Journal of Himalayan Earth Sciences Volume 53, No. 2, 2020 pp. 52-59

Role of electrical resistivity method to identify fresh water aquifers in Nankana Sahib, Punjab, Pakistan

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Submitted date: 08/09/2018 Accepted date: 29/09/2020 Published online:

Abstract

Groundwater assessment plays a crucial role for town planning and urbanization in an area. This research aims to delineate subsurface quality zones by using electric resistivity technique in Nankana Sahib area (31° 45′ 12″–31° 25′ 1″ N; 73° 39′ 48″–73° 55′ 30″) Tehsil of Lahore, Pakistan. Around 36 vertical electric sounding data points were collected using schlumberger electrode configuration. Depth of investigation is upto 180m. Inversion method is applied to convert apparent resistivity in to true resistivity of lithology. The true resistivity range of the various subsurface lithology's is from 2.6 to 220 Ω.m. The results obtained from vertical electric sounding are matched and calibrated with borehole lithological data in the vicinity of study area indicates that resistivity < 25 ohm.m are considered as saline water zone in formation like clay and silt, 25-35 ohm.m brackish to marginal water zone information like clayey sand, silty sand and silt. Resistivity range from 35-55 ohm.m represents fresh water zone (low quality) in formation like sand (silty), and greater than 55 ohm.m represents fresh water, fine to coarse grained sand, gravels and cankers. Aquifers identified in the study area are sand dominant at depth interval of 0-30 m, 30-90 m and 90-180 m. subsurface lithology is chiefly sand with small clay lenses and aquifer is mostly dominant by marginal fresh water.

Keywords: Groundwater quality zones, Vertical Electrical Sounding (VES), Electric Conductivity (EC), Aquifer, Fresh water, Saline water.

1. Introduction

Groundwater is regarded as one of the most reliable source of drinking water in all over the globe. Many countries now have the growing water scarcity and deteriorating water quality because of rapid surge in industrialization, urbanization and agricultural practices. In Pakistan, over exploitation and prevailing drought conditions are the possible causes of extinction of potable water reserves and inadequate replenishment of groundwater aquifers (Basharat, 2012). About 60 percent of crops are grown using groundwater and 90 percent of drinking water need is fulfilled by using groundwater (Qureshi et al., 2003). Declining trend of availability of fresh water resources and already identified global freshwater crises immediately demands proper management of our available water resources for food security and betterment of the livelihoods of the large population (Misra, 2014).

Nankana Sahib (Fig.1) is located in Province Punjab, Pakistan between Ravi and Chenab waterway, also widely recognized as Rechna Doab. Although river Ravi is the main source of subsurface aquifer recharge, but various geochemical studies have been carried out in the area and gave some evidence of intermixing of saline water in fresh water aquifer (WRS, 2014). The groundwater quality is good toward the river side areas

Electrical resistivity method is a non-invasive geophysical technique measures the ground apparent resistivity which is largely related to the mineralogy, porosity, degree of saturation pore fluid chemistry and temperature (Daily et al., 2005; Pomposiello et al., 2012). Electrical resistivity technique has been widely used by different researchers for quantification and assessment of groundwater such as to delineate subsurface lithology and hydro-stratigraphy (Al-amri., 1998; Farid et al., 2014). Groundwater prospecting and aquifer parameter estimation (Sharma et al., 2005; Niwas et al., 2003; Basarian et al., 2017). Hydraulic properties estimation (De lima et al., 2000; Singh et al., 2016), groundwater quality zones (Hussain et al 2017; Muhammad et al.,

2017) and it has also been considered as suitable technique by different researchers to map subsurface clay layers (Farid et al., 2017).

VES (Vertical Electrical Sounding) has been used widely for subsurface geology and hydro stratigraphy delineation (Gnanasundar and Elango, 1999). Information related to depositional environment as well as water salinity and water saturation are obtained by the resistivity variations analysis (Chidambaram et al., 2013). The VES is cost effective and convenient for the delineation of subsurface lithological variation and groundwater exploration. It is also assumed one of applicable method to estimate aquifer properties (Uhlemann et al., 2017).

This study is carried out in Tehsil, Nankana Sahib to delineate subsurface lithology and groundwater quality zones using VES technique. Field data is interpreted using IPI2Win software and water quality zonation maps are generated in Arc GIS 10.2.1. in Tehsil, Nankana Sahib.

