwala	10	1.6	29	2.5	7	6	39	16	14	174	KHK
39	Dundhwa	15	4	6	9.2	3	60	18	127			QQ
62	Farshmajra	19	2.5	79	2.7	19	6	161	21	36	168	KHK
16	Franswala	12	1	22	9	78	11	15	162	6	17	AKQ
40	Geong	11	1	22	4	4.6	6	31	37	12	152	KHK
50	Habri1	23	2.5	107	20	16	25	28	152			KH
25	Hansumajra1	6	2	9	10.5	110	18	145	169			AA
6	Jaswanti	13.5	1.2	10.5	1.3	34	3	17	95	65	100	HKH
9	Kaithal	35	1.5	17	2	110	2	16	195			HK
60	Kakyurmajra	42	1.2	62	10	217	12	50	177			AK
38	Kalayat	13.5	1.2	27	1.3	6.4	3	3.5	195			KQ
56	Kasan3	27	4.6	19	4.4	39	8	6.6	183			HK
30	Kasauli	7	1.4	16	3	199	18	23	88		90	AK
22	Kathwar	27	1	5	1	16	27	33	172			HA
5	Keorak	31	4	9	6	42	8	24	182			HK
33	Kharal	35	3	88	40	26	157					K
28	KheriDabar	8	2.6	5	5	133	43	49	149			HK
10	KheriGulamali	17	1	4.5	1	61	2.5	7	4	24	192	HKH
42	Khurana	20.5	2.5	43	9	14	189					K
58	Kithana1	7	2.5	32	9	1	12	5.6	177			KH
37	Kolekhan	4.9	2	2	3	8	11	4	184			HK
53	Kukarkanda	18	5	133	3	30	30	12	162			KQ
8	Kultaran	23	3	10	4	32	27	15	166			HK
34	Kurar	20	3.3	52	2	17	54	10	141			KQ
13	Ladana baba	39	2	20	7	8	13	19	178			QH
12	Manas	1.7	2	3	22	15	20	3.4	157			AK
55	Mandwal	9	0.3	22	7	16	33	11	159			KQ
2	Mataur	18	1.2	24	1.5	6	65	3	83	8	49	KQH
61	Meghamajra	6.9	1	45	10	233	19	21	170			AK
21	Mundri	5	2	2.3	2	29	40	13	157			HK
57	Narwal2	13	6	16	24	7	170					K
48	Pabnawa	21	2.4	202	5	40	141	8	51			KQ
47	Pai	24.6	2.5	68	3	26	36	8	20	25	139	KQH
43	Patti Khot	6.4	1.2	22	19	5	12	13	168			KH
26	Peedal	25	8	144	49	44	143					K



N	1	2	3	4
ρ	17.0	65.9	20.6	6.02
h	1.06	2.45	31.1	
d	1.06	3.51	34.6	
Alt	-1.06	-3.51	-34.61	

N	1	2	3	4	5
ρ	16.7	12.2	59.2	11.6	26.9
h	1.2	4.04	5.71	11.9	
d	1.2	5.24	11	22.9	
Alt	-1.2	-5.244	-10.96	-22.9	

N	1	2	3	4
ρ	23.2	21.8	9.23	0.563
h	4.2	29.2	157	
d	4.2	33.4	190	
Alt	-4.2	-33.4	-190.4	

N	1	2	3	4
ρ	38.88	19.07	6.614	18.39
h	1.721	7.958	9.952	
d	1.721	9.679	19.63	
Alt	-1.721	-9.679	-19.631	

Fig. 4. VES curves obtained from Badsikri, Barot, Bamniwala and Babaladana

probing depth. Surface layers are mainly composed of alluvial plain (sand, silt and clays) which is the major groundwater prospect at upper level in the study area as they show low resistivity values (Singh, 2009). These data were used to determine the depth and nature of the alluvium and the boundaries of the aquifer with a reasonable accuracy. The high resistivity in the north and northwest of the aquifer is due to better water quality and the existence of alluvial fan with coarse grain materials. The lower resistivity in the southern parts of the aquifer is due to presence of finer materials.

