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Geo-electrical Investigations for Shallow Ground Water at IARI Farm, New Delhi

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Abstract : Vertical Electrical Soundings (VES) adopting Schlumberger configuration and profiling by Wenner configuration, were carried out at 16 locations and along two traverses, to assess the ground water potential zones and their continuity in a micro-watershed at IARI Farm, New Delhi. Five geoelectric layers were identified within a depth of about 40m below ground level. VES data from two points were compared with the bore hole litholog obtained from secondary data. Using the resistivity fence diagram and the geometry of the aquifer zone, approximate quantity of ground water under phreatic condition was computed. Chemical analyses of ground water samples indicated medium to slightly higher salinity and low alkali hazard, which could be grouped as C_3S_1 under USDA classification of irrigation water quality.

Key words: VES, resistivity, geo-electric layer.

The most important aspect of water resources development planning of an area is the information on quantity and quality of ground water. Exploration of ground water sources by geo-electrical methods is one of the inexpensive and *in-situ* method and has been in vogue (Keller and Frischnecht, 1966; Koefoed, 1979; Balakrishna *et al*., 1978; Chandra and Athavale, 1979; Chandrasekharan and Sharma, 1985; Chandrasekharan, 1988 and Chandrasekharan and Singh, 1995). The factors controlling ground water potentials of a region are climate, topography, lithological formations and recharge characteristics. The study reported here aims to assess the available ground water resource at shallow depth in a micro-watershed within the research farm of Indian Agricultural Research Institute (IARI), New Delhi.

Characteristics of Study Area

Area of investigations

Earlier studies in IARI farm were confined to estimating ground water conditions based mainly on secondary data (Dakshinamurthy and Sarma, 1970 and Sarma *et al*., 1974, 1979 and 1980). Information on quality and quantity of ground water and its georeference was not available.

The IARI farm area, located within a 473 ha campus in a semi-arid climate, has been divided into three micro-watersheds (Fig. 1; Singh, 1992). The present investigations were carried out at the watershed (W_2) which comprises farm lands, buildings, roads, orchards, play ground and a *nallah*, and covering about one third of the total area of the IARI campus.

Physiography and drainage

The topography of the IARI farm is moderately rolling to flat. Located in the fork of the Aravali hill ranges the farm has a gentle slope from south-east to north-west (Fig. 1). There are some low lying areas (Main Block 15 and 16 and their neighbouring areas towards the western boundary), commonly known as the new area. The natural drainage stands modified as a result of farm development, but maintains a general trend. The water down the hill from National Physical Laboratory (NPL) - Todapur side seeps to the IARI farm area during the rainy season. The storm water which earlier used to flow all over the land, is now diverted through drains into two large PWD drains which run through the farm land along the eastern and western boundaries of the institute. The drain which runs along the western boundary also passes through the study area. Small field drains which run along the downslope end of each plot, carry the drainage water from individual plots to the large drain.

Hydrogeological conditions

Alluvium and Alwar quartzite of Delhi system are the major lithological formations in the area. Thick deposits of possible glacial drift cover the bedrock. The deposits are composed dominantly of stratified clayey material, sand and gravel. Sand, clay and gravel ranging in thickness from a few centimeters to few metres, occur as irregular lenses or layers in the till. The ground water movement in the overlying unconsolidated alluvium comprised of clay, kankar, sand and gravel, is fairly uniform. Ground water from these tube wells is conveyed to a part of the study area (Main Block) through pipelines. Ground water samples of the IARI farm show an average EC value of 3.5 dS m^{-1} at 25°C (Yadav, 1973).