2. Hydrogeological settings

The current studies which lies in a Rechna Doab also called Bar upload. Metamorphic and igneous rocks of Precambrian age is covered with Alluvium deposit as observed in other plains of Punjab province (Shah, 2009). Thick alluvial and river deposits cover the area. The study area includes the terrigenous sedimentary rocks of stream deposits, flood plain deposits, and detrital sedimentary rocks. Borehole data suggest that sediments coexist in different proportions and alternate from sandy clay to clayey sand mainly of grey to brownish grey. The sand, gravel and their admixtures serve as water bearing strata. Most of the aquifers in this region are confined however some places are characterized by unconfined aquifers with gravels and boulders at the top. Moreover, the unlined canals, water channels and percolation through irrigation practices and rainfall are the main sources of aquifer recharge. The water table in the area is fluctuating depending upon seasonal recharging.

In Rechna Doab Total dissolved solid concentration is higher because soluble material is present in in geological setting. Low to no salinity and fairly good quality groundwater is found toward river at shallow depth (Qureshi et al., 2002).

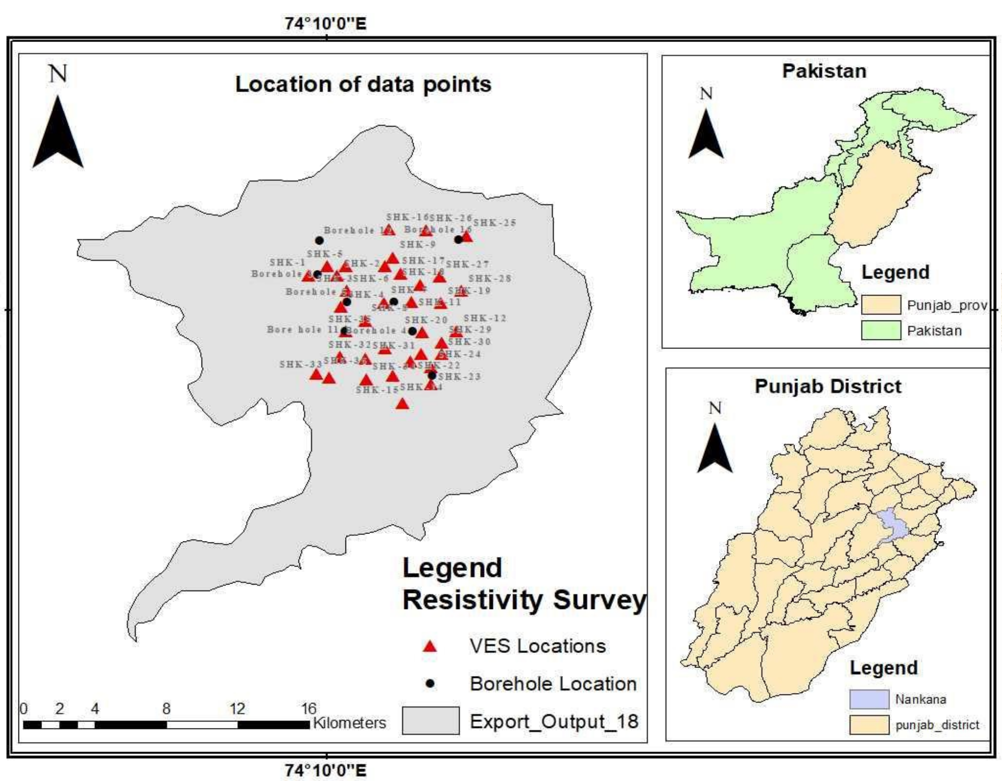

Fig. 1. Location map of the study area.

3. Methodology

Data were collect at 36 locations using vertical electrical sounding method. The depth of investigation was up to 180-meter (Fig. 1). Schlumberger electrode configuration was used. In which potential and current electrodes are not placed equidistance from one another. Geometric arrangement for this array is shown in figure. 3. Apparent resistivity obtained from VES is the bulk average resistivity of all layers is useful for first stage of interpretation. To get the most realistic section of earth we convert it in to true resistivity.

IPI2Win software was used to estimate the true resistivity by curve matching method through itineration process. Principle of equivalence is used for Curve matching technique. The Root Mean Square Error (RMS) should be less the 5 percent.

Most of the resistivity points are conducted close to the available water boreholes (Fig. 5) to correlate the borehole data with Resistivity data to get more meaningful interpretation.

