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Research Article

Assessment of Ground Water in a Part of Coastal West Bengal using Geo-Electrical Method

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ABSTRACT

Vertical Electrical Soundings (VES) assuming Schlumberger configuration were carried out in sixteen positions at the research farm of CSSRI, Canning Town covering an area of 13.3 ha in the coastal areas of West Bengal. Five geoelectric layers were found in the area within a depth of 50 m below ground level. The VES data from two points were compared with bore hole data to assign resistivity values to different strata. Using resistivity fence diagram, the quantity of ground water under shallow aquifer was computed as 5.0 ha-m. Chemical analysis of ground water samples showed that the quality of water was good with low salinity and low alkali hazard and could be grouped as $C_{3/2}S_{1/2}$ under USDA irrigation water quality classification.

Key words: Vertical electrical soundings, Ground water, Geochemical data

Introduction

Water is one of the most essential natural resources for sustaining life and it is likely to become critically scarce in the coming decades, due to continuous increase in its demands, rapid increase in population and expanding economy of the country. A well-planned long-term strategy is required for sustainable water resources assessment and management (Kumar *et al*., 2005). Appraisal of water resources encompasses twin approaches to explore and assess the available water in the light of its present and anticipated withdrawal and also to ensure crop planning based on available water. It is, therefore, necessary to get the information on quantity and quality of ground water at the first place. Exploration of ground water sources by geo-electrical methods is one of the inexpensive and *in-situ* methods and has been used for long (Chandrasekharan, 1988; Chandrasekharan and Singh, 1995).

Ground water occurs at shallow depth in different coastal areas of West Bengal. But the water is mostly saline and not suitable for irrigation. In some areas, there is availability of non-saline ground water in perched aquifer at a greater depth. These areas are mostly rice cultivated. Therefore, it is necessary to assess ground water in terms of its potential and quality at various depths for withdrawal of non-saline water for cultivation of rice crop. The resistivity method in combination with hydrogeological data and borehole lithology has been proved to be very successful for the same. In this study, assessment of ground water potential and quality at various depths in the research farm of Central Soil Salinity Research Institute, Regional Research Station, Canning Town was done with the help of resistivity soundings and geochemical parameters.

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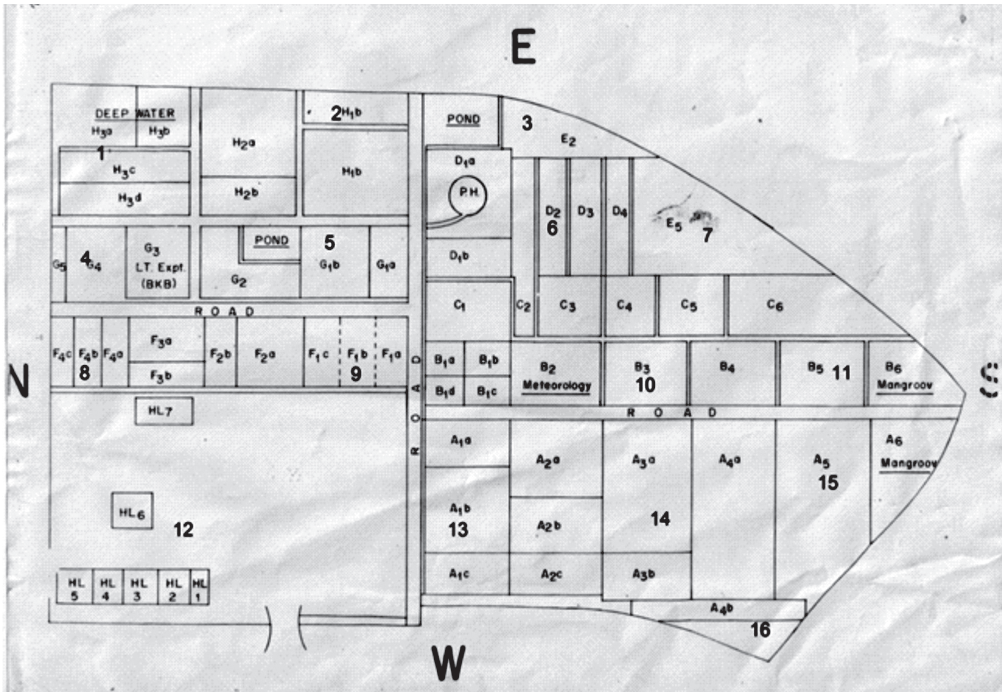