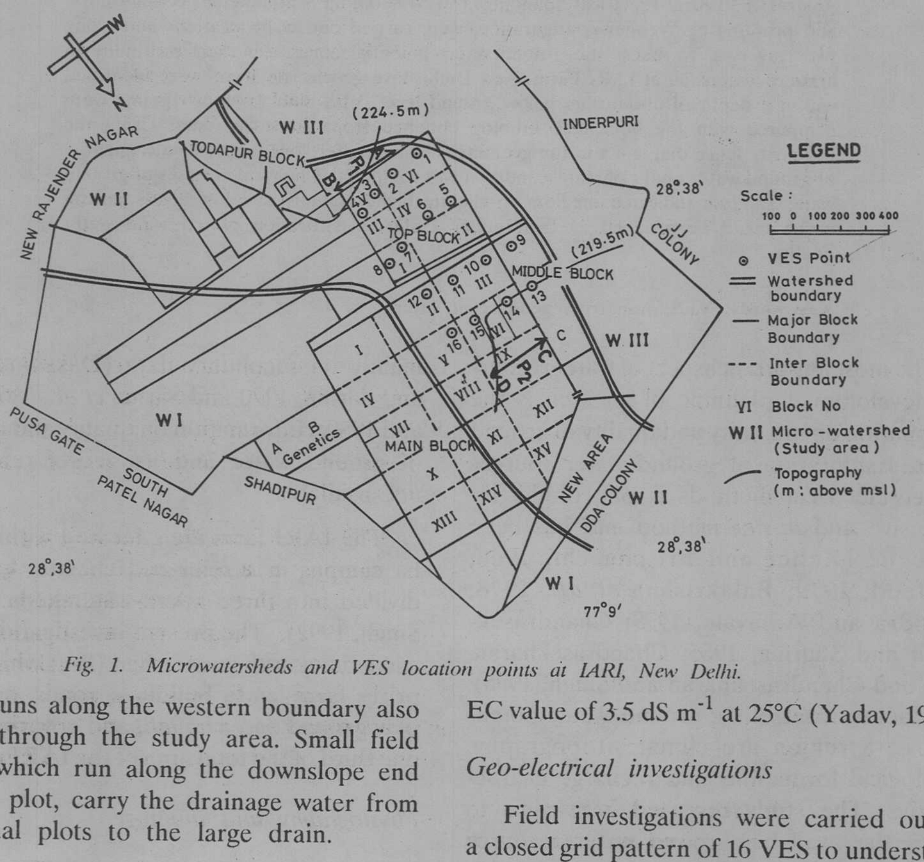

Fig. 1. Microwatersheds and VES location points at IARI, New Delhi.

Geo-electrical investigations

Field investigations were carried out in a closed grid pattern of 16 VES to understand the overall geohydrological situation within the microwatershed (Fig. 1). Two profiles (AB and CD) were constructed for top block (TB) and main block (MB) near VES points 1 to 4 and VES 13 to 16, respectively. Sounding data were interpreted for true resistivity and corresponding thickness of various subsurface horizons. To locate the potential aquifer, the Dar Zarrouk parameters were used. A com-