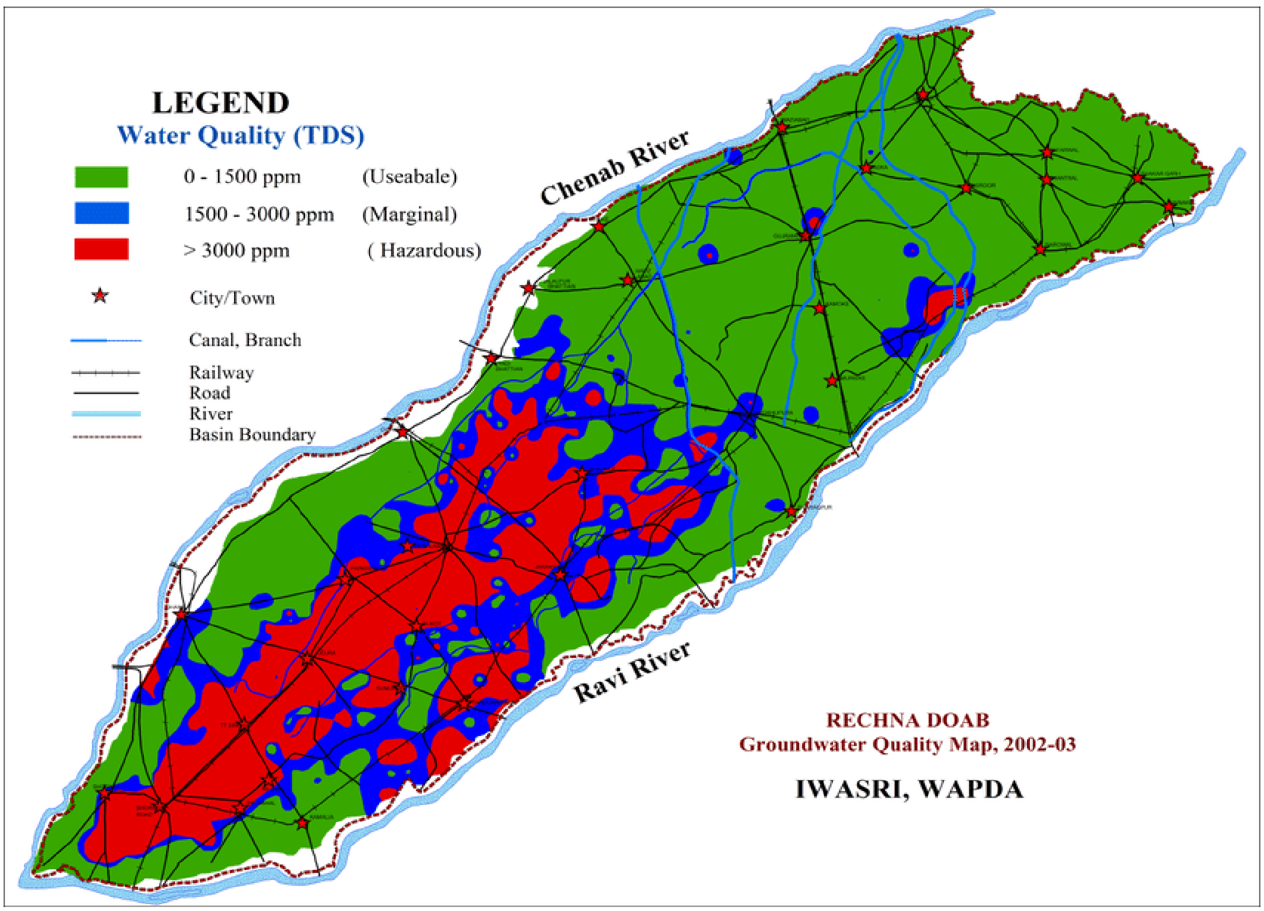

Fig. 2. Rechna Doab Surface salinity map (Source: Soil survey of Pakistan).

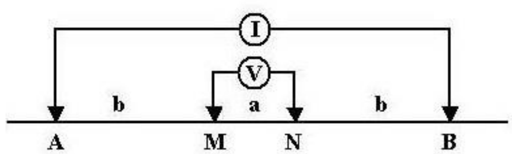

Fig. 3. Schlumberger configuration.

Fig. 4. Interpretation using IPI2Win software.