Fig. 1. Study area (CSSRI, RRS, Canning Town; 1: VES points)

Materials and Methods

Physiography and drainage

The study area (13.3 ha) is mostly under *kharif* rice. It is a plain area and is drained in the eastern part through a small channel (Fig. 1). The elevation is 3 m above mean sea level. It is an extensive alluvial tract and the general slope is towards east and south-east.

Hydrogeology

The major water bearing formation in the study area is quaternary & tertiary alluvium. Quaternary deltaic sediments composed of clay, silt and sand of various grades, gravels, pebbles etc., remain underlain by upper tertiary formations.

Ground water is restricted to weathered residuum with medium yield (5-6 lps). The fine sand and clay layers form the potential aquifers which are regionally extensive and often inter-connected. Adequate thickness of aquifers (12-60 m) is available for tapping in shallow and deep tube wells. Water table lies 0.5-6 m below the ground level. The pH of ground water is 4.5 and the chlorine content is high.

Results and Discussion

Geo-electrical investigations

Field investigations were carried out in a close grid pattern in the study area. Sixteen VES were carried out throughout the villages (Fig. 1) to understand the overall geohydrological situations. Out of these, VES 1, 2, 4, 5, 8, 9 and 12 come in the northern side and VES 3, 6, 7, 10, 11, 13, 14, 15, 16 come in the southern side of the study area. A farm road passing east-west direction divides the VES points. The field data were interpreted for true resistivity and corresponding thickness of different sub-surface horizons. To locate the potential aquifer, the Dar Zarrouk parameters were used. Ground water samples were collected from tube wells situated near different VES locations and analysed for EC, pH, Na, K, Ca, Mg, CO_3, HCO_3, Cl etc.

The interpreted (true) resistivity values along with the thickness of different formations for VES points indicate five geoelectric layers (Table 1). The iso-resistivity contour map for different depth zones were drawn separately in Surfer 9 (Fig. 2). Resistivity data of VES 1 and 12 were compared

Table 1. Resistivity data, CSSRI, Canning research farm

VES No.		Layer number					T (30 m) ohm-m^2	S (30 m) dS
		I	II	III	IV	V		
1	h	5.3	0.5	6.4	8.4	?	4023.4	0.23
	p	100.1	60	138.3	90	55.7		
2	h	5.3	1.4	8.4	8.4	?	4643.1	0.25
	p	117.6	19	194.4	91	55.2		
3	h	4.8	3.2	11.8	7.7	?	7705.3	0.31
	p	804.3	449.8	77.5	53.7	430.9		
4	h	6.1	3.1	5.7	12.6	?	5770.3	0.18
	p	257.5	335.6	236.9	130	66.9		
5	h	7	3.8	8.4	8.4	?	6032.3	0.22
	p	226.5	426.7	237.7	81.5	57.6		
6	h	7.1	2.8	10.7	6.9	?	2334.7	0.54
	p	140.3	88.4	34.1	60.3	124.1		
7	h	3	44.4	3.3	16.7	?	3419.7	0.40
	p	234.2	94.0	227.1	51.7	276.3		
8	h	4.2	9.8	6	7.5	?	19833.3	0.21
	p	234.5	322.9	422	285.3	19.6		
9	h	2.0	6.8	4.7	13.9	?	3949	0.46
	p	182.7	38.6	41.8	89.0	755		
10	h	5.9	7.1	1.0	13.5	?	1961	0.49
	p	58.5	78.1	184	53.1	62.2		
11	h	2	3	18.1	4.4	?	6505.4	0.19
	p	240.8	92.9	269.2	64.8	235		
12	h	6.4	4.5	6	10.5	?	5180.3	0.30
	p	306	293	190	63.3	39.5		
13	h	5.6	8.1	9.7	4.1	?	2134.1	0.56
	p	110.0	90.8	43.4	209.4	392.8		
14	h	6.0	8.9	2.2	10.3	?	3246.1	0.37
	p	180.9	147.2	58.3	60.9	36.2		
15	h	2	2.5	18.6	4.5	?	5810.1	0.20
	p	241	93	238.5	65	236		
16	h	4.7	4.2	7.2	11.4	?	3036.1	0.32
	p	93.5	201.1	79.5	78.7	113.1		