Table 1. Resistivity data of the microwatershed at IARI Farm, New Delhi

V E S No.	Location & Elevation (m)		Layer Number I	II	III	IV	V	T (25) (Ohm-m^2)	S (25 m) (dS)
1	TB-6B	h	1.6	1.1	2.7	9.7	?	88	19.4
	223.5	p	37.0	10.6	91.2	6.2	51.7		
2	TB-6A	h	0.6	2.4	2.2	6.6	?	1557	26.3
	223.5	p	32.4	16.9	72.8	2.9	100.4		
3	TB-5B	h	0.9	1.7	3.4	8.5	?	486	12.0
	224.5	p	23.5	42.3	12.0	33.6	6.1		
4	TB-5A	h	0.3	1.4	7.1	10.7	?	434	16.6
	224.5	p	30.2	28.8	20.8	17.8	8.3		
5	TB-4B	h	0.6	1.5	6.7	11.6	?	519	23.9
	222.5	p	64.9	34.4	20.6	6.1	47.5		
6	TB-4A	h	0.3	1.3	5.8	7.5	?	1298	20.0
	222.0	p	43.5	48.8	21.6	4.7	104.9		
7	TB-1B	h	0.3	0.7	0.8	21.8	?	479	13.7
	222.3	p	47.3	16.3	47.1	18.3	13.0		
8	TB-1A	h	0.2	1.0	4.3	6.0	?	4350	15.3
	222.3	p	96.3	23.8	31.3	4.6	306.5		
9	MID-A	h	0.2	2.0	4.0	21.2	?	328	19.5
	220.0	p	29.6	20.3	10.4	12.7	7.1		
10	MB-3B	h	0.2	2.4	3.0	17.5	?	372	19.2
	221.0	p	36.0	25.5	8.5	15.2	6.1		
11	MB-3A	h	0.2	0.4	3.6	22.7	?	430	24.4
	221.0	p	444.2	5.6	21.9	11.5	7.8		
12	MB-2	h	0.3	0.6	3.5	25.8	?	441	36.6
	221.0	p	31.5	16.0	42.7	8.5	10.3		
13	MID-B	h	0.2	0.2	8.4	6.8	?	1227	22.1
	219.5	p	23.7	89.3	14.1	4.5	111.5		
14	MB-6B	h	0.4	0.6	1.7	24.3	?	462	20.0
	219.5	p	54.5	30.8	8.1	14.1	35.4		
15	MB-6A	h	0.7	0.9	19.6	53.4	?	284	47.3
	219.5	p	25.4	35.7	11.7	1.3	14.2		
16	MB-5	h	0.3	1.3	11.6	33.3	?	252	32.7
	220.0	p	28.6	35.5	11.4	5.3	16.8		

h in m; p in Ohm-m; T in Ohm-m^2; S in dS.

bination of low value of S and high value of T represents a potential aquifer of a region where quality of ground water is more or less uniform (Chandra and Athavale, 1979).

Results and Discussion

The interpreted (true) resistivity values along with the thickness of different formations for VES points (Table 1) indicate five geo-electric layers. The iso-resistivity contour map for different depth zones were drawn separately (Figs. 2 a-d). Resistivity data of VES 12 and VES 13 were compared with the bore hole lithology of adjoining tube wells. The interpreted resistivity data of VES 13 indicate a layer of 24 Ohm-m up to 0.2 m and another layer of 89 Ohm-m at 0.4 m (Fig. 3). As the apparent resistivity curve drawn on the basis of field data alone starts with 1 m on the half-current electrode spacings, the curve was extrapolated backwards to show the resistivity data for depths < 1 m to represent