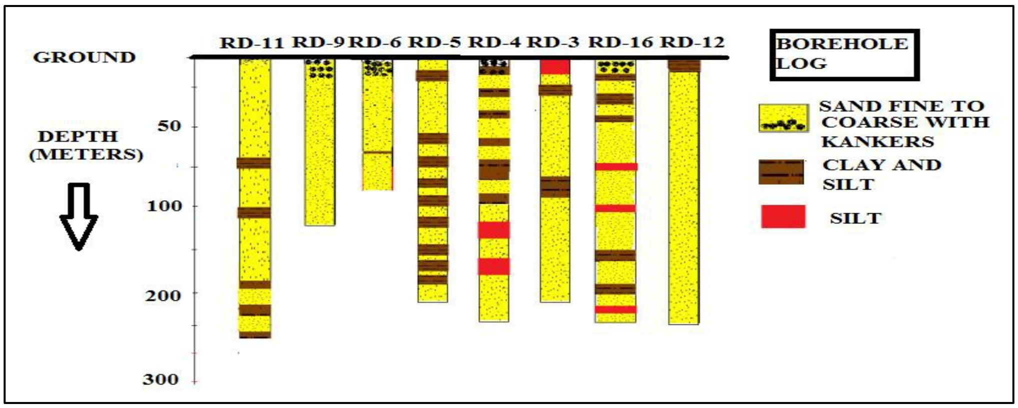

Fig.5. Borehole logs of an area.

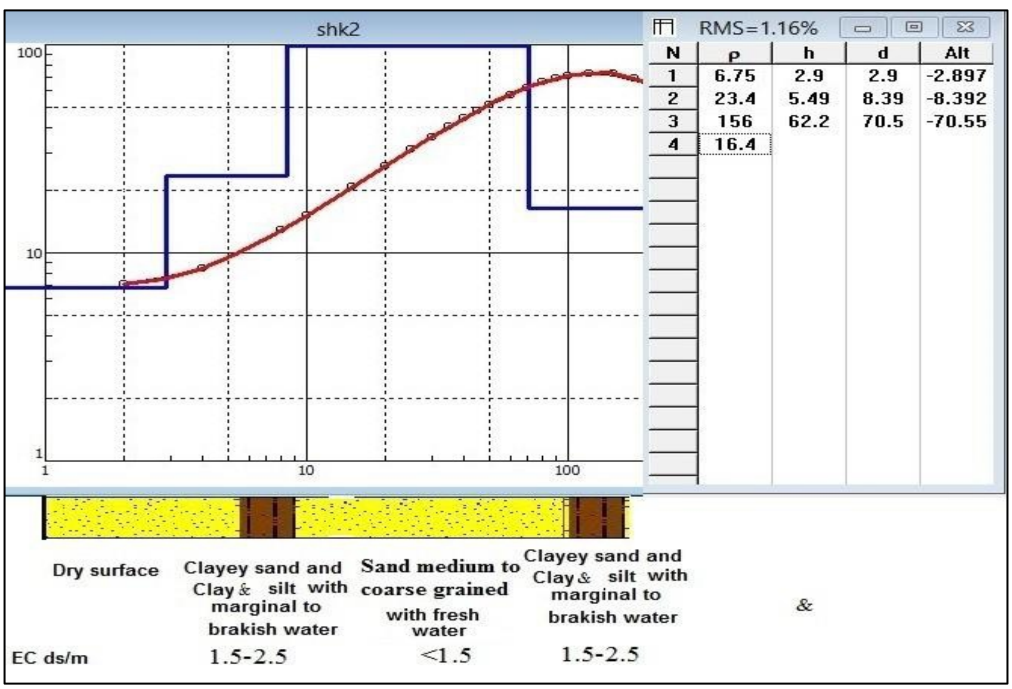

Fig. 6. Correlating resistivity with well logs.

Three possible water quality layers were obtained by introducing apparent resistivity value to ArcGIS 10.2.1 software. Ranges from (0–30 m), (30–90 m), and (90–180 meter) were formulated. And zonation maps for water quality were generated (Fig. 7, 8, 9) through Inverse distance weighted interpolation processing by setting the boundary extent of research area.

Table.1. Resistivity zones with inferred subsurface lithology.