Correlation of average resistivity and depth to water level

The aquifer properties and their relation with electrical resistivity values obtained from surface geoelectrical measurements have been investigated in Haryana and a positive correlation was found (Israil et al., 1994). In the present study, the average resistivity of sub-surface layers up to a depth of 200 m at the sounding locations were computed (Table 3). The lateral distribution of average resistivity in study area was mapped by carrying out point interpolations. This map was

Table 3. Average resistivity of sub-surface layers at sounding points along with depth and resistivity of groundwater

Point Id	Location	Depth to water level (m)	Resistivity of water (Ω m)	Average resistivity (Ω m)
35	BadSikri	71	2.5	9
36	Bamniwala	10	3.2	11
3	Barot	21	4.5	27
1	Batta	8	3.0	15
4	Begpur	20	5.6	67
32	Bhagal	23	8.1	27
44	Chandana	10	4.9	12
17	Chhot	21	2.7	9
46	Dadwana	19	7.0	48
23	Dhons	18.3	7.1	8
19	Dhundrehri	11	2.3	21
15	Dilluwala	25	5.3	16
39	Dundhwa	6	3.1	3
62	Farshmajra	27	5.7	49
16	Franswala	16	4.0	18
40	Geong	17	5.8	15
50	Habri	17	7.3	35
25	Hansumajra	30	6.8	133
6	Jaswanti	21	6.5	41
9	Kaithal	16	5.0	18
60	Kakyurmajra	25	6.1	60
38	Kalayat	6	2.9	4
56	Kasan3	7	2.8	9
30	Kasauli	20	6.5	53
22	Kathwar	18	6.4	31
5	Keorak	20	6.5	24
33	Kharal	24	7.2	38
28	KheriDabar	26	6.8	65
10	Kheri Gulamali	30	7.2	24
42	Khurana	21	6.1	16
58	Kithana	8	1.3	7
37	Kolekhan	4	2.9	4
53	Kukarkanda	9	4.8	16
8	Kultarandr	18	6.5	17
34	Kurar	9	3.1	13
13	Ladana Baba	29	6.4	18
12	Manas	23	4.8	4
55	Mandwal	7	3.0	12
2	Mataur	7	3.0	6
61	MeghaMajra	34	6.3	42
21	Mundri	14	8.1	16
57	Narwal 2	7	3.2	9
48	Pabnawa	19	7.0	36
47	Pai	12	6.6	34
43	Patti Khot	18	4.4	13

further classified into average resistivity zones of ranges 0-15, 15-30, 30-70 and 70-130 ohm-m respectively (Fig. 5). The four average resistivity zones so obtained were found to match with depth to water level zones of 3-10, 10-20, 20-30 and 30-45 m (Fig.5). It was observed that the average resistivity of sub-surface formations was more in the zones where water table was deep (greater thickness of unsaturated layer above water table). This showed that spatial distribution of average resistivity had a relationship with spatial distribution of depth of the water table.

The dependence of average vertical resistivity on depth to water levels is also indicated by the scatter graph plotted between the average resistivity at the sounding locations and the depth to water levels at these locations (Fig. 6). The trend showing that average resistivity increased with increase in groundwater level depth can be attributed to effect of unsaturated thickness on resistivity. Greater thickness of unsaturated zone will result in higher resistivity of the layers. The low value of the coefficient of correlation is may be due to random locations of the VES sounding