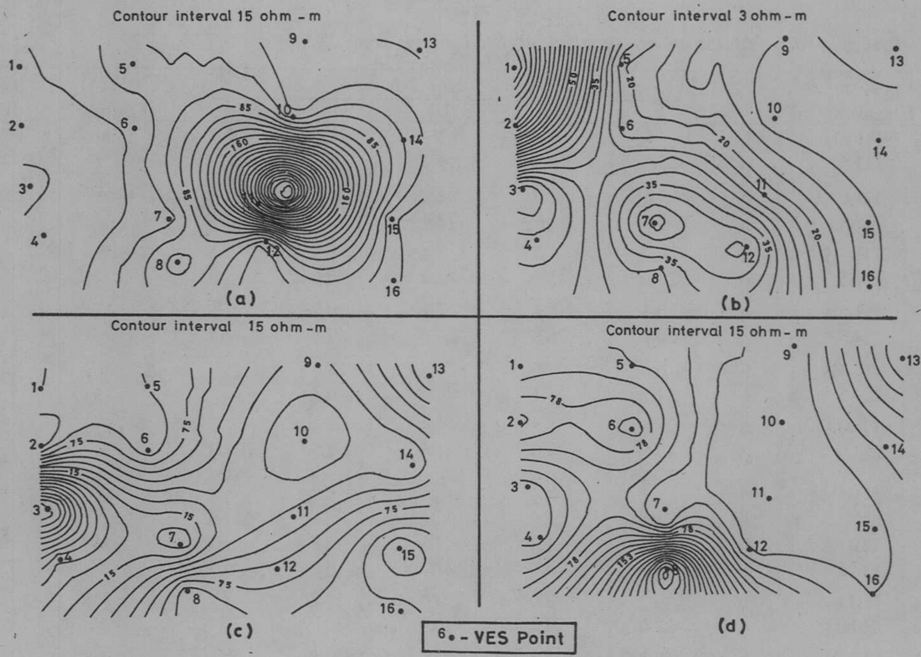

Fig. 2. Iso-resistivity contours of geoelectric layers for depth range (m) below ground level: (a) 0.2-4.0, (b) 5.0-22.0, (c) 20.0-35.0 and (d) >35.0.

the soil cover. The resistivity value of 14 Ohm-m up to 8.4 m below ground level indicates sand, clay and very small amount of kankar. Thereafter, the 4 Ohm-m resistivity up to 15.4 m represents clay with a very small amount of sand encountered by the tube well. The fifth layer with a resistivity of 112 Ohm-m corresponds to kankar, sand and very little clay. In the interpreted data, the interface between the fourth and the fifth layer is at 15.4 m below ground level which agrees well with the bore hole data. The increase in clay content from 8.4 to 15.4 m below ground level indicates that this zone (fourth geo-electric layer) is not a water potential zone. The inferences drawn from the five geo-electric layers are presented in Table 2.

Geo-electric section along traverse TB6-TB4-MB3-MB5

Qualitative and quantitative interpretations of VES data along this traverse indicate a thin layer of formation representing the soil cover with a resistivity of 6 Ohm-m to 444 Ohm-m. The high value of 444 Ohm-m (at VES 11) may be due to surface crusting. This value decreases sharply to 6 Ohm-m in the next layer, indicating the presence of clay of limited geometry (Fig. 4). A distinct clay lens of varying thickness (5 to 20 m) limits the quantity of available groundwater in the aquifer zone which otherwise is homogeneous along the traverse.

Resistivity fence diagram

The resistivity fence diagram (Fig. 5) gives a realistic picture of the subsurface configuration of the micro-watershed. Field data corresponding to VES numbers 2, 6, 10 and 15 have not been incorporated in the fence diagram, because the interpreted data from their preceding and succeeding VES provide almost identical information. Clay soil dominates most of the geo-electric layers, as is supported by bore hole data. Sand and

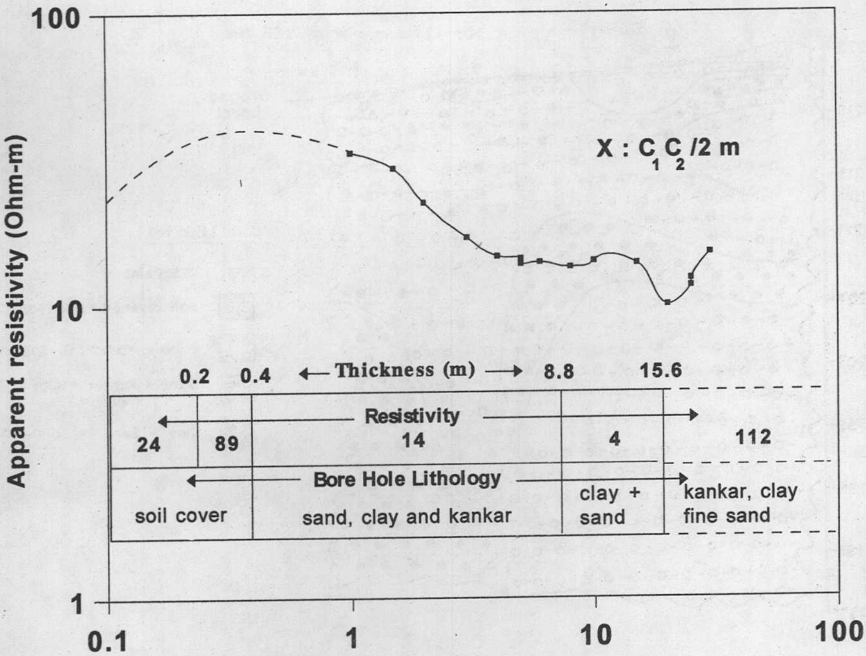

Fig. 3. Comparison of VES 13 data with bore hole lithology.