S. No.	Resistivity zone	Resistivity range(Ω.m)	Lithology
2	High resistivity zone	>51	Gravels, medium to coarse grained sand, Cankers
3	Medium resistivity zone	36-55	Sand, silt and clay
4	Low resistivity zone	26-35	Clayey sand, silty sand and Cankers
5	Very low resistivity zone	<25	Clay, silt

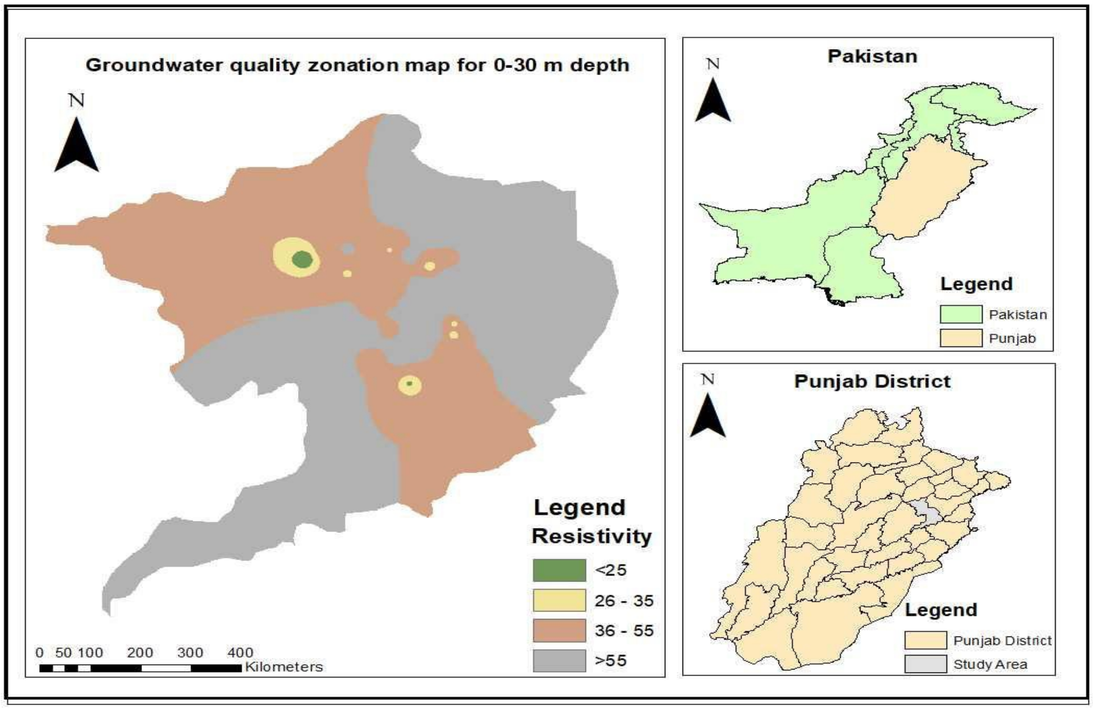

Fig. 7. Groundwater quality map at depth 0-30 m.

