Indexed in
Scopus Compendex and Geobase Elsevier, Chemical
Abstract Services-USA, Geo-Ref Information Services-USA

ISSN 0974-5904, Volume 05, No. 02

www.cafetinnova.org

International Journal of Earth Sciences and Engineering

April 2012, P.P. 282-287

Correlation Study between Geoelectrical and Aquifer Parameters in West Coast Laterites

A. G. CHACHADI and PRADIP D. GAWAS
Department of Earth Science, Goa University, Taleigao Plateau, Goa, India
Email: *chachadi1@rediffmail.com and pradipgawas@yahoo.co.in*

Abstract: The objective of this study was to develop surface electrical resistivity technique for estimating hydraulic conductivity of lateritic aquifer in the Konkan coastal laterites of Goa. Aquifer electrical resistivities were determined from the results of Schlumberger electrical soundings at three sites in Tericol area, North Goa where three pumping test data was gathered at the same time. Hydraulic conductivities and transmissivities determined from pumping tests were then correlated with true resistivities obtained from interpreted electrical sounding data. Results indicate that true electrical resistivities of aquifers determined from sounding can be used to predict fairly accurate aquifer hydraulic conductivities. Empirical relations between electrical resistivity and aquifer hydraulic conductivity and transverse resistance and transmissivity were developed for lateritic aquifers.

Keywords: *Tericol, Transmissivity, Electrical Resistivity, Pumping Tests*

Introduction:

Groundwater is an important source of fresh water and requires efficient methods for locating potential aquifers. To accomplish this, it is essential to have knowledge of aquifer parameters such as hydraulic conductivity. The hydraulic conductivity is commonly estimated through pumping tests carried out on wells. However, in many circumstances the availability of wells at suitable points may be lacking. Furthermore, drilling new wells and carrying out pumping test at each site may be time consuming and costly.

A large number of empirical and semi-empirical equations correlating geoelectrical results and hydraulic parameters of aquifers, under different geological conditions, have been proposed in the literature (Kelly 1977; Mazac and Landa 1985; Kosinski and Kelly 1981; Kelly and Reiter 1984; Sri Niwas and Singhal 1985; Yadav and Abolfazli 1998). Both direct and inverse relations between aquifer resistivity and hydraulic conductivity are reported (Worthington 1976; Kelly 1977; Urish 1981; Mazac et al. 1985). The analytical relationship between aquifer transmissivity and transverse resistance has been developed by Sri Niwas and Singhal (1981).

Singhal and Sri Niwas (1983) proposed a modification in their 1981derived relationship (between transverse resistance and aquifer transmissivity) by multiplying the aquifer water resistivity by the ratio of actual average aquifer resistivity and aquifer water resistivity at a particular location. Sinha, Israil and Singhal et al., (2009) proposed hydrogeophysical model of the relationship between geoelectric and hydraulic parameters of an anisotropic aquifer in Ganga-Yamuna interfluves aquifer in North India.

Surface geophysical methods have been used to delineate aquifer zones in the area, and the geophysical character of the aquifer zone has been estimated at various points. Since there are only a few wells available in the study area, these are utilized to carry out pumping tests wherever possible and thus to estimate aquifer hydraulic parameters at these sites. Correlation coefficients were then established between aquifer electrical resistivity and hydraulic parameters. These correlations were utilized to estimate aquifer parameters at other places in the study area, where wells were not available. This method has proven to be cost effective and has rapidly characterized the aquifer system in the study area.

Location of the Study Area:

The study area is located in Tericol village in Pernem taluka of North Goa. It is a small coastal village located at the North western extremity of the state, covering an area of 1.43 km2. It is the only village of Goa that is located across the river Tiracol, at the scenic junction of the river with the Arabian Sea. Being a coastal village it is bounded on the western side by Arabian Sea and on the northern and the eastern side by the Maharashtra state. It is located within the latitudes 15043’13”N and 15043’48.52”N and longitudes 73040’32.03”E and 73041’47.90”E. The region is shown on the Survey of India Toposheet No. 48 E 10/4 on 1:25000 scales (Fig.1).

Topography:

Topographically, the area is a part of headland projecting into Arabian Sea. It can be divided into 3 parts –

- The northern highland
- Headland plateau, and
- The low lying valley.