kankar form a potential aquifer at shallow depth in almost all the VES points. On the basis of resistivity data and information on bore hole lithology, the resistivity range for a given subsurface configuration has been assigned and mentioned in Fig. 5. The approximate available groundwater from the shallow (phreatic) aquifer of the investigated area, using the geometry of the aquifer zone (thickness ~ 10 m) and specific yield (0.1 assumed) of the formation, has been worked out as 2.6 ha.m (Raut, 1994). The moderate

Table 2. Sub-surface configuration based on iso-resistivity contours

Geo-electric layer	Depth below ground level (m)	Resistivity range (Ohm-m)	Inference
1 and 2	0.2 - 4.0	6 - 44	Upper ploughed layer and unsaturated soil. Very high resistivity of 444 Ohm-m is due to surface crust formation. This high value drops down to 60 Ohm-m with increase in depth indicating dominance of clayey minerals.
3	5.0 - 22.0	8 - 92	Water potential zones throughout. Resistivity value of 22 Ohm-m in MID block A indicates occurrence of groundwater at shallow depth (5 m).
4	20.0 - 35.0	1 - 34	Presence of good quality groundwater in Top Block I, IV and in Main Block III and clayey zones around other blocks.
5	> 35	34 - 112	Relatively high resistivity values near Top Block I, IV and VI and MID Block B represent presence of kankar and rock pieces; and in other blocks within study area good quality water.

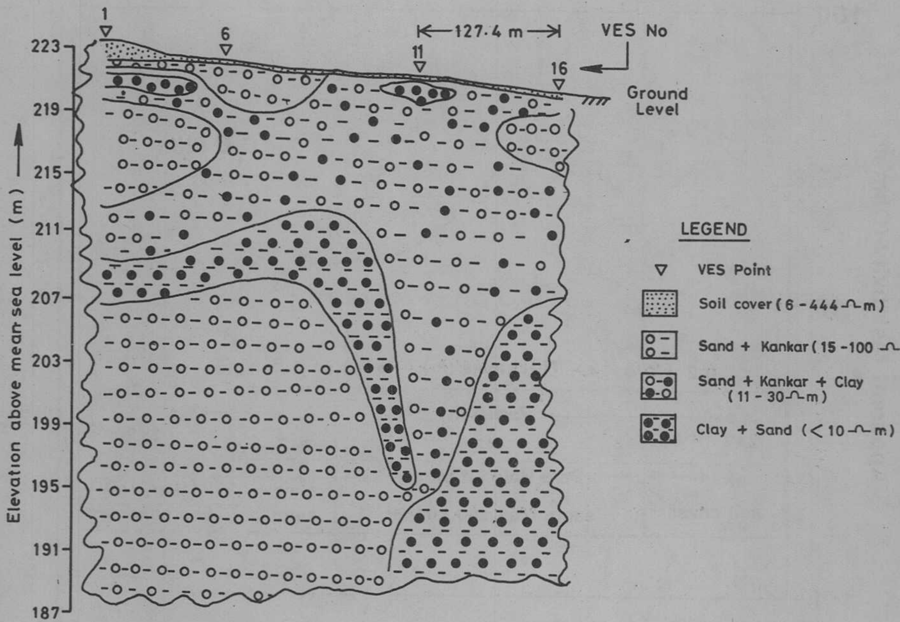

Fig. 4. Geoelectric section along 1-6-11-16 VES points in a microwatershed at IARI Farm, New Delhi.

resistivity of the formations suggests a good quality ground water.