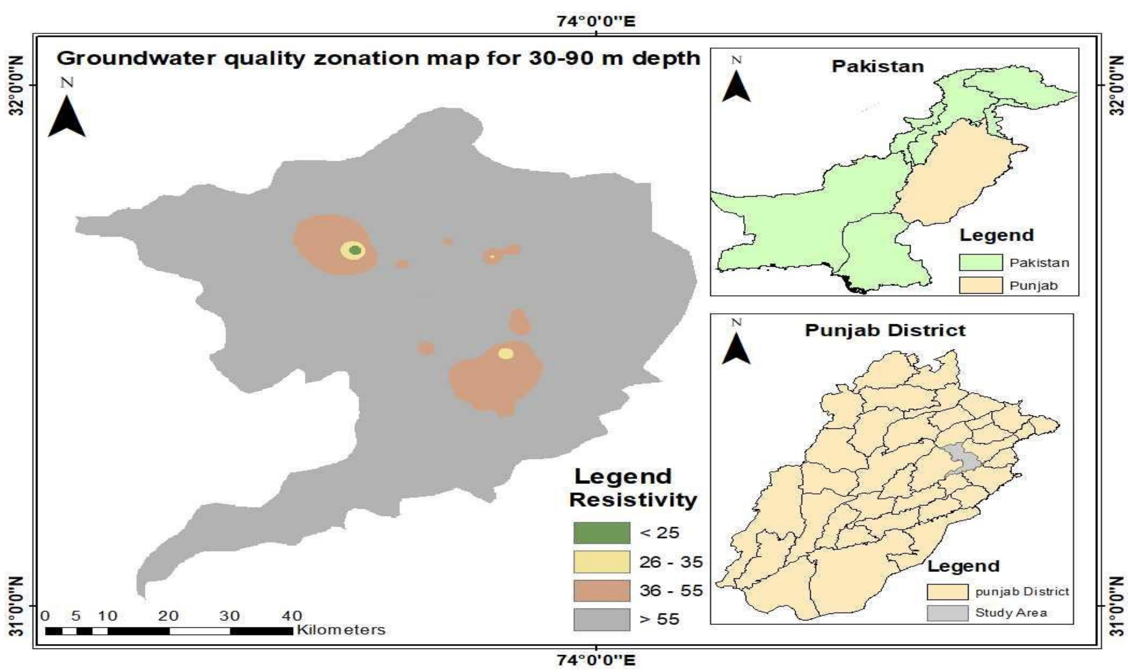

Fig.8. Groundwater quality map at depth 30-90 m.

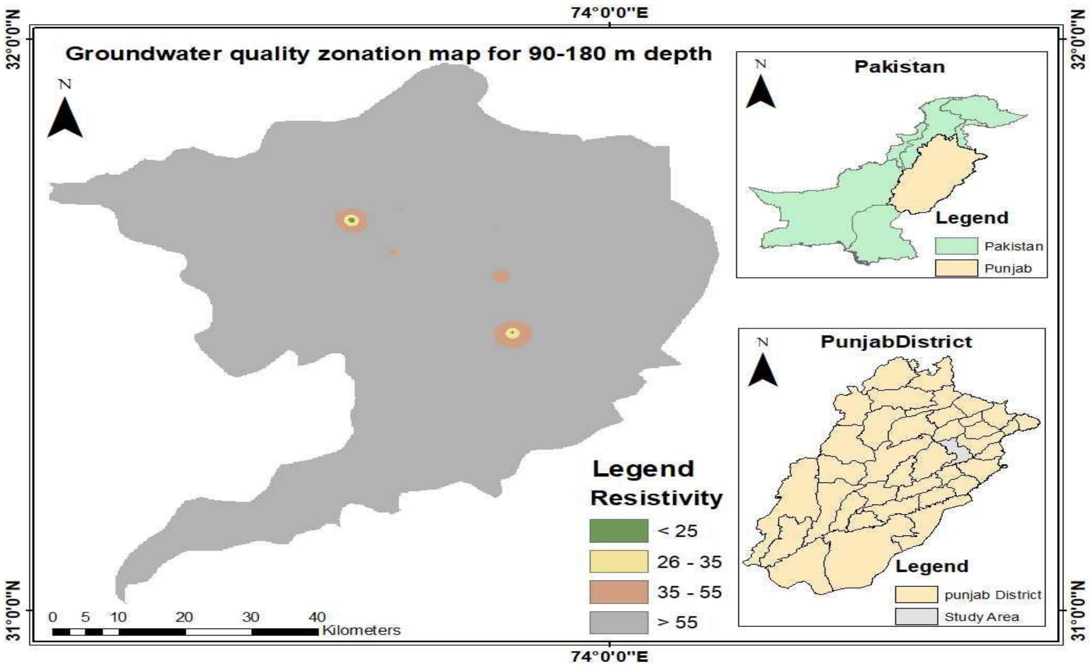

Fig. 9. Groundwater quality map at depth 90-180 m.

Interpretation regarding to subsurface lithology, groundwater quality zones and fresh water aquifer, was made at different horizons of the measured soundings. The variation in resistivity value is based on mineralogy, porosity, degree of saturation pore fluid chemistry can be used to define a possible subsurface freshwater aquifer zone. Lithological and hydrogeological model of an area is obtained by correlation of resistivity values obtained from VES with local geology of an area. Among resistivity soundings, SHK-10 (Fig. 6) shows a resistivity range of (6.75-156 Ω m) which may be top haphazard material or clayey sand (0-10 m) and freshwater aquifer is present at (10-70 m). The true resistivity analysis of the sounding SHK-10 (Fig. 10) shows a resistivity range (23.7–143.3 Ω m), which may be clayey sand with marginal to brackish water (0–20 m) and may be the presence of fresh water aquifer at (20-160 m).

Resistivity analysis for 0-30 m top geoelectric layer demonstrates that this area has medium to high resistivity zone. Lithological it may have fine sand intermixed of clay and silt. Corse grain sand and gravel may also be present. Intermediate (30-90 m) and lower (90-180 m) geoelectric layers show that these areas have high resistivity zone lithological it may have coarse grain sand and gravels with small silt and clay lenses. Different geoelectric layers (Table 2) has demonstrated that groundwater quality is brackish to marginal at shallow depth because of agricultural practices.