The high ground has E-W trend with gentle slopes on the either side. Its western margin projects into the sea with a steeper slope forming headland. Whereas it is intercepted on the eastern side by another structure trending in N-S which itself forms a headland in the south east extremity of the village. The maximum elevation of the high ground region is 65m along the northern boundary with Maharashtra. The valley portion is a low lying area covering the central part of the village made up of thin layer of alluvium deposited by weathering and erosion of surrounding higher relief. It supports the majority of the population of the village.

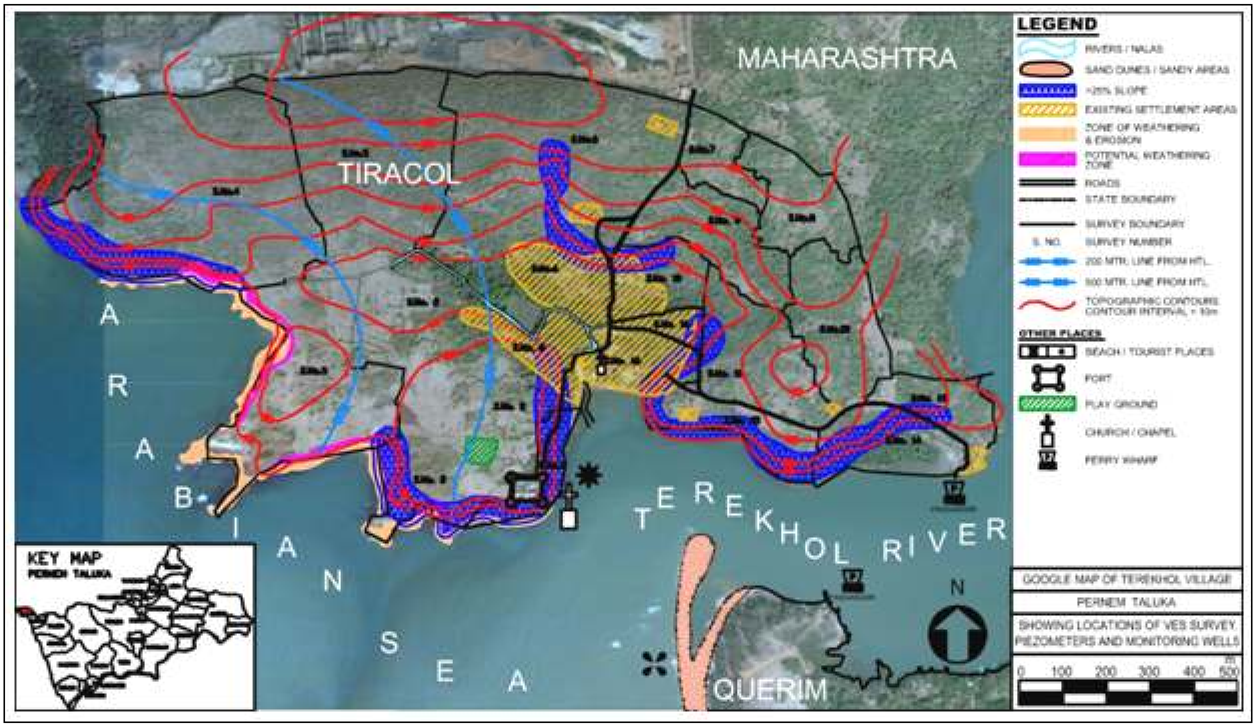


Figure 1: *Location of the Study Area*

Hydrogeology:

The area is covered by the Goa Group of rocks falling under Bicholim Formation of Dharwar supergroup (Archaean). This formation is made up of Quartz-Chlorite-Biotite Schist with layers of Chert and Iron oxides. These rocks are capped by a variable thickness of laterite layer which is formed due to leaching of the basement rocks. Partially lateritised basement rocks are exposed along the coast showing relict features as bedding and fractures. There are small alluvial sand deposits along the southern side of the area. The groundwater occurs under unconfined conditions in the intergranular pore spaces of sand, gravel and pebble which are intercalated with clays in the low lying valley region and in the voids and fractures of detrital laterites at low lying topography. Deeper confined aquifer is found in the fractured basement rocks at depths of 60m to 90m below ground. Recharge is essentially by rainfall infiltration. The Tiracol River, forming the southern boundary, acts as the groundwater discharge site indicating the effluent nature of the river.

