

## ***Interactive comment on “Nonlinear estimation of aquifer parameters from surficial resistivity measurements” by K. P. Singh***

**Anonymous Referee #2**

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General comment

The relationship between electrical conductivity and hydraulic permeability is of great interest in hydrogeology and hydro-geophysics and has been widely investigated in the literature (see e.g. Guéguen and Palciauskas (1994) Introduction to the Physics of Rocks, Revil, A. and Cathles III, L.M. (1999) Permeability of shaly sands, Water Resour. Res., Vol. 35, N. 3, Pages. 651-662 for a list of publications on this subject) and a certain number of empirical or semi-empirical equations have been proposed, such as the well known Kozeny-Carman equation, which relates permeability to porosity. This latter can be recovered from the electrical conductivity, e.g. via Archie's law. All the existing models involve some parameters which depend on the geometrical and lithological properties of the medium (tortuosity of the pore space, surface conductance, role of the conductive minerals, etc.). For example, it is well known that a small

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or moderate clay content can produce a lowering of the hydraulic conductivity while produces an increase in the electrical conductivity. Because of the complexity of the discussed relationship, is usually assumed that no general model exists, which can be considered valid in any situation. In the present manuscript, the author is just trying to fit some data of electrical conductivity versus hydraulic conductivity with an equation having general formula  $K=A*\exp(B*\rho)$  (eq. 18 in the paper) where K is the hydraulic conductivity,  $\rho$  is the electrical resistivity and A, B are fitting parameters. Obviously, because of the great flexibility of the proposed equation, he obtains a quite good fit for all the shown dataset. The author finds that the range of variability of the two parameters covers several orders of magnitude (A varies from about  $1e3$  to  $1e-8$ , while B has both positive and negative values) but he is never justifying such a wide range and is not trying to find out a relationship between the parameters and the aquifer properties. My main concern is related to this point: to suggest a general equation suitable to translate electrical conductivity values into the corresponding hydraulic conductivity the author should: 1) try to discuss the 'physical' or lithological meaning of the parameter, if any. 2) Validate the model on a larger dataset. 3) Discuss the validity limits of the model. As is, the manuscript is not reporting any new result or methodology. Because of this, I think that is not suitable for publication.

#### Specific comments

I've already discussed my main concern about the paper, but I think that there are several other issues:

1) In the recent years the geo-electrical phenomena have been widely studied and several papers have been published on this topic in the scientific literature. The author is mostly referring to quite old papers (end of the '70s and beginning of the '80s) and is not discussing how is work is related to the previous studies. A wider literature review should be added to the manuscript.

2) The author is stating that "...non conventional methods may be useful to detect a hid-

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den aquifer (Singh, 2003a)" (beginning of pg. 920), and that "Information on thickness of the aquifer is extracted here using a non-conventional method proposed by Singh (2003a)" (pg. 922, lines 19-20). The cited reference about such non-conventional method refers to a journal (J. Geolog. Soc. India) which is not readily available (at least this is my case). The author should present in this paper the method discussed in (Singh, 2003a).

- 3) Pg. 921, lines 15-18, the sentence must be corrected and modified.
- 4) Pg. 923, lines 2-3: the author should show that the exponential fit is best correlated than a linear relationship (e.g. reporting the correlation coefficient for the two cases).
- 5) Pg. 924, lines 3-5. The author suggests that the negative correlation is due to hard rock lithologies. It is possible to explain this behaviour (here and in the following paragraph)? Is it due to conductive minerals? Moreover, the author should discuss other possible explanations for this phenomenon (e.g. significant clay content, as already pointed out in the General Comment).
- 6) Eq. 18 shows the general equation of the adopted model for hydraulic conductivity,  $K$ . How is recovered eq. 19, which shows the corresponding relationship for transmissivity ( $T$ )? Why it's related to eq. 13? This point is very unclear and confusing. Why the value of  $A$  is reported and has units  $h$  (hours)?
- 7) Pg. 926, lines 20-21, 'The yield... (Singh 2003b, 2004) '. This sentence is confusing and should be removed. If the author needs to estimate the yield of the bore-holes, he should explain the technique he adopted and/or report more references about the method.
- 8) Pg. 929, lines 5-8: this reference should be removed because is a conference presentation and not (I suppose) a publication on a referred journal.
- 9) Finally, although I'm not a native English speaker (and yet my English is really poor), I think that both the structure and the language of the manuscript should be strongly improved.

I think that all this points should be addressed before being the manuscript suitable for publication. Please note that because I've just a very little experience with the inversion of geo-electrical data, I haven't discussed this point. I hope that the other reviewers will be able to do it.

#### Technical corrections

There are several typing error that must be corrected. I just want to suggest to the author:

- a) Define what the formation factor is (line 19, pg. 919).
- b) Same line, explain what does 'aquifers per se' means.
- c) Use always the same notation for the units (use meters or m).
- d) Pg. 922, line 19: define what rms means before using it.
- e) Use always the same scientific notation (e. g. see eq. 13 and 16).
- f) Pg. 926, line 23: the figure number is probably wrong.

Notice that this list is not really detailed and is probably incomplete.

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