GROUND WATER INVESTIGATIONS USING ELECTRICAL RESISTIVITY SURVEY IN RECHNA DOAB, PUNJAB, PAKISTAN

By

Ghulam Zakir Hassan[1], Faiz Raza Hassan[2] and Saleem Akhtar[2]

ABSTRACT
Ground water quality is deteriorating in certain areas of the Punjab owing to excessive pumping by tubewells and many other factors. Electrical Resistivity Survey (ERS) is a technique which is applied to investigate the potential of fresh ground water in an aquifer. Electrical Resistivity Survey was carried out at nine locations upto a depth of 250-300 m on the left side of Jhang Branch Canal (JBC) in the vicinity of Faisalabad city in Punjab Province of Pakistan. The equipment used for ERS was ABEM, Terrameter SAS 1000 IP, SP, and Resistivity System. The resistivity data collected has been interpreted by computer-aided techniques using computer software. The Quality of ground water from 10 to 60 meter depth is marginal to saline which improves afterwards gradually upto the depth of 150 m and afterwards deteriorates at locations R-1 and R-2. At site R-3 it contains top surface material upto 12 m and afterwards there is marginal to saline water. At sites R-4, R-6, and R-9 resistivity value is in the category of Low Resistivity Zone only a small layer contains fresh quality water and the remaining three sites also fall in Low Resistivity Zone.

Key Words: Resistivity, Ground water; Aquifer, Quality; ERS; Rechna Doab, Punjab, Faisalabad, Pakistan.

1. Introduction

Faisalabad is the third largest city of Pakistan with a population of 6.047 M and is the hub of industrial activities in the country. Ground water underlying the city is brackish and water is transported by means of underground piping network from the nearby aquifer near the Chenab River on Western side of the city mainly for drinking purposes. Already a well field is working since 1992 at a discharge capacity of 1, 55,351 m^3 / day on the Western side of Jhang Branch Canal (JBC) near the village Rajoa. Recently a new well field with an anticipated pumping capacity of 180,000 m^3 / day with funding from JICA along left bank of JBC is almost near commissioning. In addition to these pumpings, the area surrounding the city is agricultural area and private farmers tubewells are also pumping ground water to meet with the crop water requirements.

Faisalabad Development Authority (FDA) has launched a housing scheme namely "**FDA City Housing Scheme**" to meet the housing demand for ever increasing population of Faisalabad. The housing scheme is located on Faisalabad-Sargodha road near motorway (M3) interchange at Faisalabad spreading over an area of 1,256 acres. FDA is interested to install tubewells along the Jhang Branch Canal near RD 209-216 of proposed capacity of 20,000 m^3 / day to meet the water requirements of this new housing scheme. Keeping in view the socio-environmental impacts of the existing well field it was deemed imperative to get the seepage and ground water investigations carried out before installation of the proposed well field. Accordingly, Irrigation Research Institute (IRI) of Punjab Irrigation Department was assigned the job. Main objective of the study was to assess the possibility of development of environment friendly well field and safe abstraction of ground water for water supply to FDA-City housing scheme. Current study on performance of Electrical Resistivity Survey (ERS) in the field has been accomplished as a part of the main study on ground water investigations.

Some uses of ERS method in ground water are: determination of depth, thickness and boundary

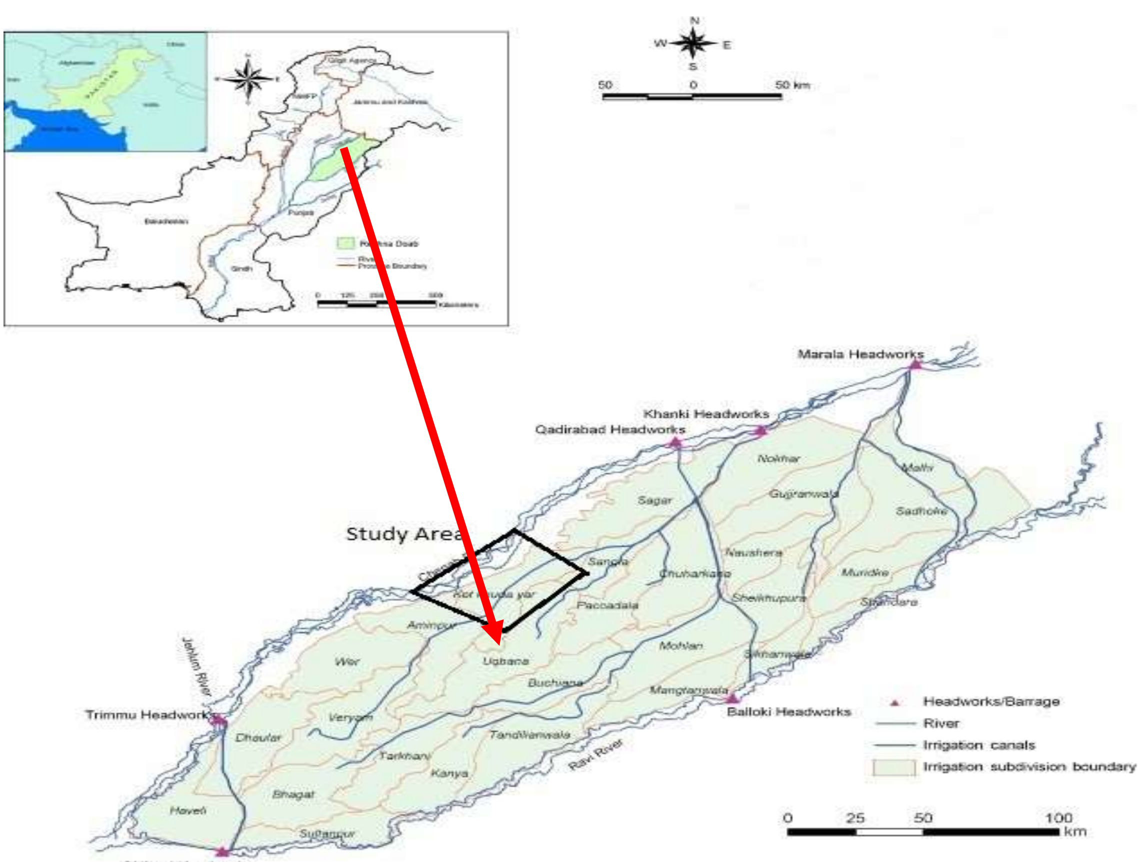
---

1. Director, Irrigation Research Institute (IRI), Government of the Punjab, Irrigation Department, Library Road Lahore, 54000, Pakistan. Corresponding author's e-mail: zakirjg@gmail.com
2. Assistant Director, Irrigation Research Institute (IRI), Government of the Punjab, Irrigation Department, Library Road Lahore, 54000, Pakistan. Corresponding author's e-mail: faizrazahassan@gmail.com

of an aquifer, determination of interface of saline water and fresh water, porosity of aquifer, hydraulic conductivity of aquifer, specific yield of aquifer and contamination of ground water **CHOUDHURY, et al (2001).** In recent years many investigations have revealed that in certain areas of the Punjab, the drinking water quality is significantly deteriorated with respect to certain constituents such as faecal coliforms, pesticides, nitrates, fluorides and chromium by **PROF. DR. JAVAD. A. AZIZ.**