h in m, p in ohm-m

with the borehole lithology of adjoining tube wells. The comparison of VES 12 with borehole lithology is given below.

The true resistivity data of VES 12 show the presence of a layer of 306 ohm-m up to 6.4 m and another layer of 293 ohm-m at 10.9 m (Fig. 3). As the apparent resistivity curve drawn on the basis of field data started with 1 m half electrode spacings, the curve was extrapolated backwards to show the resistivity data for depths below 1 m to represent the soil cover. The resistivity values of 100.1-306 ohm-m up to 5.3-6.4 m indicate presence of soil cover (loamy clay) and mangrove roots. The 293 ohm-m resistivity up to 10.9 m represents fine sand. The 3rd layer with a resistivity of <190 ohm-m corresponds to fine sand with small amount of clay. In the interpreted data, the interface between 4th and 5th layers is at 27.5 below ground level (bgl) which agrees well with the borehole data. The presence of clay and small amount of fine sand in the 4th and 5th layers

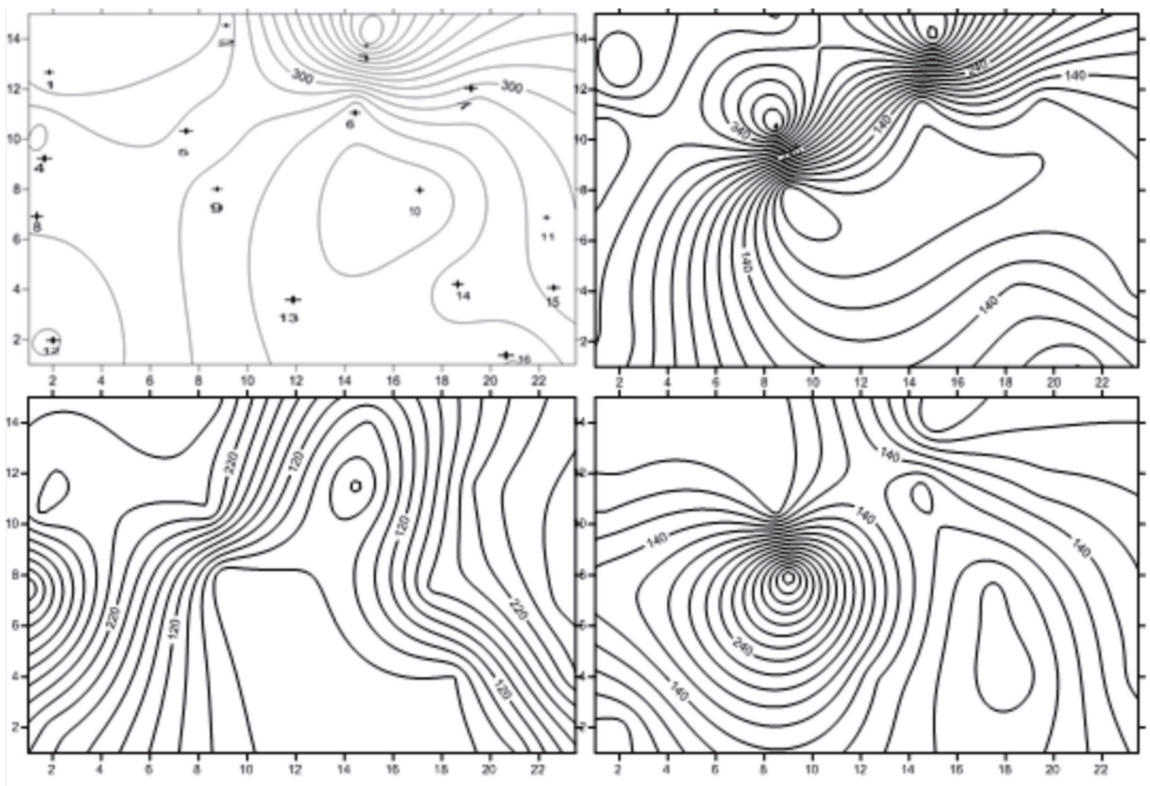

Fig. 2. Iso-resisitivity contours of geoelectric layers for depth range (m) below ground level (1) 2-7.1, (2) 4.5-16.9, (3) 7.5-27 and (4) >11.6 (+ VES points)

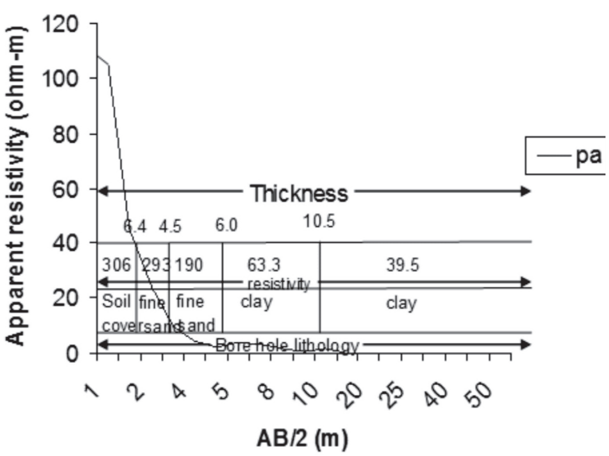

Fig. 3. Comparison of VES12 data with borehole lithology

started from a depth of 17 m bgl and extends up to >27.5 m indicates water potential zones. But from geochemical data, it was found that the ground water was mostly saline. The inferences drawn from the five geoelectric layers are presented in Table 2.

Resistivity fence diagram