Of the two Wenner profiles with the electrode spacing of 25 m (AB and CD; Fig. 6) the apparent resistivity of the profile 1 (AB) varies from 13 Ohm-m at B to 84 Ohm-m at observation points 2 and 4. The resistivity decreases to 12 Ohm-m in the next three observation points. These data indicate a continuity of water potential zones in top blocks. On the other hand, in profile 2 (CD), the constant apparent resistivity values of around 15 Ohm-m indicates that the aquifer matrix along this traverse is associated with more clay than along the traverse AB. This is supported by the bore hole data of tube wells located in the vicinity (Fig. 3).

Geochemical investigations of ground water in the micro-watershed

Geochemical data of ground water samples in the micro-watershed (Table 3) provide the following information. The electrical conductivity (EC) of ground water ranges from 0.93 dS m^{-1} to 1.91 dS m^{-1}, representing medium to high salinity group (C_3) of USDA classification for irrigation water. The maximum salinity is observed in ground water near VES 12.

An attempt has been made to study the interrelationship, if any, between the Longitudinal Unit Conductance (S) and the EC of ground water samples collected from the adjoining VES points. The electrical conductivity of ground water has been found to increase linearly with the S values (Fig. 7). Similar results have been obtained elsewhere (Kelly, 1977). The slope of the possible regression line between EC and S is, however, low due to higher clay content in the aquifer, due to which there is large increase in S value compared to the EC value.

The marginal variation in pH from 8.7 to 8.9 indicates that the ground water is alkaline. Carbonate ions in the water samples

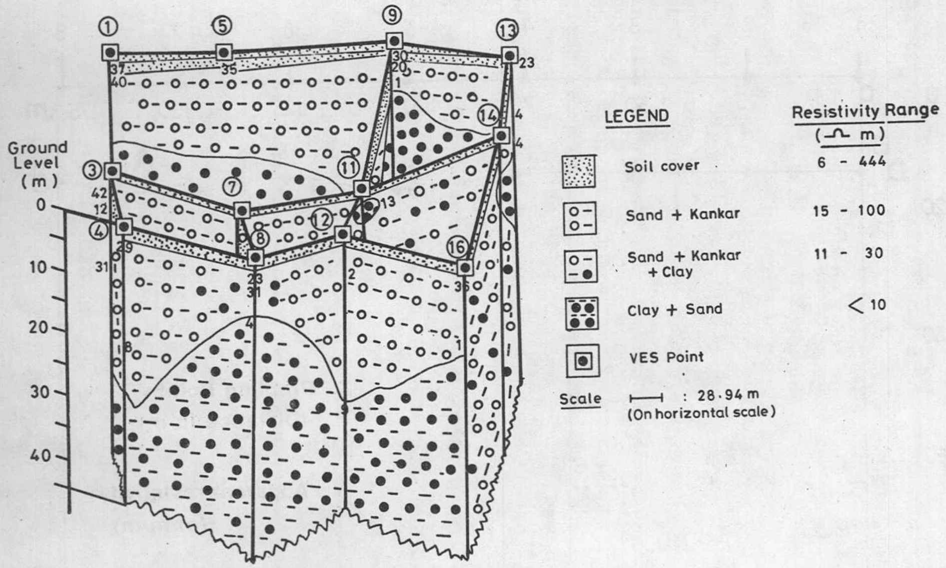

Fig. 5. Resistivity fence diagram of a microwatershed at IARI Farm, New Delhi.

are in trace amount. On the other hand, bicarbonate ions range from 6.96 to 10.44 meq L^{-1}. The highest value is for sample 3 and the lowest for 4. High bicarbonate causes alkalinity in ground water. The residual sodium carbonate varies from 0.92 to 4.24 meq L^{-1} in the samples. According to RSC irrigation water classification, samples 2 and 4 are safe. Although the RSC in other samples are slightly higher, harmful effects are not prominent because of low carbonate content (Kanwar and Kanwar, 1969; Paliwal *et al.*, 1975). In sandy loam soils under Indian conditions, the samples 1, 3, 5 and 6 are considered to be safe, although these are not suitable for use as per USDA classification (Paliwal, 1972).