2. Study Area

Study area falls in the Rechna Doab (the land between river Ravi and Chenab). The Rachna Doab, as a whole, is an inter-fluvial area and lies between longitudes 71.48' E to 75.20' E and latitude 30 to 32.51'. Rachna Doab covers a gross area of about 2.97 million hectares which is mainly under irrigated agriculture and falls in the rice-wheat and wheat-sugarcane agro-ecological zones of the Punjab Province. It covers a vast canal network upto distributaries and minors. The Rechna irrigation system consists of Lower Chenab Canal (LCC), Upper Chenab Canal (UCC), Bomban–wala Ravi Badian Depalpur (BRBD) Canal, Marala-Ravi (MR) Link and Trimu-Sidhnai (TS) Link canal. Agriculture is the major economic activity with Kharif and Rabi as two crop seasons. The kharif season extends from April to October which covers monsoon season; Cotton, Rice, Sugarcane and Maize are grown during this season of the year whereas Rabi which is dry and prevails from September to March; wheat is main crop of this season **ZAMIR-UDDIN KIDWAI, (1962).** Climate of Rechna Doab is characterized by large seasonal fluctuations of air temperature and rainfall. Climate of Rechna Doab is characterized by extremely hot in summers and mild in winters. The summers are long and hot, lasting from April through September, with maximum air temperature ranging from 21°C to 49°C. Winter lasts from December through February, with maximum air temperature ranging from 25°C to 27°C during the day and sometimes falling below zero at night. The spring and fall months are generally limited to March and October. The monsoon rain occurs from mid-July to mid-September caused by winds arising from the Bay of Bengal whereas the winter rains normally originate from the Arabian Sea. Annual precipitation is about 370 mm. The monsoon accounts for about 75% of annual rainfall. Location of study area is shown in Figure-1.



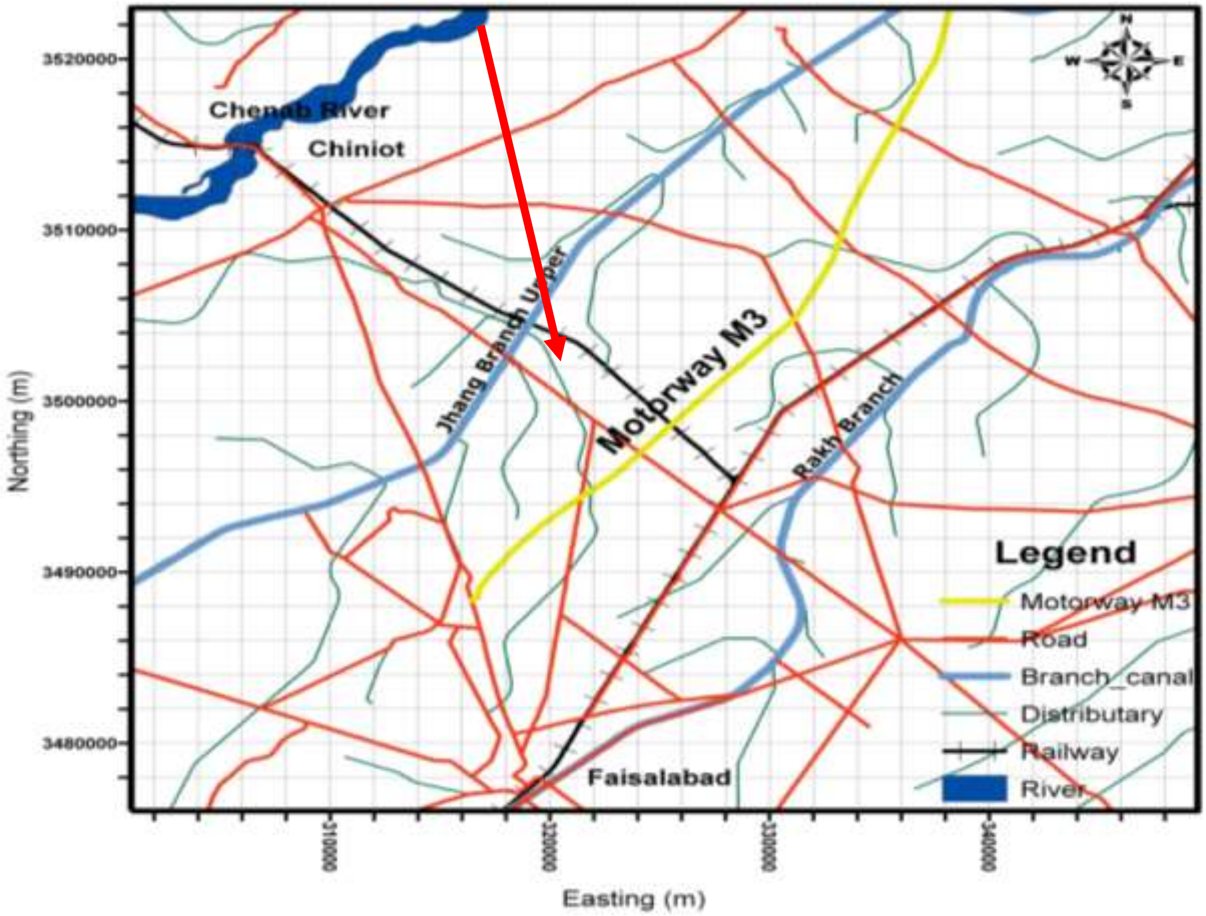


Figure-1: Location of Study Area in Rachna Doab

3. Literature Review

The electrical resistivity of an alluvium is related largely to the water content, the ground water salinity and the clay content. Below the water table, the water content is controlled by the porosity and hence, by the lithology. In the case of sand and silts the porosity will depend on degree of sorting and, to a lesser extent, the angularity of the grains and the degree of compaction. Clays show low resistivity values because of the ability of the clay minerals to attract ions and water. **Emenike**, **(2001)** tested the ground water potential and a correlation of the curves with the lithologic log from a nearby borehole and suggested that the major lithologic units penetrated by the sounding curves were laterite clay sandstone and clay**.** The sandstone unit, which was the aquiferous zone, had a resistivity range between 500 ohm-m and 960 ohm-m and thickness in excess of 200 m. The option of a particular method is governed by the nature of the terrain and cost considerations. Contamination frequently reduces the electrical resistivity of fresh water due to increase of the ion concentration by **FROHLICH, et al (2002).** Conversely, as resistivity methods are used, constraint can be expected if soil inhomogeneties and anisotropy are offered by **MATIAS, (2002).** Electrical sounding method provides an inexpensive method for characterizing the ground water conditions of the region. ERS tests also revealed three sub-surface geo-electric layers consisting of surface layer (top soil), alluvium layer and saturated (bottom soil) layer by **ARSHAD, et al (2007).** ERS technique, using resistivity meter, is effective to study ground water conditions and to assess the subsurface geo-electrical layers by **OSEJI, et al (2006).** The geo-electrical method (ERS technique) has been used successfully for investigating the ground water potential and its quality in different lithological settings because the instrumentation is simple, field operations are easy and the analysis of data is economical and less tedious than other methods by **EKINE, et al (1996).**

Low Resistivity Zone 0-30 ohm-m, containing clay / silt or alternate layers of clay and sand saline water (expected EC above 1500 µ S / cm). Medium Resistivity Zone 31 - 100 ohm-m containing alternate layers of clay and sand with fresh water (expected EC below 1500 µ S / cm). High Resistivity Zone above 100 ohm-m containing dry strata above water table by **(WAPDA), (2008**). Resistivity < 15 ohm-m, admixture of fine sand, clay and silt with brackish quality of water. Resistivity 15 - 25 ohm-m fine to medium sand intermixed thin silty clay containing marginal to saline water. Resistivity > 25 ohm-m medium to coarse sand or kankers intermixed thin silty clay layers containing fresh quality water by **IRI, (2012)**. The aquifers having different ground water salinities were classified into fit, marginally fit and unfit for irrigation purpose. The ground water quality in aquifer having resistivity more than 45 Ω m is safe for irrigation purpose, between 25 to 45 Ω m is marginally fit and resistivity less than 25 Ω m is unsafe for irrigation purpose. The interpreted subsurface hydrogeological conditions were classified into three resistivity zones by **SIKANDAR, et al (2008).**