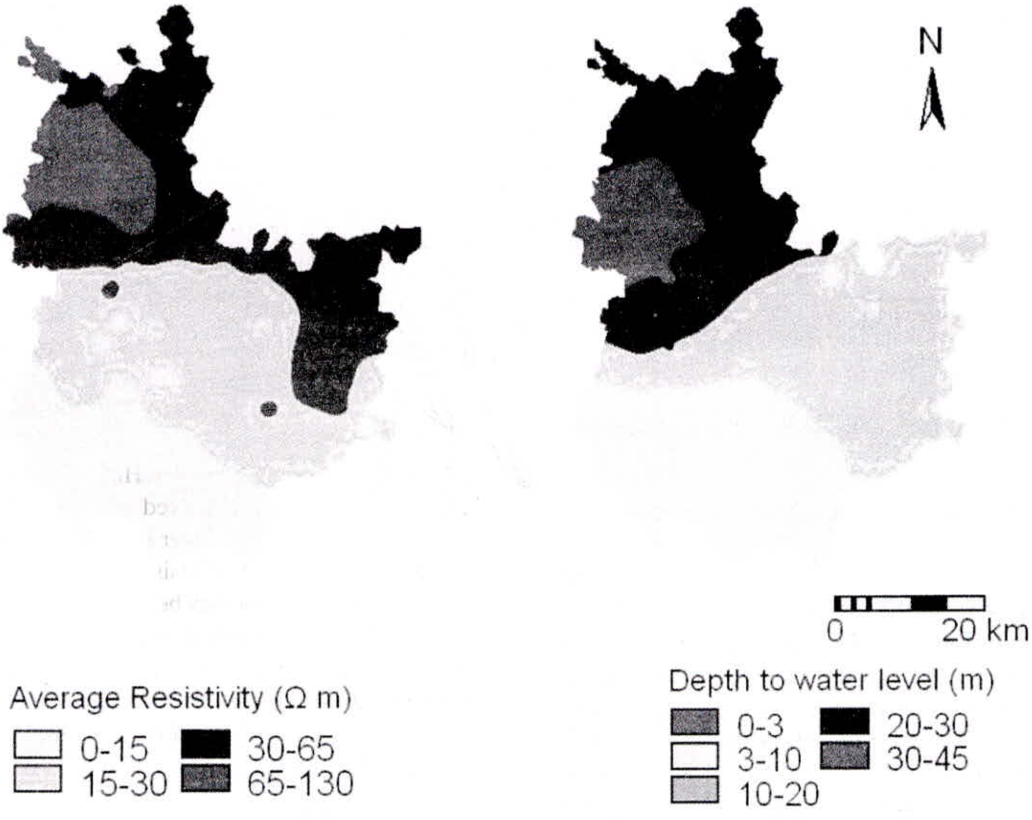


Fig. 5. The lateral distribution maps of average resistivity and depth to water level classified into different zones.

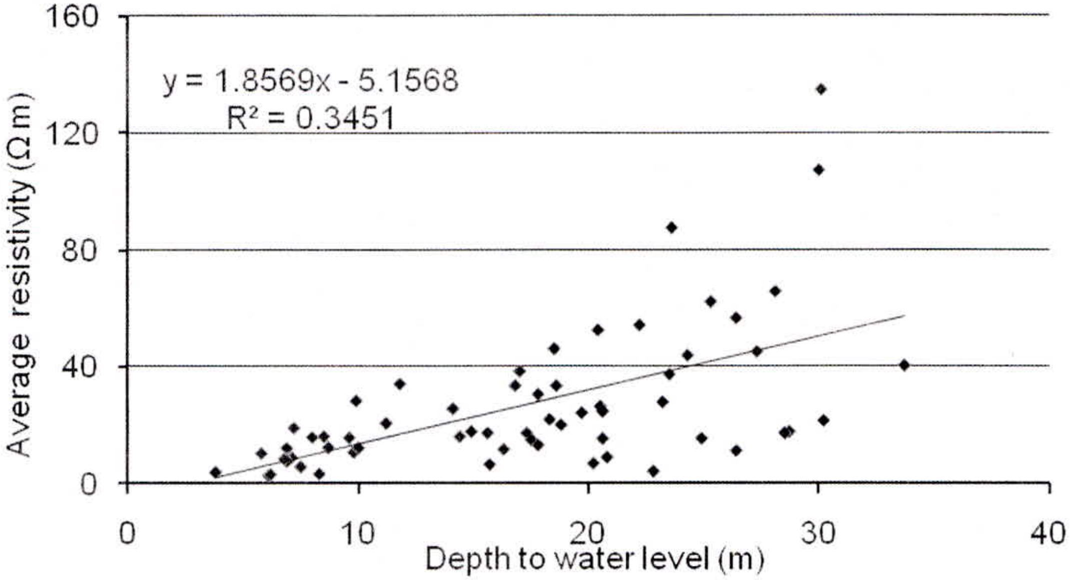


Fig. 6. Graph showing the relation of average resistivity of sub surface layers with depth to water level.

points as majority of them were found to be in areas of low depth to water level.

Correlation of average resistivity and EC of groundwater

The resistivity pattern of sub-surface formations has been investigated and observed to compare well with electrical conductivity of groundwater (Ballukraya, 1999). Moreover, the relationship between water resistivity and earth resistivity was also used for delineation of groundwater quality zones (Mondal et al., 2004). The lateral EC variation map of groundwater result in classification of the Kaithal district into resistivity zones of ranges 0-6, 6-16 and 16-130 ohm-m. These zones were found to match with the zones of EC in ranges 750-2250, 2250-4000 and more than 4000 μS/cm, respectively (Fig. 7). The scatter plot of the average resistivity of sub-surface formations versus resistivity of groundwater also depicted the relation between these parameters (Fig. 8). However, the correlation is poor (low R^2) which may be attributed to uneven distribution of sounding locations in areas having different quality of groundwater. High salinity and concentration of total dissolved solids (TDS) in groundwater resulted in lower resistivity values. Therefore, higher average resistivity observed in the north and northwest may be due to good water quality and the existence of alluvial fan with coarse grain materials. The lower resistivity in the southern and south-western parts of the district can be attributed to observed higher salt content in the groundwater.