The sodium absorption ratio (SAR) of ground water samples varies from 2.65 (sample 4) to 6.74 (sample 2). On the basis of irrigation water classification by USDA for SAR values, the samples may be classified under S_1; that is, low alkali hazard. The high chloride (14.3 meq L^{-1}) and sodium ion (12.8 meq L^{-1})

Table 3. Geochemical data of ground water in the microwatershed at IARI Farm, New Delhi

Tubewell location	EC (dS m^{-1})	pH	Some anions and cations (me L^{-1})							RSC (me L^{-1})	SAR
			Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3	HCO3	Cl^-		
SE of VES 4	1.5	8.8	9.5	0.1	2.0	3.4	Tr	8.1	8.9	2.7	5.8
Near VES 12	1.9	8.9	12.8	0.3	1.8	5.4	Tr	8.1	14.3	0.9	6.7
Near VES 13	1.3	8.9	7.1	0.2	0.8	5.4	Tr	10.4	8.1	4.2	4.0
NW of VES 15	0.9	8.8	4.6	0.1	2.4	3.6	Tr	7.0	4.9	1.0	2.7
35 m to VES 14	1.2	8.9	6.3	0.1	1.6	4.4	Tr	8.1	7.5	2.1	3.6
35m to VES 15	1.1	8.9	6.0	0.1	1.4	5.0	Tr	8.0	7.3	1.6	3.4

RSC - Residual Sodium Carbonate; SAR - Sodium Adsorption Ratio; TR - Trace amount.

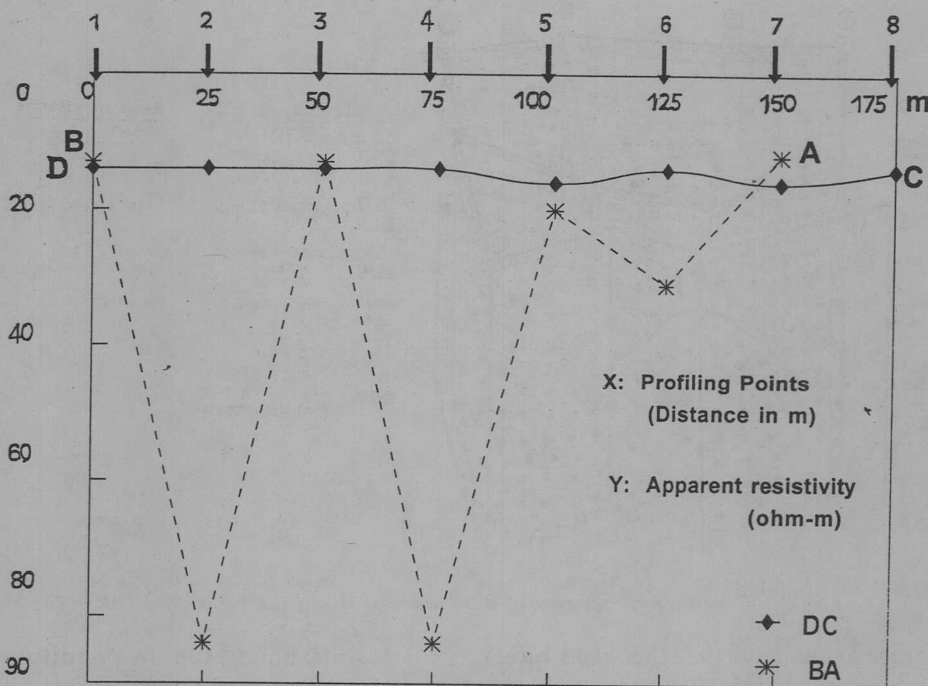

Fig. 6. Resistivity profilings along traverse BA and DC.

of the ground water samples collected from a tube well near VES 12 are responsible for relatively higher EC values. On the whole, the ground water of the watershed can be grouped under C_3S_1.