The resistivity fence diagram reveals the vertical and probable lateral extension of the several lithological units. Fine sand and clay dominate most of the geoelectric layers, as is supported by borehole data and occupies about 60-70% of the total formation encountered down to a depth of 40 m bgl. This soil along with sand, clay and hard root of mangrove plants in the upper layer form a potential aquifer at shallow depth in almost all the VES points. The sand and hard clay with high resistivity (>300 ohm-m) occupy about 15-20% of the total strata down to a depth of 40 m. On the basis of resistivity data and information on borehole lithology, the resistivity range for a given subsurface materials were assigned and shown in Figs. 4 and 5. The approximate quantity of available ground water from the shallow (phreatic) aquifer (area of water bearing zone = 4.5 ha) of the investigated area (approx. 13.0 ha), using the geometry of the aquifer zone (thickness 8.0 m) and specific yield

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

Geo-electric layer	Depth below ground level (m)	Resistivity range (ohm-m)	Inference
1	2-7.1	58.5-306	Upper ploughed layer and unsaturated soil. Predominantly clayey, high resistivity of 804.3 ohm-m at VES3 is due to the presence of hard plant root. Hard layer below the puddled rice soil, contains sand and clay with relatively higher resis tivity values.
2	4.5-16.9	38.6-449.0	Lower ploughed layer and saturated soil.
3	7.5- 27	34.1-269.2	Semi weathered zone of gneisses, contains clay and fine sand at lower depth upto 20 m and clay and hard sand (kankar) with relatively high resistivity (>120 ohm-m) at higher depth upto 25 m. Occurrence of good quality of ground water throughout.
4 and 5	>11.6	19.6-130	Water potential zones. Relatively high resistivity at VES3 & 13 materials with saline to good quality ground water.