With the help of ERS technique fresh water layers could be targeted for drilling a well upto the lower end of these layers to avoid unnecessary drilling. The thicknesses of these layers also guide us for well site selection at a point, which has bigger thickness within the land holding of the farmers. This technique is a non-destructive and useful method to detect depth and thickness of various subsurface geological formations and the ground water quality within these formations of the layers by **SIKANDAR, et al (2010).** The transmissivity T values calculated from the Vertical Electrical Survey (VES) results range from 0.48 to 19.50 m^2 / day while the equivalent obtained from pumping test vary from 1.07 to 33.74 m^2 / day by **OKORO, et al (2010).** The use of electrical resistivity survey for assessing the ground water quality and aquifer potential has increased over recent decades in the world due to rapid advances in geophysical investigations by **LASHKARIPOUR, et al (2005).**

4. PERFORMANCE OF TESTS IN FIELD

ERS were carried out in the field at nine locations to ascertain the geo-physical features of the aquifer. Besides, ERS, boreholes were drilled at some locations to verify the results of ERS. Similarly, ground water quality from existing tubewells in the study area was checked at the spot for comparison upto certain depth. Locations of these sites are shown in Figure-2 and basic features are given in Table-1.

Table-1: Basic Features of ERS Test Sites

Sr. No	ERS Site No.	Location Address	Northing (m)	Easting (m)	Depth of Investigation (m)
1.	R-1	Left Side of JBC at RD 212	3503788.9	318722.8	250
2.	R-2	Left Side of JBC at RD 208+600	3504726.3	319271.3	250
3.	R -3	Near Railway station Burj Mandi	3504272.5	319542.2	250
4.	R -4	South East side (about 300 ft) of Chak No 20JB Khankay	3505659.8	323460.6	300
5.	R -5	Chak No 23/JB Noon Bhattian,	3502793.5	321499.2	300
6.	R -6	Chak No 109/JB, Nilian wala,	3497271.3	322770.8	300
7.	R -7	Chak No 25/JB Sathio wala,	3499332.0	323014.8	300
8.	R-8	Chak No 157/JB Gojra,	3503470.3	327827.5	300
9.	R-9	Chak No 24/JB Lahorian wala,	3503402.6	324597.4	300

Electrical Resistivity method can easily be employed for subsurface investigations where electrical resistivity contrast exists among the subsurface formations. Considering the variable electrical properties of subsoil , the technique of electrical resistivity survey makes use of measuring the current and potential differences of different subsoil material at the surface. Generally, current conduction is electrolytic in the soils and rocks containing interstitial fluids. The resistivity is controlled by porosity , water content , as well as the quantity of dissolved salts. Since clays are capable of storing electrical charges so their behavior is electronic and electrolytic.

Performing Electrical Resistivity Survey in Study Area at Different Site

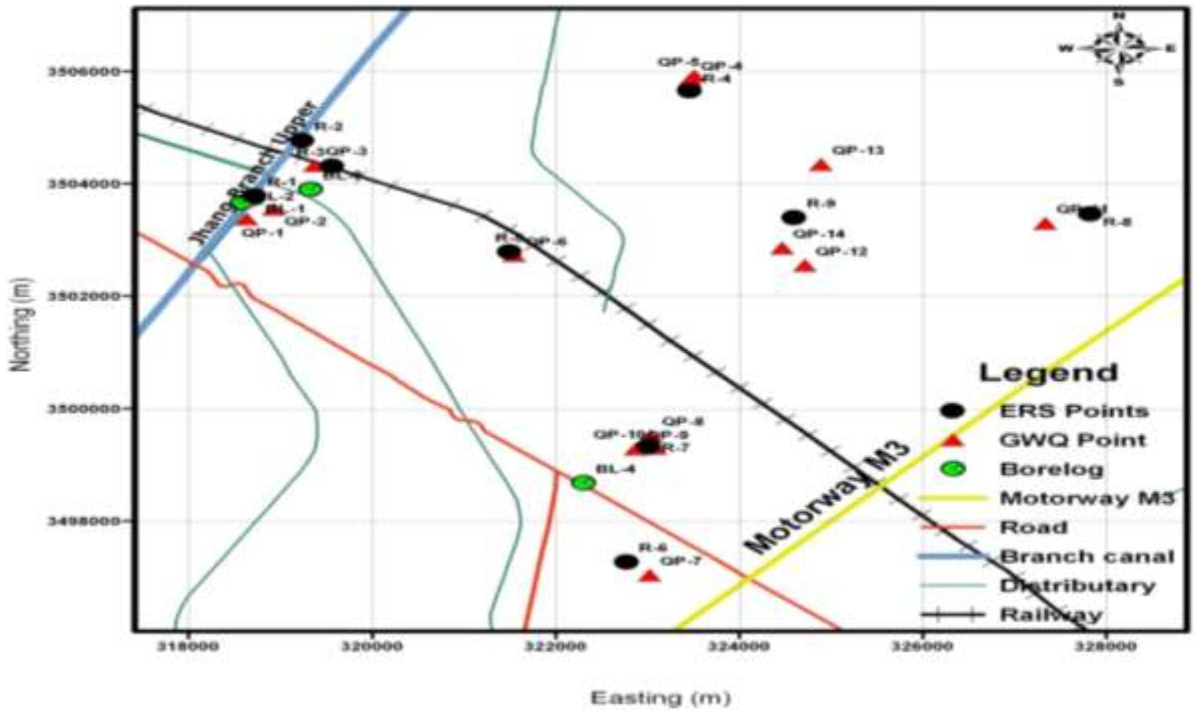


Figure-2: Location of test sites in study area

Thus the resistivity of soils and rocks depends upon the Resistivity of contained electrolyte and clay minerals and is inversely related to the porosity and degree of saturation of the formation . Therefore, Resistivity of soils and rocks vary considerably not only from formation to formation, but also within the same layer.

In particular the Resistivity variations can be large in unconsolidated sediments. It has generally been observed that the Resistivity increases progressively from fine grained to coarse grained material in the order which is clay, silty clay , clay silt , silt, sandy silt, silty sand , sand gravels and boulders **IRI, (2012)** .

The Resistivity increases progressively from fine grained to coarse grained material in the order which is clay, silty clay , clayey silt , silt, sandy silt , silty sand , sand gravels and boulders. During resistivity survey , commutated direct or very low frequency (less than 1Hz) current is introduced into the ground though two current electrodes A and B inserted in the ground surface as shown schematically in Figure-3.