Conclusions

Five geoelectrical layers up to an average depth of 40 m below ground level have been observed in the micro-watershed. The first two layers extended from the surface to about 4 m, and indicated a mixed layer of ploughed soil with high porosity and higher moisture content at some places. The resistivity range of 12-22 Ohm-m from 8 m to 22 m form the third geo-electric layer, and indicate the presence of ground water under phreatic condition. Very low to low resistivity values (1-16 Ohm-m) of the fourth geoelectric layer indicates the presence of more clay and less sand and kankar, as well as an increase in salinity. However, other resistivity values (15-34 Ohm-m) at few other VES points for this layer indicate probable occurrence of limited good quality water. The fifth layer shows not only the presence of good quality water of limited quantity but also the possibility of saline water at some places.

Dar Zarrouk parameters (S and T values at 25 m depth) showed a combination of low S and high T at three VES points, representing water potential zones. On the basis of linearity between transmissivity and T, the VES 9, 10, 15 and 16 are expected to have lower transmissivity than the other points.

The approximate quantity of ground water from the shallow aquifer was found to be around 2.6 ha.m. The ground water has medium to slightly higher salinity, but low alkali hazard.

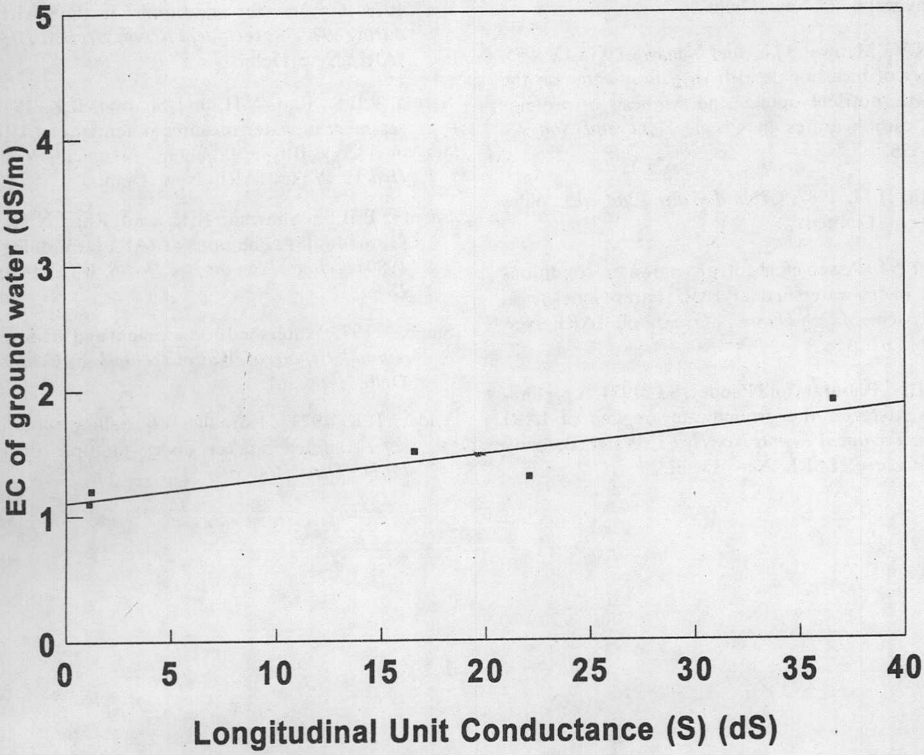

Fig. 7. Variation of EC of groundwter with Longitudinal Unit Conductance (S).

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