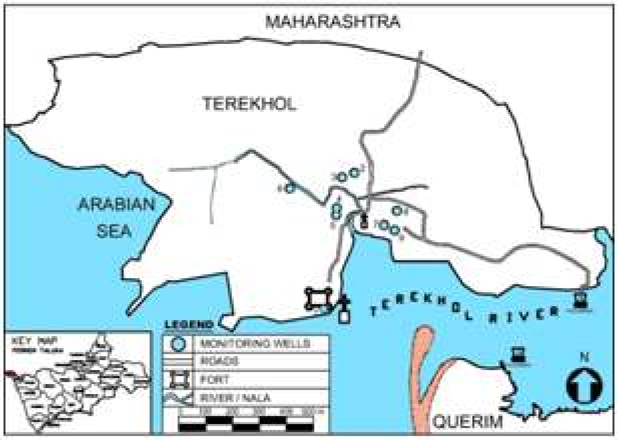


Figure 2: *Wells in the Study Area*

The small stream present in the study area also shows the effluent nature. Presently the groundwater is developed only in the village area through dug wells. The area is potentially being developed for tourism activities. The area is having nine open wells for supply of village. All these wells were monitored for hydrogeological study (Fig.2)

Pumping Tests and Geoelectrical Investigation:

Of these 9 wells only 3 were available and feasible for carrying out pumping tests. Short duration pumping tests were conducted on these open wells and the data was analyzed using appropriate type curve methods. The plot of one of the pumping test data on log-log paper is shown in Fig.3. Mishra and Chachadi (1985) type curve method has been used for estimating the aquifer parameters. The values of transmissivity (T), storativity (S) and hydraulic conductivity (K) are given in Table-1.

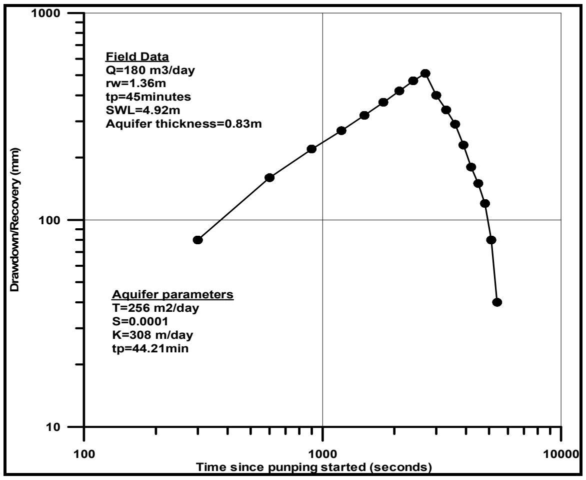


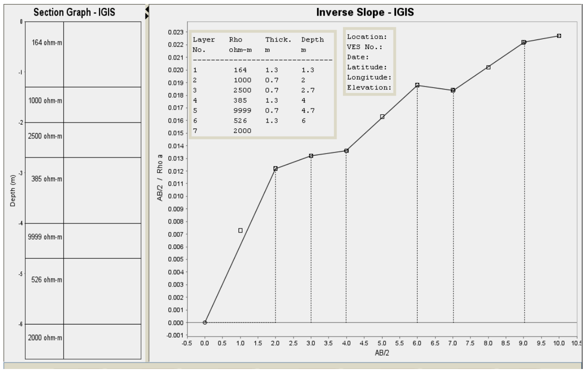
Figure 3: *Plot of Pumping Test Data*

VES survey with short AB/2 distance of 15m was carried out near each of the well where pumping test was conducted. The short AB/2 distance was used owing to the shallow depth of the aquifer encountered in the adjacent wells. This VES data was interpreted to get the thickness and the true resistivity of each layer. Both master curve matching and automated techniques were used to derive the geoelectrical parameters.

Table 1: *Summary of Aquifer Parameters*

Well No.	T m^2/day	S fraction	K m/day
2	256	0.0001	308
4	35	0.0001	10
9	214	0.0001	108

The automated inverse slope method developed by Integrated Geophysical Instruments Services (IGIS) Hyderabad, was also used in the interpretation (Fig.4). The Dar Zarrouk Parameters were then computed. The water resistivity was computed using TDS values measured in the field. The interpreted resistivity data and the computed Dar Zarrouk parameters for the three test sites adjacent to pumping wells are given in Table-2.