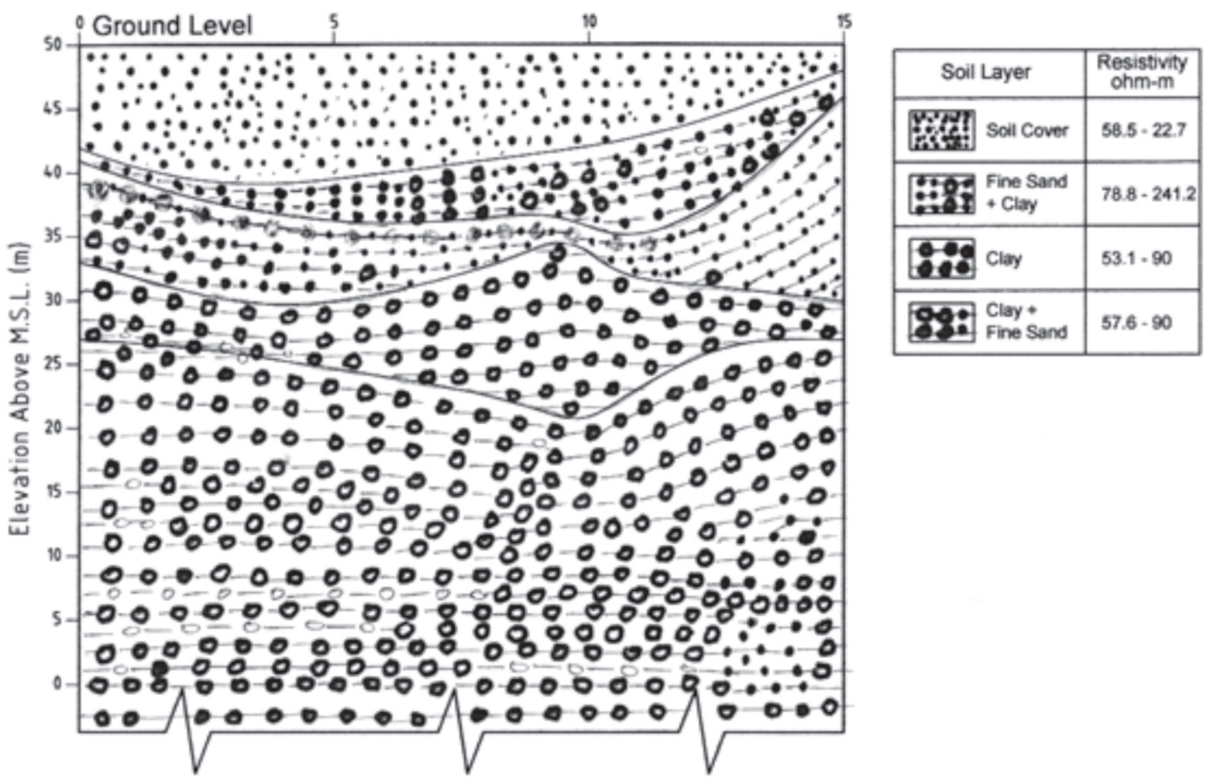

Fig. 4. Geo-electrical section along VES 1-5-10-15 of the study area

(0.2 assumed) of the formation, were worked out as 5.0 ha-m. The low to moderate resistivity of the formation particularly at a greater depth suggests a slightly saline ground water (Raut *et al.*, 2011).

Geo-electric section along traverse 1-5-10-15 VES points

Qualitative and quantitative interpretations of VES data along this traverse indicate a thin layer of formation (0-6.5m) representing the soil cover