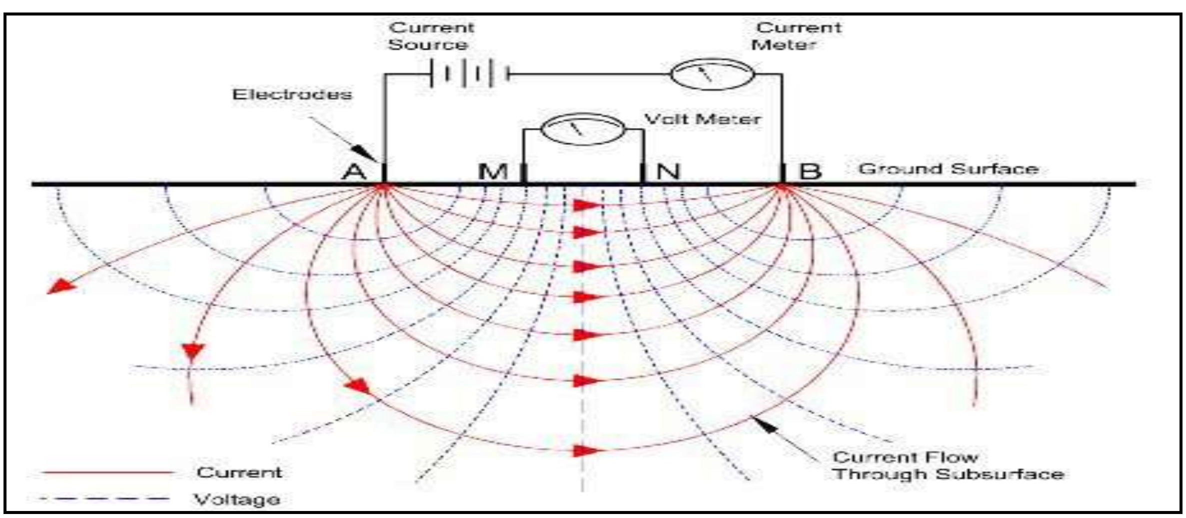


Figure-3: Schematic Schlumberger Electrode Configurations

Schlumberger Electrode Configuration was used during this study because it is less laborious and provides good resolution of horizontal layer and good depth sensitivity by **WARD, S. H. (1990).** The average potential gradient measured between M and N is a close approximation to the potential gradient at center of the array by **Lashkaripour, (2003).** The potential electrodes M and N are inserted in the ground between the current electrodes A and B. The four electrodes can be arranged in any of the several possible patterns and these patterns are called Electrode configurations. By measuring the current (I) between the two current electrodes A – B and the associated potential differences (V) between the potential electrodes M – N , the resistivity (R) is computed by the following well known Ohm's Law as under:-

$$R = K * \frac{V}{I} \qquad (1)$$

Where, "**K"** is called the geometric factor of the electrode arrangement. In homogeneous ground this is the true ground resistivity, but in anisotropic and non-homogeneous ground, it represents a weighted average Resistivity of the formation through which the current passes. Since subsoil is normally heterogeneous and anisotropic the resistivity value computed from equation (1) is called apparent resistivity and is denoted as (ρa) **SUBBA RAO, N. (2002).** Therefore,

$$\rho a = K * \frac{V}{I} \qquad (2)$$

Where:

ρa	=	Apparent resistivity in ohm-meter
K	=	Geometric factor for individual electrode arrangement
V	=	Potential difference in milli volts
I	=	Current passing through ground in milli amperes

The apparent resistivity values are obtained from various depths from surface by extending the current and potential electrodes from its centre in a straight line. The spacing between the electrodes is maintained according to the specific configuration used. Schlumberger electrode configuration is commonly used. In configuration, distance between the current electrodes is very large compared with the distance between the potential electrodes. Lateral inhomogenities are easily identified in this configuration and it requires less electrode spacing at the surface to achieve the required depth of investigation as compared to other configurations Resistivity-measuring equipment was used for recording current and potential difference in the field. Schlumberger electrode configuration was used for the survey.

In case of Schlumberger array, the distance of the current and potential electrodes from the center, which are referred as AB / 2 and MN / 2 respectively, characterizes the array. MN / 2 is always kept sufficiently small relative to AB / 2. The average potential gradient measured between M and N is a close approximation to the potential gradient at the center of the array.

In case of Schlumberger electrode configuration, the apparent resistivity is computed as under:-

$$\rho a = \pi \ x \ \frac{\left\{ \left(\frac{AB}{2}\right)^2 - \left(\frac{MN}{2}\right)^2 \right\}}{MN} \ x \ \frac{V}{I} \qquad (3)$$

The resistivity field curves are obtained by plotting the apparent resistivity values against depths on a bi-log graph paper. After smoothing the plotted curves all the field data is registered to computer. The interpretation of sounding is done with the help of computer and direct interpretation software. The resistivity sounding data collected from the area is interpreted by computer-aided techniques using computer software. The layer models are calculated by an iterative procedure. During each iteration, the model parameters are adjusted and the deviation of the corresponding curve from the measured curve is checked. The deviation is defined by the RMSE (root mean square error), which is displayed after each iteration. At the end of calculations, the model, which results in the smallest error, is plotted showing layer's true resistivity and corresponding thickness.

5. RESULTS AND DISCUSSION

5.1 INTERPRETATION OF ERS DATA

The measured resistivity when subjected to evaluation process yields different sub-surface geo-electrical layers. These geo-electrical layers need a correlation with the sub-surface hydrogeological conditions for interpretation. Transformation of geo-electrical layers into hydrogeological zonings are essentially based on the information obtained from test holes, tube wells and other data of previous investigations conducted in similar areas. The evaluated resistivity values of the sub-surface layers and the assumed formation factor in the area has been used to estimate electrical conductivity of the ground water contained in the subsurface aquifer zones. Interpretation of ERS field data Distance versus apparent resistivity using Computer Software are shown in Figure-4. After correlating all the available information, the interpreted sub-surface hydrogeological conditions at each sounding location are presented in the form of columnar section in Figure-5.

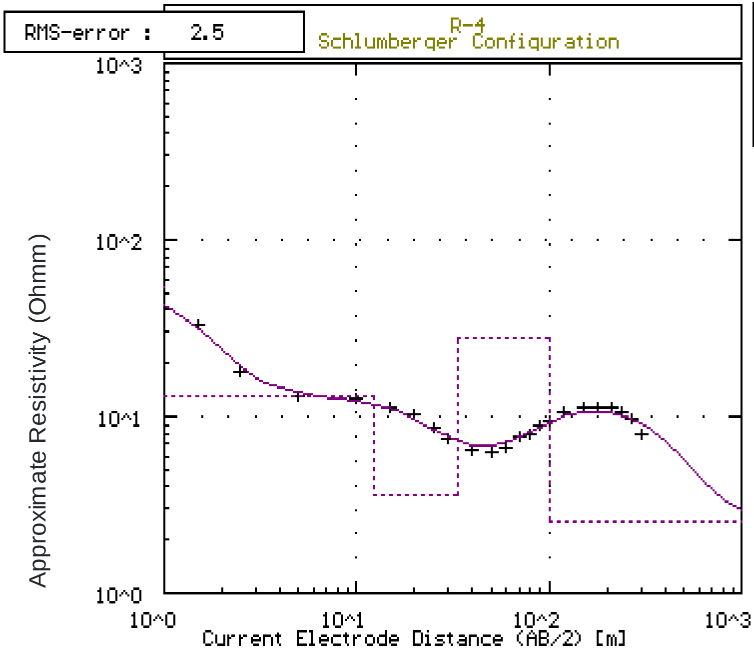
Table-2: Resistivity Values versus Lithology

Sr. No	**Resistivity Zone**	**Resistivity Value Ohm-meter**	**Interpretation Lithology**
1.	Zone above water Table	Haphazard	Surface Materials
2.	Medium Resistivity Zone	≥ 25	Medium to coarse sand or Kankers Intermixed thin Silty Clay layers
3.	Low Resistivity Zone	≈ 15- 25	Fine to medium sand Intermixed with thin Silty layers
4.	Very Low Resistivity Zone	< 15	Admixture of fine sand, clay and silt