In the study area lithological data obtained from eight boreholes is correlated with true resistivity. Majority of upper most part contains marginally fresh water. The Pseudo sections reflects the presence of medium-to-coarse sand intermixed with some silty clay at the shallow depth and coarse grain sand with gravels and cankers are present at greater depth.

Table. 2. Inferred results from study area.

Resistivity zones	**Resistivity Ranges (Ω m)**	**Water quality**
High	> 120	Fresh water
Medium	35-55	Low quality Fresh water
Low	25-35	marginal water to brackish water
Very Low	<25	saline water

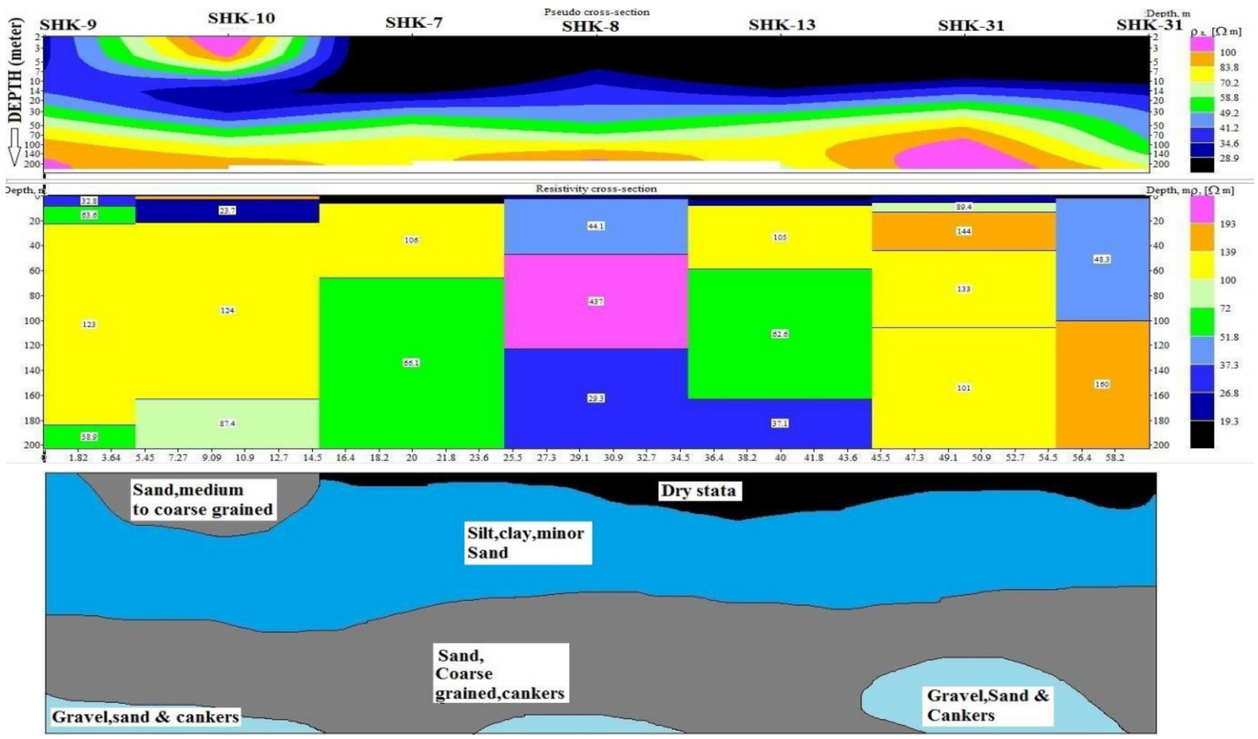

Fig. 10. Cross section of subsurface lithology.

5. Conclusion

The research work demonstrates the presence of three geoelectric layers in the study area. Lithologically area is dominant with fine to coarser grain sand and gravel with small lenses of clay and at shallow depth groundwater is brackish to marginal fresh. Lower geoelectric layer is comparatively better in quality.

Author's contribution

Haider Shabbir, proposed the main concept and involved in write up and assisted in establishing sequence stratigraphy of the section. Haider shabbir, also collected field data. Nabeel Afzal, did provision of relevant literature, and review and proof read of the manuscript. Haider Shabbir and Nabeel Afzal, did technical review before submission and proof read of the manuscript. Haider Shabbir, did also involve in processing and interpretation of field data. Adeela Zafar and Khalid Mir, was involved in assistance in preparation of illustration and plates of figures.