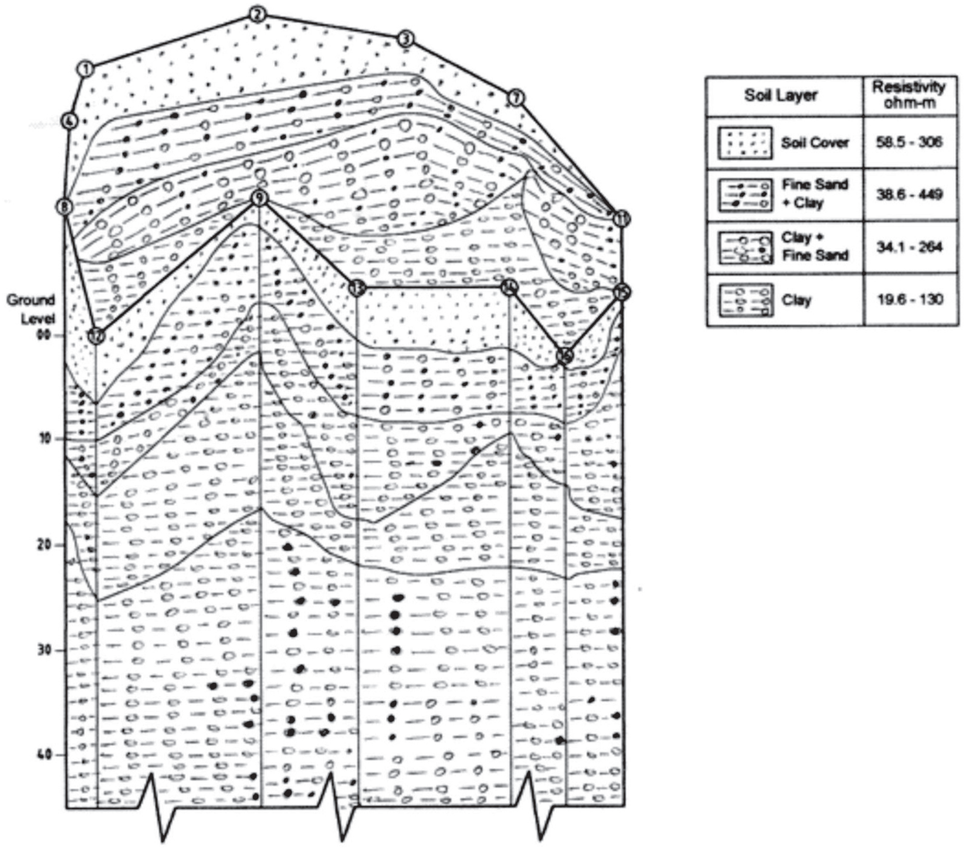

Fig. 5. Resistivity fence diagram of the study area (130: resistivity in ohm-m)

with a resistivity of 58.5-227.0 ohm-m (Fig. 4). High values of 226.5 and 241 ohm-m at VES 5 and 15 may be due to hard clay layer below the rice soil. Below this layer there is a thin layer of fine sand with low to moderate resistivity (>78.8 ohm-m). A layer of fine sand and clay exists at a depth of 7-40 m bgl with a resistivity of 53.1-241.2 ohm-m throughout the traverse which along with the previous layer forms the potential aquifer for ground water in the study area. A distinct clay and hard sand and clay layer of variable thickness (15-40 m) exist below this zone.

Geochemical investigations of ground water

The electrical conductivity (EC) of ground water ranged from 0.45 to 0.95 dS m^{-1}, representing medium to high (C_2 and C_3) salinity group of USDA classification of irrigation water. The relatively high salinity (C_3) of irrigation water near some of the VES points was possibly due the presence of saline aquifer zone (Table 3).

The pH of the water samples varies from 6.5-6.9 with majority of the samples having pH<7.0, which indicates that the ground water was acidic to neutral. Carbonates in the ground water samples were in trace amount except the tube well situated near VES2 which contained high carbonates (6 me l^{-1}). Bi-carbonate ions ranged from 8.0-17.0 me l^{-1}. The bi-carbonate content of the tube well water 5 and 6 were less than the other tube wells. High bicarbonate caused slight alkalinity in the ground water. The residual sodium carbonate (RSC) of the samples varied from 1.0 to 5.0 me l^{-1}. According to RSC irrigation water classification, samples 3, 6, 9, 10 and 11 could be safe, although RSC of other samples were slightly higher (samples 1, 2, 4, 5, 7, 8, 10), the harmful effects were not prominent because of low carbonate content. In clay loam to loam soil under Indian conditions, the samples 1, 2, 4, 5, 7, 8, 10 are also considered to be safe, although these are not suitable for use as per USDA classification.