Source: **IRI, (2012)**

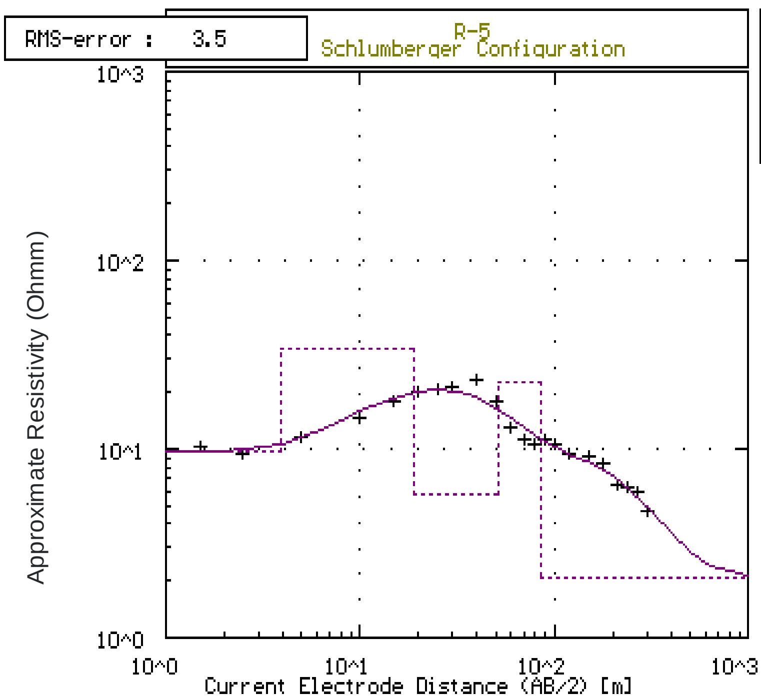
Interpretation of ERS field data Distance versus apparent resistivity using Computer Software at some locations is given below:-

Site R-4 (Reference figure-2)



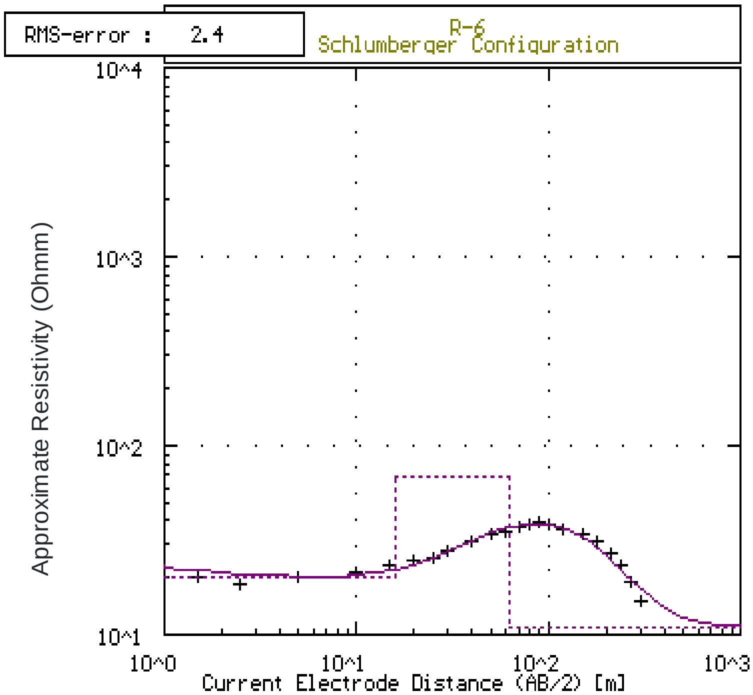
No	Res	Thick	Depth
1	55.0	0.7	0.7
2	12.9	11.5	12.2
3	3.6	21.3	33.5
4	28.1	66.1	99.6
5	2.5	-.-	-.-

Site R-5 (Reference figure-2)



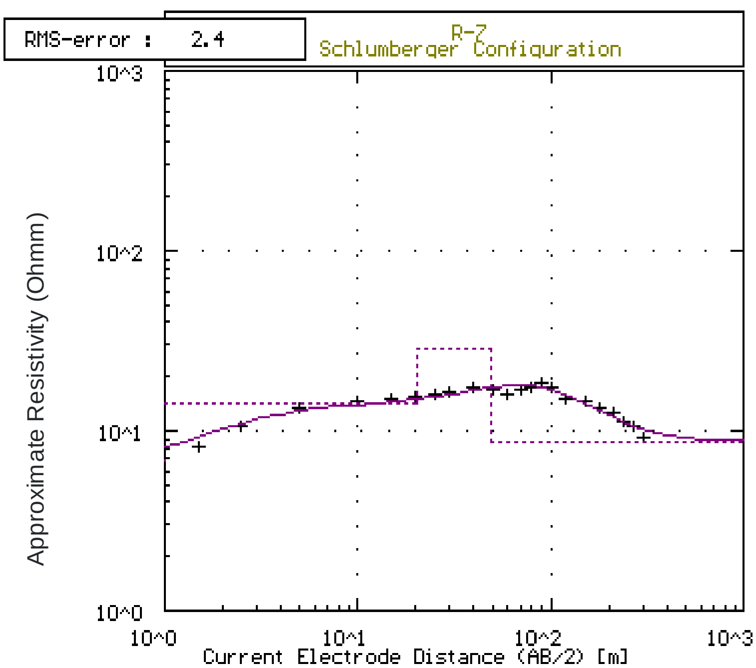
No	Res	Thick	Depth
1	9.6	3.9	3.9
2	33.9	14.8	18.7
3	5.7	32.3	51.1
4	22.9	33.5	84.6
5	2.1	-.-	-.-

Site R-6 (Reference figure-2)



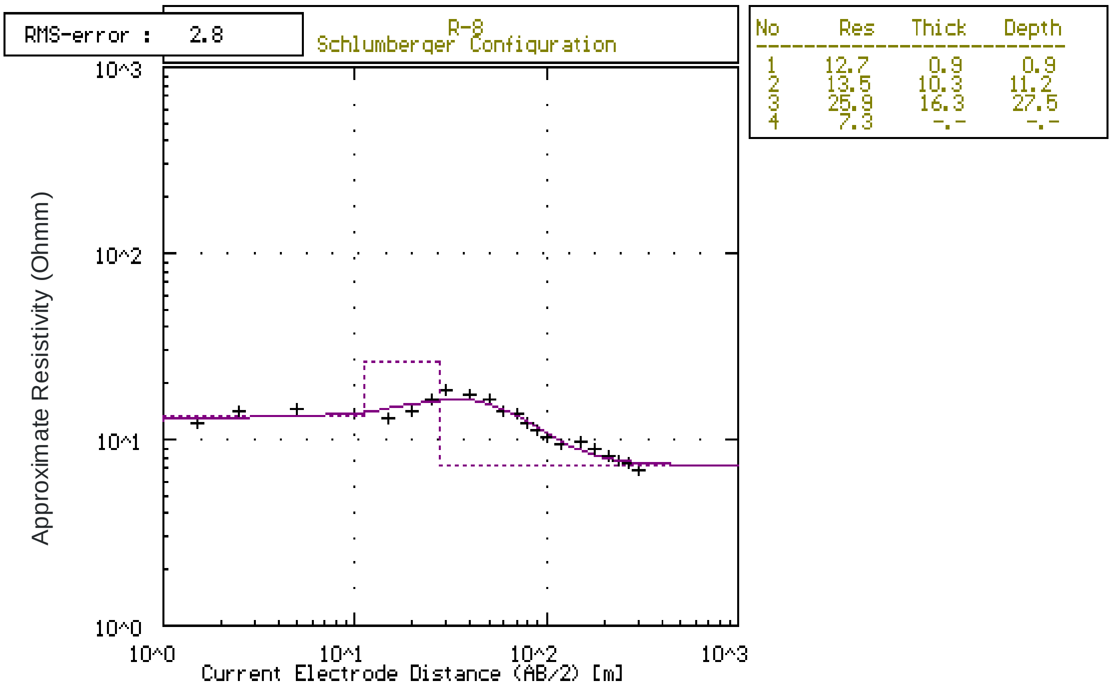
No	Res	Thick	Depth
1	23.0	0.7	0.7
2	20.0	15.5	16.2
3	68.5	45.7	61.8
4	10.8	-.-	-.-

Site R-7 (Reference figure-2)



No	Res	Thick	Depth
1	6.9	0.6	0.6
2	14.3	19.6	20.2
3	28.9	28.7	48.9
4	8.7	-.-	-.-

Site R-8 (Reference figure-2)