References

Al-amri, A. M., 1998. The application of geoelectrical vertical soundings in delineating the hydrostratigraphy of the southern Red Sea coastal area, Saudi Arabia. Earth Sciences, 10(1).

Basarian, M. S., Tahir, S. H., 2017. Groundwater prospecting using geoelectrical method at Kg Gana, Kota Marudu, Sabah. Earth Sciences Malaysia, 1(2), 7-9.

Basharat, M., 2012. Integration of canal a groundwater to improve cost and quality equity of irrigation water in a canal command. Thesis, University of Engineering and Technology Lahore, Pakistan.

Daily, W., Ramirez, A., Binley, A., LaBrecque, D., Butler, D. K., 2005. Electrical resistance tomography—Theory and practice. Near-Surface Geophysics, 13, 525-550.

De Lima, O. A. L., Niwas, S. 2000. Estimation of hydraulic parameters of shaly sandstone aquifers from geoelectrical measurements. Journal of hydrology, 235(1-2), 12-26.

Farid, A., Khalid, P., Jadoon, K. Z., Jouini, M. S., 2014. The depositional setting of the Late Quaternary sedimentary fill in southern Bannu basin, Northwest Himalayan fold and thrust belt, Pakistan. Environmental monitoring and assessment, 186(10), 6587-6604.

Farid, A., Khalid, P., Jadoon, K. Z., Iqbal, M. A., Shafique, M. 2017. Applications of variogram modeling to electrical resistivity data for the occurrence and distribution of saline groundwater in Domail Plain, northwestern Himalayan fold and thrust belt, Pakistan. Journal of Mountain Science, 14, 158–174.

Gnanasundar, D., Elango, L., 1999. Groundwater quality assessment of a coastal aquifer using geoelectrical techniques. Journal of Environmental Hydrology, 7(2), 1–8.

Hussain, Y., Ullah, S. F., Akhter, G., Aslam, A. Q., 2017. Groundwater quality evaluation by electrical resistivity method for optimized tubewell site selection in an ago-stressed Thal Doab Aquifer in Pakistan. Modeling Earth Systems and Environment, 3(1), 15.

Misra, A. K., 2014. Climate change and challenges of water and food security. International Journal of Sustainable Built Environment, 3(1), 153-165.

Muhammad, S., Khalid, P., 2017. Hydrogeophysical investigations for assessing the groundwater potential in part of the Peshawar basin, Pakistan. Environmental Earth Sciences, 76.

Niwas, S., de, Lima, O. A. 2003. Aquifer parameter estimation from surface resistivity data. Ground Water, 41(1), 94-100.

Pomposiello, C., Dapeña, C., Favetto, A., Boujon, P., 2012. Application of geophysical methods to waste disposal studies. Municipal and Industrial Waste Disposal, 3-26.

Qureshi, A. S., Hussain, A., 2002. Integrated database development for river basin management: An example from Rechna Doab, IWMI, 53.

Qureshi, A., Shah, T., Akhtar, M., 2003. The groundwater economy of Pakistan.

Water Resources Study (WRS), 2014. Water Balance Study Nestle, Sheikhupura.

Shah, S. M. I., 2009. Stratigraphy of Pakistan. Memoirs of the Geological Survey of Pakistan, 22, 293-298.

Sharma, S. P., Baranwal, V. C., 2005. Delineation of groundwater-bearing fracture zones in a hard rock area integrating very low frequency electromagnetic and resistivity data. Journal of Applied geophysics, 57(2), 155-166.

Singh, S., Singh, V. S., 2016. Estimation of hydraulic characteristics from electrical resistivity data in coastal aquifers of southern India. Journal of the Geological Society of India, 88(1), 77-86.

Chidambaram, S., Srinivasan, K., Poongothai, S., 2013. Identification of groundwater potential zone by using GIS and electrical resistivity techniques in and around the Wellington reservoir, Cuddalore District, Tamil Nadu, India. European Scientific Journal, 9(17), 312–331.

Uhlemann, S., Kuras, O., Richards, L. A., Naden, E., Polya, D. A., 2017. Electrical resistivity tomography determines the spatial distribution of clay layer thickness and aquifer vulnerability, Kandal Province, Cambodia. Journal of Asian Earth Sciences 147, 402-414.