Table 3. Geochemical data of ground water, CSSRI, Canning research farm

Tube well location	EC (dS m^{-1})	pH	Cations and anions (me l^{-1})							RSC (me l^{-1})	SAR (me l^{-1})
			Na^+	K^+	Ca^{2+}	Mg^{2+}	CO_3	HCO_3	Cl^-		
1	0.95	6.5	25	1.5	2.4	6	Tr	12	11	3.6	12.3
2	0.88	6.6	27	1.6	9	4	6	12	14	5.0	10.8
3	0.90	6.6	9	1.0	3	11.6	Tr	16	9	1.4	3.3
4	0.71	6.6	28	2.0	3	6	Tr	12	10	3.0	13.3
5	0.86	6.5	10	1.8	4	1.4	Tr	8	15	3.6	3.3
6	0.91	6.5	12	2.0	3	4.6	2	8	7	2.4	6.3
7	0.45	6.9	23	1.7	3.2	4.4	1	10	4	3.4	12.1
8	0.50	6.4	18	1.9	3.4	10.6	Tr	17	12	3.0	2.8
9	0.71	6.7	21	1.05	3	6	Tr	10	5	1.0	3.1
10	0.86	6.6	23	1.6	2	7.4	2	10	10	2.6	10.5
11	0.72	6.7	25	2.0	3	6	Tr	10	10	1.0	11.9

Tube well location: 1. Near VES16, 2. Near VES15, 3. Near VES11, 4. Near VES3, 5. Near VES2, 6. Near VES1, 7. Near VES4, 8. Near VES5, 9. Near VES9; 10. Near VES 12, 11. Near VES 8, Tr: Trace amount

The sodium absorption ratio (SAR) of ground water samples varied from 3.1-13.3 me l^{-1}. On the basis of USDA classification, the samples may be classified under S_1 and S_2 (low to moderate alkali hazards). The high chloride and sodium ion concentration (> 5 me l^{-1}) in the ground water samples were responsible for relatively high SAR values. On the whole, the ground water of the study area could be grouped under C_2S_1 $C_3S_{2/1}$.

The interrelationship between the longitudinal unit conductance (S) and the EC of ground water samples collected from the tube wells adjoining to VES points showed that EC values of ground water increase linearly with the S values (Fig. 6). Similar results were obtained elsewhere (Ezeh, 2011). The slope of the possible regression line between EC and S is low which might be due to the high clay content for which there is large increase in S compared to EC values. The correlation matrix of soil texture and Dar Zarrouk parameters shows that S values are positively correlated (r = 0.30) with clay and EC (r = 0.28) and negatively correlated with sand (r = -0.20) and silt (r = -0.24). Similarly T values were negatively correlated with clay (r = -0.42) and positively correlated with sand and silt (r = 0.13 and 0.31, respectively) (Table 4).

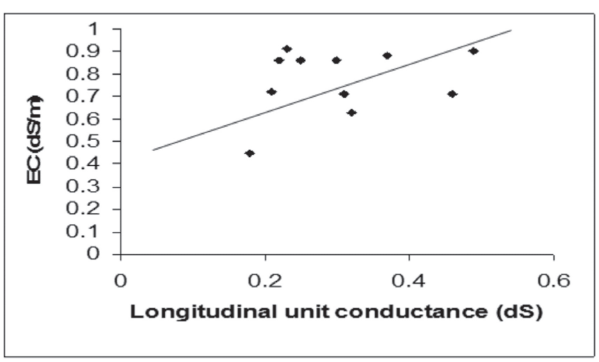

Fig.6. Variation of EC of ground water with Longitudinal Unit Conductance (S) (dS)

Table 4. Correlation matrix for geo-electrical parameters (S, T), soil texture and EC.

Variables	S (30 m)	T (30 m)
Sand (0-0.15m)	-0.20	0.13
Silt (0-0.15m)	-0.24	0.31
Clay (0-0.15m)	0.30	-0.42
E.C. (1:2)	0.28	-

Conclusions

The interpreted (true) resistivity values along with the thickness of different formations for VES points indicate presence of five geoelectric layers in the study area. The quality of ground water is more or less uniform. The approximate available water from the shallow (phreatic) aquifer (area = 15.25 ha) of the investigated area (approx. 410 ha) were worked out as 12.2 ha-m. The ground water was low to medium saline (<1.0 ds m^{-1}) for agricultural use with respect to salinity and less sodic as observed with SAR values (<13.3).

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