Layer No.	Rho ohm-m	Thick. m	Depth m
1	164	1.3	1.3
2	1000	0.7	2
3	2500	0.7	2.7
4	385	1.3	4
5	9999	0.7	4.7
6	526	1.3	6
7	2000		

Figure 4: *Interpreted VES Data at Well no.2*

Table 2: *Results of Interpreted Ves Data and Dar Zarrouk Parameters*

Well No	Aquifer Resistivity ‘$\rho_{\square 0}$’ (Ω-m)	Aquifer Thickness (m)	Conductivity of Water (µmhos/cm)	Resistivity of Water ‘ρ_w’ (Ω-m)	Formation Factor FF = $\rho_{\square 0}/\rho_w$
2	614.2747	0.83	95.31 (61)*	104.918	5.85
4	46.8823	3.34	587.5 (376)*	17.021	2.75
9	245.8855	1.98	33.125 (21.2)*	301.887	0.81
Well No	**Longitudinal Unit Conductance (mhos)**	**Transverse Resistance (Ωm^2)**	**Aquifer Conductivity (mhos)**	**Transmissivity (m^2/day)**	**Hydraulic Conductivity (m/day)**
2	0.0014	509.85	0.00163	255.91	308.325
4	0.0712	156.59	0.02133	34.6164	10.3642
9	0.0081	486.85	0.00407	213.73	107.94

*values in bracket are TDS in ppm

Correlation of Geoelectrical and Aquifer Parameters:

When large volumes of earth materials are covered, surface geoelectrical methods offer an alternative approach for the estimation of hydraulic characteristics at aquifer scale. Electric current follows the path of least resistance. Within and around pores, the mode of conduction of electricity is ionic and thus the resistivity of the medium is controlled more by porosity and water conductivity than by the resistivity of the rock matrix. Thus, at the pore level, the electrical path is similar to the hydraulic path and the resistivity should reflect hydraulic conductivity (Sri Niwas and Singhal, 1985). Since late 1960s electrical resistivities determined from surface measurements have been used to estimate aquifer properties. Ungemach et al., (1969) correlated transmissivities with transverse unit resistance. Kelly (1977) and Kosinski and Kelly (1981) correlated aquifer resistivities with hydraulic conductivites obtained from pumping test. Sri Niwas and Singhal (1981) concluded that relations between transverse resistance and transmissivity are more meaningful in alluvial aquifers than relations between longitudinal conductance and transmissivity and later in 1985 they widened their applicability by considering variation in water quality.

Formation Factor:

The value of Formation Factor (FF) is calculated by Archie's Law using the aquifer resistivity (ρ) estimated from VES and the water resistivity of the formation (ρw) measured during the field investigation as

$FF = \rho / \rho_w$ ...(1)

The resistivity (ρw) of water is calculated from the Total Dissolved Solids (TDS) values obtained from the chemical analysis data using the equation:
TDS(ppm)=Conductivity(µmhos/cm)X 0.64…(2)
□w(Ohm-m)=10000/conductivity of water …(3)

Making use of aquifer resistivity, hydraulic conductivity, transverse resistance and formation factor the following three relational graphs have been plotted:

1) Aquifer resistivity(ρ) vs Hydraulic Conductivity (K)
2) Transverse Resistance (Tr) vs Transmissivity (T)
3) Formation Factor(FF) vs Hydraulic Conductivity(K)

Relation between Aquifer Resistivity (ρ) and Hydraulic Conductivity (K):

The relational graph showing aquifer resistivity (ρ) vs hydraulic conductivity (K) is shown in Fig.5. As seen from this graph there exist a linear relation between the two variables.

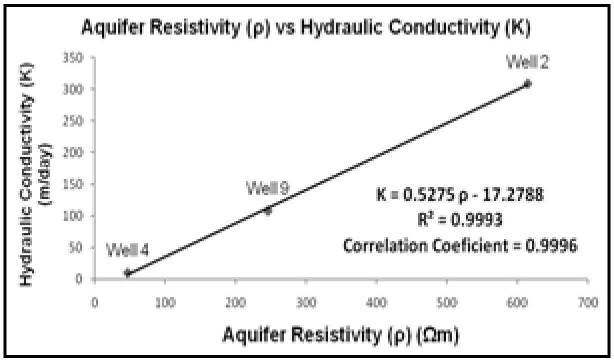


Figure 5: *Graph of Aquifer Resistivity (ρ) Vs Hydraulic Conductivity (K)*

The following relationship obtained with correlation coefficient = 0.9996 for computing hydraulic conductivity.