CONCLUSIONS

Vertical electrical soundings carried out in the study area were found to have successfully delineated the layers of formations having relative

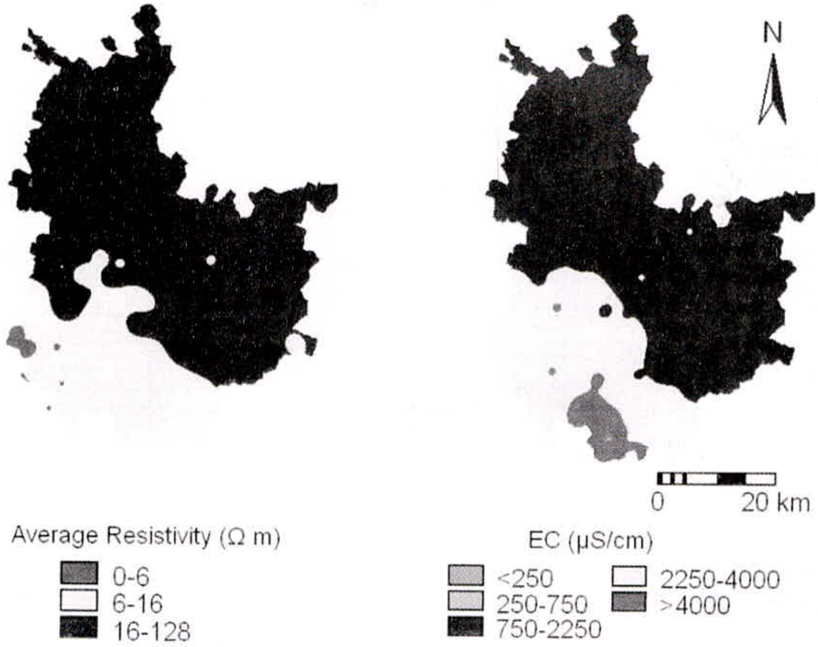


Fig.7. Graph showing the relation of average resistivity of sub surface layers with electrical conductivity of groundwater.

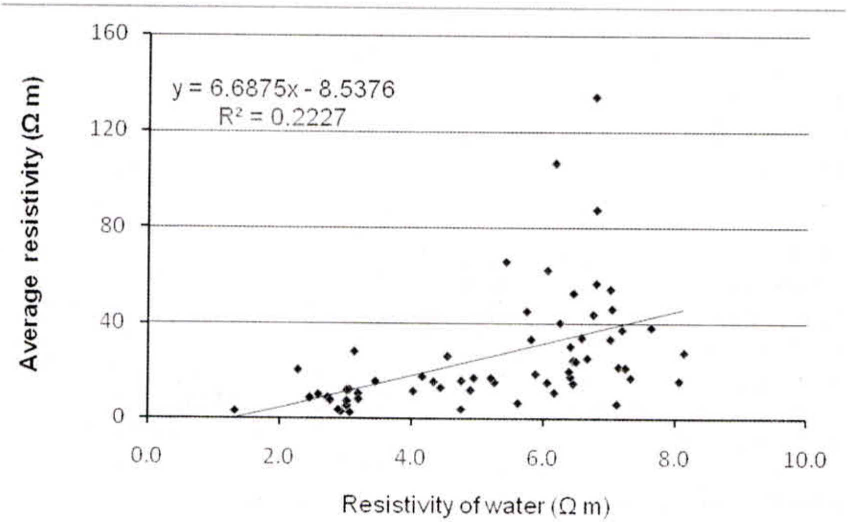


Fig.8. Graph showing the relation of average resistivity of sub surface layers with electrical conductivity of groundwater.

resistivity change in the litho units. The interpretation revealed the presence of 3-5 geo-electric sub-surface layers. The large number of curve types indicated of variations subsurface lithology. The high resistivity in the north and northwest parts can be due to higher water quality and the existence of alluvial deposits with coarse grain materials. The lower resistivity in the central and southern parts of the aquifer may be due to finer materials. The vertically downward dipping low resistivity contours indicated the presence of finer grains with increasing depth. The litho units of this area were found to be clay predominant with minimum intercalations of sand. In the shallow subsurface, the presence of water controls much of the conductivity variation.

The study showed that average resistivity of subsurface resistivity at a particular location could be taken as an indicator of depth to water level and quality of groundwater at that place. Increasing saturation and increasing salinity of the groundwater was found to result in decrease in the measured resistivity. The use of geo-electrical soundings provides an inexpensive method for characterizing the groundwater conditions of the region. The study further illustrates the usefulness of geoelectrical investigations in mapping sub-surface geology and delineating fresh water – saline water bearing zones in an area.

The advantages of the resistivity method are the simple theory and methodology. Data can be obtained and qualitatively interpreted reasonably rapidly. The limitations of the resistivity technique include the more difficult interpretation in the presence of complex geology and the existence of natural currents and potentials.

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