Site R-9 (Reference figure-2)

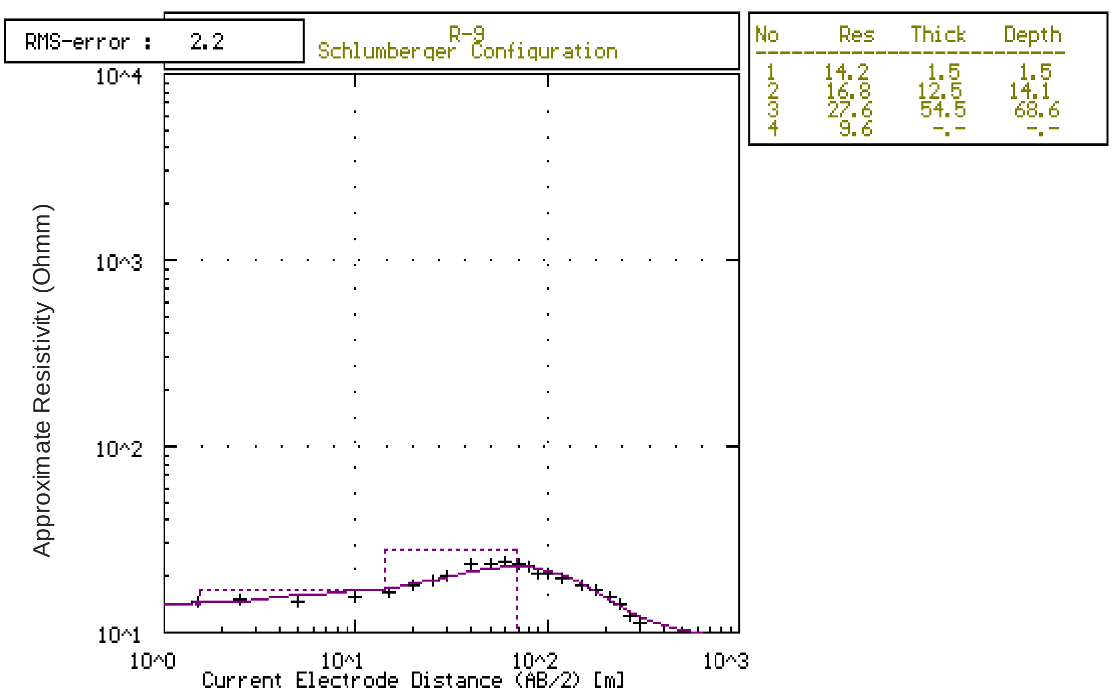


Figure-4: Distance vs Apparent Resistivity

Resistivity values for different depths for all nine test locations are as under:-

Table-3: Summary of True Resistivity Values

ERS Site	**Depth (meter)**	**True Resistivity Ohm-meter**	**ERS Site**	**Depth (meter)**	**True Resistivity Ohm-meter**
R-1	0 – 10 10 – 60 60 – 150 150 – 250	21 23 49 25	R-6	0.00 – 0.70 0.70 – 16.2 16.2 – 61.8 61.8 – 300	23 20 68.5 10.8
R-2	0 – 10 10 – 60 60 - 150 150 – 250	21 23 49 25	R-7	0.00 – 0.60 0.60 – 20.2 20.2 – 48.9 48.9 – 300	6.9 14.3 28.9 8.7
R-3	0.00 – 12 12.00 – 250	18 25	R-8	0.00 – 0.90 0.90 – 11.2 11.2 – 27.5 27.5 – 300	12.7 13.5 25.9 7.3
R-4	0.00 – 0.70 0.70 – 12.2 12.3 – 33.5 33.5 – 96.6 96.6 – 300	55 12.9 3.6 28.1 2.5	R-9	0.00 – 1.5 1.5 – 14.1 14.1 – 68.6 68.6 – 300	14.2 16.8 27.6 9.6
R-5	0.00 – 3.90 3.90 – 18.7 18.7 – 51.1 51.1 – 84.6 84.6 – 300	9.6 33.9 5.7 22.9 2.1			

At R-1 site the resistivity of top surface material is slightly less which gradually increases with depth and at the depth of 60-150 m the value of resistivity is 49 ohm-meter containing fresh layer of water and same situation has been observed at site R-2. At location R-3 the value of resistivity at 12-150 m depth is 25 ohm-meter with marginal to saline water. At site R-4 the value of resistivity gradually decreases from top surface upto depth of 33m and increases after that upto the depth of 96 m where the resistivity value is 28 ohm-meter containing fresh layer of water. At site R-5 the value of resistivity at the depth of 4-18 m where the resistivity value is 34 ohm-meter containing fresh layer of water and after that gradually decreases. At location R-6 the value of resistivity gradually decreases at top surface and increases at the depth of 16-62 m where the resistivity value is 68 ohm-meter containing fresh layer of water. At site R-7 the value of resistivity gradually decreases at top surface and increases at the depth of 20-48 m where the resistivity value is 28 ohm-meter containing fresh layer of water. At site R-8 the value of resistivity at the depth of 11-27 m where the resistivity value is 25 ohm-meters with marginal to saline water. At site R-9 the value of resistivity at the depth of 14-68 m where the resistivity value is 27 ohm-meter containing fresh layer of water. Overall the quality of ground water from 10 to 60 meter depth is marginal to saline which improves afterwards gradually upto the depth of 150 m and afterwards deteriorates at locations R-1 and R-2. At site R-3 it contains top surface material upto 12 m and afterwards there is marginal to saline water. At sites R-4, R-6, and R-9 resistivity value is in the category of Low Resistivity Zone only a small layer contain fresh quality water and the remaining three sites also fall in Low Resistivity Zone. At ERS points R-5, R-6 and R-9 resistivity value is sufficient enough to fall in the category of Low Resistivity Zone otherwise at remaining three points ER value is13 – 15 Ohm-m which is below 15 but still these three segments fall in the low resistivity zone category because electrical noise due to saline regime of the area has suppressed the values at these points. Interpreted lithology for this zone is predominantly admixture of fine sand, clay and silt containing brackish quality of water. The thickness of Very Low Resistivity Zone increases from R-4 to R-8 and there is slight decrease at R-9.

On the basis of True Resistivity which is obtained by the use of computer software in Figure-4 and in Table-3 is used to drawn Columnar View of Subsurface Lithology as shown in Figure-5.

The depth to water table in the study area is generally 3-7 meters as measured from observation well. With the help of computer software ERS data also indicated that depth to water table in the project area is generally more than 3 meters. The results obtained from interpretation of ERS data using computer software at different sites have been compared with borelog lithology obtained to some extent. To have a comparative idea for comparison purpose by drilling the test wells upto about 20 m depth indicate good comparison as depicted in Figure-6. Similarly, results of ground water quality tested at different locations near ERS test points are given in Table-4.