$K = 0.5275 (\rho) – 17.2788$ ...(4)

Relation between Transverse Resistance (Tr) vs Transmissivity (T):

The graph of Transverse Resistance (Tr) vs Transmissivity (T) also showed a linear relationship (Fig.6) with correlation coefficient = 0.9925 and R2 = 0.9851. The expression for computing aquifer transmissivity hence derived is T = 0.59 Tr - 58.7296 …(5)

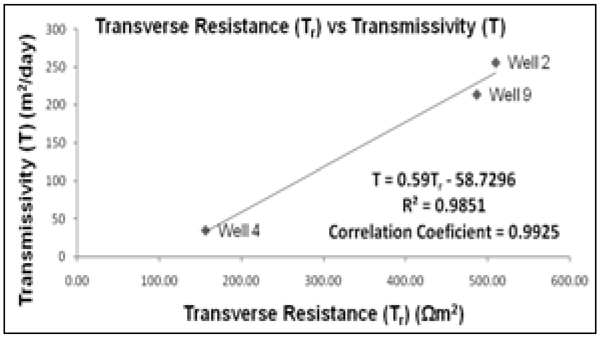


Figure 6: *Graph of Transverse Resistance (Tr) Vs Transmissivity (T)*

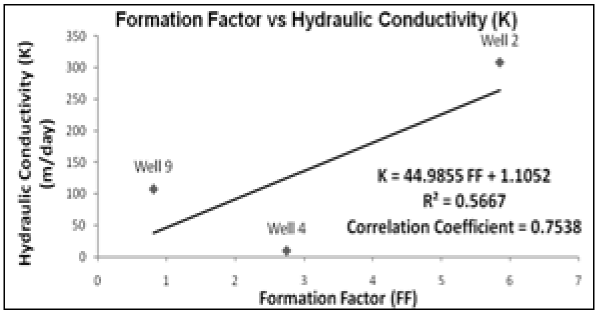


Figure 7: *Graph of Formation Factor (FF) Vs Hydraulic Conductivity (K)*

Relation between Formation Factor (FF) and Hydraulic Conductivity (K):

The graph of Formation Factor (FF) vs Hydraulic Conductivity (K) showed weaker linear relationship (Fig.7) with R2 = 0.5667 and correlation coefficient of 0.7538.The expression for K is given by the following relation:

K = 44.9855 FF + 1.1052 …(6)

Table 3: *Comparison between Computed and Field Measured Parameters*

Well No	aquifer resistivity ρ_0 (Ω-m)	transverse resistance (Ω-m)	field transmissivity (m^2/day)	computed transmissivity (m^2/day)	field hydraulic conductivity (m/day)	computed hydraulic conductivity (m/day)
2	614	510	256	242	308	307
4	47	157	35	34	10	8
9	246	487	214	229	108	112

Results and Discussions:

Using expressions (4) and (5) derived from the relational graphs, the aquifer hydraulic conductivity (K) and transmissivity (T) have been computed for the well sites where pumping test were carried out. The results of comparison between computed and field measured aquifer parameters are shown in Table 3. It can be observed from the table 3 that the computed and the field measured values of hydraulic conductivity and transmissivity are matching closely with each other. Thus the empirical expressions derived from the relational graphs are calibrated for the area. Hence these expressions can be used for determining the aquifer parameters K and T using electrical resistivity data from VES survey carried out in the study area and also in any other areas with similar hydrogeology. Making use of the above expressions the aquifer hydraulic conductivity and transmissivity values have been computed at all the 16 VES sites. The aerial distribution of these parameters for the fractured basement aquifer in the study area is shown in Figs. 8 (a) and (b) respectively for K and T.