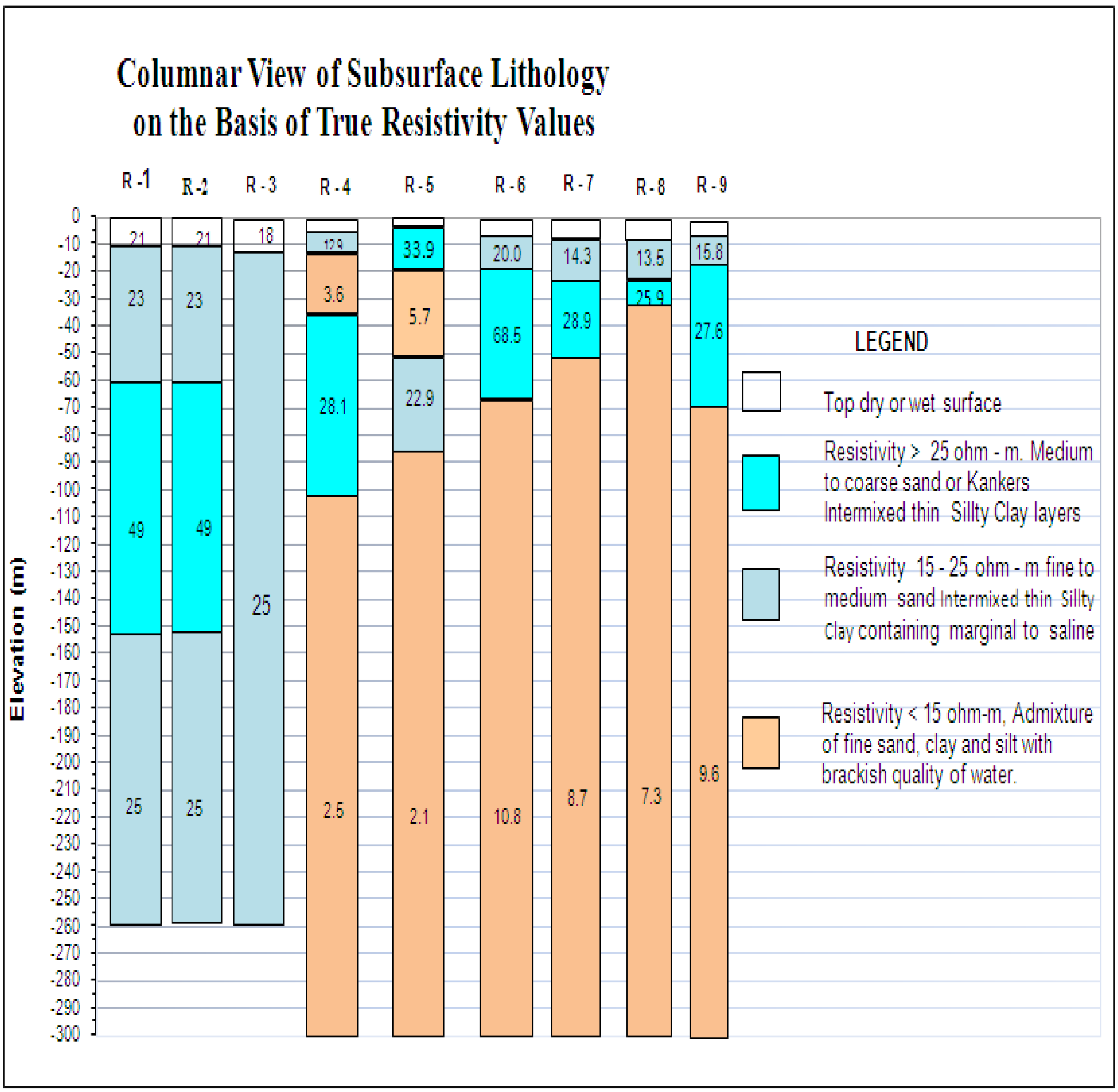


Figure-5: Sub-surface Lithology by Resistivity Surveys

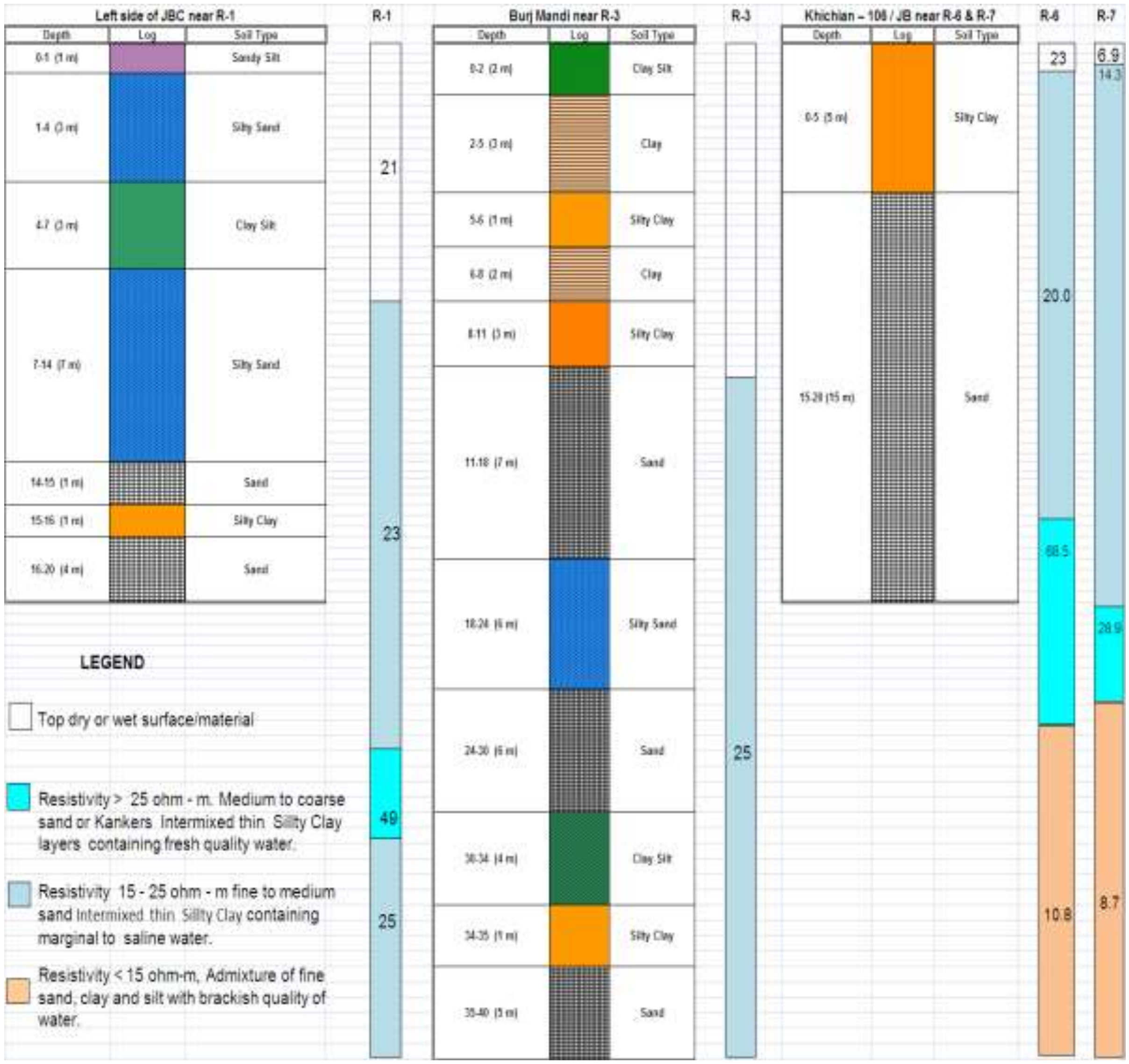


Figure-6: Comparison of Borelog Analysis with ERS Results

Table-4: Ground water Quality Measured in field near ERS Sites

Sr. No	Types of Bore	Address	ERS Site	TDS (ppm)	EC (us/cm)	Status
1	Tubewell	Dera Ch. Mustaq	Near R-1	527	823	Marginal to saline water
2	Hand pump	Dera Ch. Mustaq	Near R-1	598	934	Marginal to saline water
3	Hand pump	Burj Mandi	Near R-3	577	734	Marginal to saline water
4	Hand Pump	Dera Mestri Gulzar Ahmed, Chak No. 20 JB Khanki,FSD	Near R-4	1180	1844	Brackish quality of water
5	Tubewell	Dera Mestri Gulzar Ahmed, Chak No. 20 JB Khanki, FSD	Near R-4	1070	1672	Brackish quality of water
6	Tubewell	Dera Abid Chadhar, Chak No 23 JB, Noon Bhattian	Near R-5	885	1383	Marginal to saline water

Sr. No	Types of Bore	Address	ERS Site	TDS (ppm)	EC (us/cm)	Status
7	Tubewell	Ch.Kala Guajr, Chak No.109 JB, Nilainwala	Near R-6	1160	1813	Brackish quality of water
8	Tubewell	M.Azam Bhota, Chak No. 25 JB Sathowali, FSD	Near R-7	810	1266	Marginal to saline water
9	Tubewell	Saeed Ahmed, Chak No. 106 JB Khachian,	Near R-7	1060	1656	Brackish quality of water
10	Hand pump	Chak No. 25JB Sathowali, Brick Klin, Faislabad	Near R-7	1123	1755	Brackish quality of water
11	Hand pump	Chak No.157 RB Gojra, Faisalabad	Near R-8	1750	2734	Brackish quality of water
12	Tubewell	Chak No. 24 JB Lahorian,	Near R-9	1340	2094	Brackish quality of water
13	Tubewell	Dera M.Ismail, Chak No.21 Jb Ranika chah	Near R-9	1210	1891	Brackish quality of water
14	Hand Pump	Chak No. 24 JB Lahorianwala	Near R-9	2250	3516	Brackish quality of water

It indicates that ground water quality determined through ERS is almost similar as derived from ground water quality checked in field from hand pumps / tubewells by Ec / TDS meters.

6. Conclusions

Following conclusions have been derived on the basis of different tests / investigations performed in the filed :

a. ERS data indicated that depth to water table in the project area is generally more than 3 meters.

b. Subsurface lithology is dominantly sand with intervening clay beds within the explored depth of 300 m.

c. The quality of water deteriorates with depth particularly away from the canal towards south-east.

d. At site R-1 and R-2 (near canal bank), the underground strata from soil surface to 10 m depth consists of clay mixed with sand traces. The quality of ground water from 10 to 60 meter is marginal to saline which improves afterwards gradually upto the depth of 150 m. and becomes slightly inferior after 150 m Strata beyond 20 m is almost sand..

e. At site R-3, the underground strata from soil surface to 10 meter is almost dry consisting of top surface material. The overall quality of ground water from 10-250 m is marginal to saline. Strata beyond 10 m is sand with thin layers of silt and clay.

f. At site R-4, ground water quality is almost brackish except a layer of fresh water at 40-100 m depth with medium coarse sand. This fact has been verified by testing the ground water quality of nearby tubewell and hand pump which indicated TDS values of more than 1000 ppm.

g. At points R-5, R-6, R-7, R-8 and R-9 electrical resistivity value is sufficient enough to fall in the category of very low resistivity zone having almost brackish water below a depth of 30-50 m with sandy strata.

ERS = Electrical Resistivity Survey
TDS = Total Dissolved Solids
ES = Electrical Conductivity

h. The results of ground water quality and sub-surface lithology obtained by ERS are almost in close comparison with the results obtained by drilling test holes and testing ground water quality at site.

i. The possibility of installing tubewells for water supply can be explored along the canal bank only.

7. ACKNOWLEDGEMENTS

Provision of funds for this research by Faisalabad Development Authority (FDA) is duly acknowledged. Sincere thanks are also extended to field formations of Irrigation Department and FDA to provide necessary data and support for accomplishment of this assignment.

8. REFERENCES

1. **ARSHAD MUHAMMAD, J.M. CHEEMA AND SHAFIQUE AHMED, 2007.** Determination of Lithology and Ground water Quality Using Electrical Resistivity Survey. INTERNATIONAL JOURNAL OF AGRICULTURE and BIOLOGY1560–8530/2007/09–1–143–146.

2. **CHOUDHURY, K., D.K. SAHA AND P. CHAKRABORTY (2001)**. Geophysical study for saline water intrusion in a coastal alluvial terrain. *J. Appl. Geophysics,* 46: 189–200.

3. **EKINE, A. S. AND G. I. OSOBONYE (1996)**. Subsurface geo-electric sounding for the determination of aquifer characteristics in parts of Bonny Local Government Area of Rivers State, Nig. J. Phys. 85.

4. **EMENIKE, E.A. (2001)**. Geophysical Exploration for Ground water in a Sedimentary Environment: A Case Study from Nanka over Nanka Formation in Anambra Basin, Southeastern Nigeria. *Global J. Pure Appl. Sci.*, 7: 1

5. **FROHLICH, R.K. AND D. URISH (2002)**. The use of geoelectrics and test wells for the assessment of ground water quality of a coastal industrial site. *J. Appl. Geophysics,* 50: 261–78.

6. **IRRIGATION RESEARCH INSTITUTE (IRI), (2012),** “**GROUND WATER INVESTIGATIONS FOR WATER SUPPLY TO FDA-CITY HOUSING SCHEME, FAISALABAD** (GROUND WATER MODELLING APPROACH), IRR-PHY/577, Lahore Pakistan

7. **LASHKARIPOUR, G. R. (2003)**. An investigation of ground water condition by geoelectrical resistivity method: A case study in Korin aquifer, Southeast Iran. J. Spatial Hydrology. 3:1-5.

8. **LASHKARIPOUR, G. R. AND M. NAKHAEI (2005).** Geoelectrical investigation for the assessment of ground water conditions: a case study. Annals of Geophysics. 48:937-944.

9. **MATIAS, M.J.S. (2002)**. Squary array anisotropy measurements and resistivity sounding interpretation. *J. Appl. Geophysics,* 49: 185–94.

10. **OKORO, E I; EGBOKA, B C E; ONWUEMESI, A G (2010).** Evaluation of the aquifer characteristic of Nanka Sands using hydrogeological method in combination with Vertical Electrical Sounding (VES). J. Appl. Sci. Environ. Manage. June, 2010 Vol. 14 (2) 5 – 9.

11. **OSEJI, J. O., M. B. ASOKHIA AND E. C. OKOLIE (2006).** Determination of ground water potential in obiaruku and environs using surface geoelectric sounding. Springer Science+Business Media, Environmentalist. 26:301-308.

12. **PROF. DR. JAVAD. A. AZIZ,** Drink water Quality in Punjab. Paper no. 616, Pakistan Engineering Congress, Lahore, Punjab, Pakistan

13. **SIKANDAR P., A. BAKHSH, M. ARSHAD AND T. RANA (2008)**. The use of vertical electrical sounding resistivity method for the location of low salinity ground water for irrigation in Chaj and Rachna Doabs. Environ. Earth Sci. DOI 10.1007/s12665-009-0255-6.

14. **SIKANDAR P., A. BAKHSH, T. ALI AND M. ARSHAD (2010)**. Vertical Electrical Sounding (Ves) Resistivity Survey Technique to Explore Low Salinity Ground water for Tubewell Installation in Chaj Doab. J. Agric. Res., 2010, 48(4).

15. **SUBBA RAO, N. (2002)**. Ground water prospecting and management in an agro-based rural environment of crystalline terrain of India. Environmental Geology. 43: 419-431.

16. **WATER AND POWER DEVELOPMENT AUTHORITY (WAPDA), (2008**), Electrical Resistivity Studies for Ground water Investigations along Rakh Branch Canal Faisalabad, Hydrogeology Directorate, G.W.I. Note No. 453

17. **WARD, S. H. (1990).** Resistivity and induced polarization methods. Geotechnical and Environmental Geophysics, Vol. 1. Society of Exploration Geophysics.

18. **ZAMIR-UDDIN KIDWAI, (1962),** The Geology of Rachna and Chaj Doabs “Water and Soil Investigation Division Bulletin 5” West Pakistan, Water and Power Development Authority, Lahore, Pakistan.