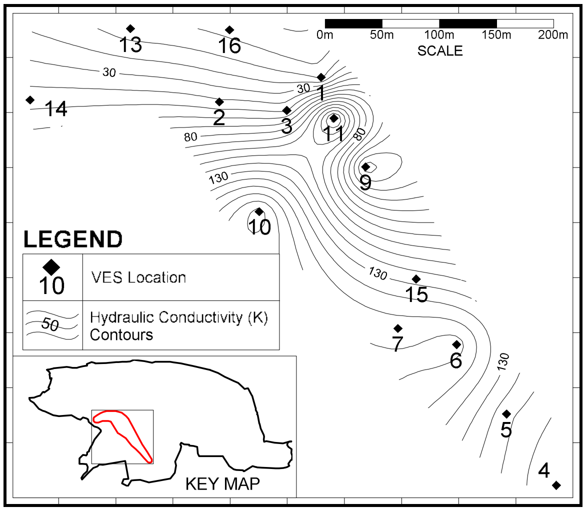


Figure 8 (a): *Computed K for Fractured Basement Rock Aquifer*

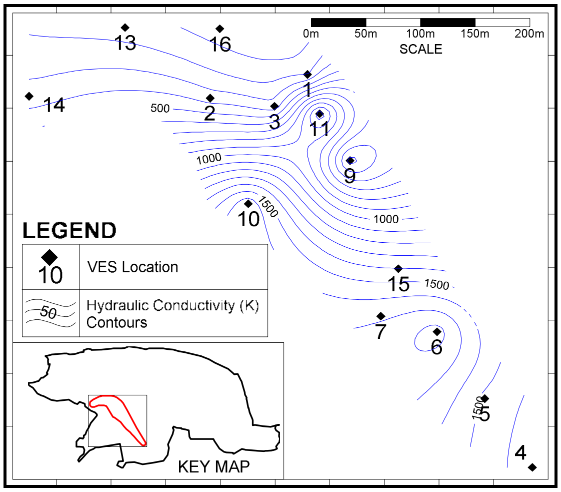


Figure 8 (b): *Computed T for Fractured Basement Rock*

Conclusions:

From the results, it can be concluded that the VES can be used not only in exploration or delineation of aquifer geometry, but it can also be used to estimate the hydraulic parameters which reduces the additional expenditures of carrying out pumping tests and offers an alternate approach for estimating the hydraulic properties. Based on the extensive VES data one can build the contour maps of K and T for an area. These contour maps showing the aerial distribution of aquifer hydraulic parameters can be effectively used. Such kind of maps can be generated for other areas having sufficient hydraulic parameter and electrical resistivity data base.

References:

[1] Kelly, William E (1977). Geoelctric Sounding for Estimating Aquifer Hydraulic Conductivity. Ground Water. Vol 16, No.6, p.420-425.

[2] Kosinski WK, Kelly EW (1981). Geoelectric sounding for predicting aquifer properties. Ground

Water 19:163-171.

[3] Kelly WE, Reiter PF (1984). Influence of anisotrophy on relations between electrical and hydraulic properties. J Hydrol 74:311-321.

[4] Mazac O, Kelly WE, Landa I (1985). A hydrogeophysical model for relations between electrical and hydraulic properties of aquifers. J Hydrology 79:1-19.

[5] Mishra, G.C, and Chachadi A.G (1985).Analysis of flow to large-diameter well during the recovery period. Ground Water, v 23, no.5, pp.646-650.

[6] Sri Niwas, and Singhal, DC (1981). Estimation of Aquifer Transmissivity from Dar-Zarrouk Parameters in porous media. Journal of Hydrology, vol.50, p.393-399.

[7] Sri Niwas, and Singhal, DC (1985). Aquifer transmissivity of porous media from resistivity data. Journal of Hydrology, vol.82, p.143-153.

[8] Singhal DC, Sri Niwas (1983). Estimation of aquifer transmissivity from surface geoelectrical measurements. Proc. UNESCO Symposium on Methods and Instrumentation of Investigating Groundwater System, Noordwijkerhout, the Netherlands, May 1983, pp. 405-414.

[9] Sinha, R., Israil, M., and Singhal,. D.C., (2009). A hydrogeological model of the relationship between geoelectric and hydraulic parameters of anisotropic aquifers. Hydrogeology Journal. 17, 495-503.

[10] Ungemach P, Mostaghimi F, and Duprat A (1969). Essais de de’termination du coefficient demanagesinement en nappe. Libre Application a’ la nappre alluvial du Rhin. Bull Int. Assoc. Sci. Hydrol., 14:169-190.

[11] Urish DW (1981). Electrical resistivity-hydraulic conductivity relationships in glacial outwash aquifers. Water resour Res 17(5):1401-1408.

[12] Worthington PF (1976). Hydrogeophysical equivalence of water salinity, porosity and matrix conduction in erinaceous aquifers. Ground Water 14(4):221-232.

[13] Yadav GS, Abolfazli H (1998). Geoelectric soundings and their relationship to hydraulic parameters in semi arid regions of Jalor Northwestern India. J Appl Geophys 39:35-51.