



Hydrogeophysical Characterization of the Unsaturated Zone.

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Summary

The flow characteristics of the moisture through the unsaturated zone remain an enigma for the scientific understanding and groundwater management as process are comparatively complex. Prediction of moisture movement through the unsaturated medium is an important issue in hydrology as it helps in estimating recharge to ground water system. However, the variability of moisture in the unsaturated zone is not easy for determining by simple experiments. Thus the indirect methods such as determining the electrical resistivity of the unsaturated zone are studied with every moisture change. The variability of moisture content is conditioned by the variability of electrical resistivity measurements through Electrical Resistivity Tomography (ERT) and calculated their variability. In the present work the influence of natural recharge on the correlation structure of resistivity data is been documented by the variogram analysis of the electrical resistivity imaging data. The study clearly shows the non-uniform distribution of the moisture in the vertical profile following the rainfall infiltration and the same has been characterized by the variographic analyses.

Introduction

Some of the most important hydrogeological parameters includes hydraulic head, transmissivity, aquifer thickness, storage coefficient, rainfall, and effective recharge for ground water management. They all are functions of space and are very often highly variable (Ahmed, 1985). However, this variability is, in general, not purely random. If measurements are made at two different locations, the closer the points of measurement, the closer are the measured values. In other words there is some kind of correlation in the spatial distribution of these parameters. Matheron (1963) has given the name "regionalized variable" to these types of parameters. The autocorrelation of these parameters depends highly on the continuity of the system and hence is affected by the geological structures, which control the movement of groundwater.

The primary geophysical method for monitoring the timing and spatial pattern of recharge in the unsaturated zone is Electrical Resistivity Tomography (ERT) using a small electrode spacings on the surface. ERT is particularly appealing because it is non-invasive and allows for long-term quasi-continuous and spatially extensive data for monitoring in the saturated and unsaturated zones. Earlier

workers Daily et al., 1992, Zhou et al., 2001 experimented to track the changes in resistivity through time and their work has been found to be useful for detecting the temporal changes in the moisture content of the unsaturated zone. Tanvi et al, 2005, have used the time lapse electrical resistivity tomography to monitor the variations in resistivity tomograms for short duration recharge. Barker et al., 2000, have used the high resolution electrical imaging to map the 3D movement of fluid in the unsaturated zone of the sandstone at a test site. Dutta et al., 2004 have used the resistivity imaging data of the hard rock terrain and also processed it to obtain a 3D variation of resistivity in the granitic terrain and identified the potential water bearing zones by correlating the results. Long-term monitoring of recharge at a fixed location under different meteorological conditions will enable an improved understanding of groundwater recharge mechanisms for this critical component of the watershed system.

The variability of moisture content is determined by the variability of electrical resistivity measurements through Electrical Resistivity Tomography (ERT). In the present work the influence of natural recharge on the correlation structure of resistivity data is been documented by analyzing the variogram of the electrical resistivity imaging



data. This analysis provides the condition or the extent of saturation of moisture in the unsaturated zone

A Case Study of South Indian Unsaturated Zone

Here we are showing the application involved in the approach of kriging and Variography to classical Vadose zone inversion problems, using observed piezometric level, soil moisture contents, rainfall events, self potential anomaly and electrical resistivity tomography for the Vadose zone characterization and monitoring. Finally we present a stochastic information fusion technology that assimilates information from both unsaturated technology is a promising tool for effectively characterizing heterogeneity, monitoring processes in the Vadose zone, and quantifying uncertainties associated with Vadose zone characterization and monitoring. Hydrologists or soil physicists generally assume that soil is homogeneous and isotropic when they deal with unsaturated flow in most field situations. However, several recent studies show that soil hydraulic parameters could vary significantly in the field.

The purpose of his work is to introduce a simple, single step kriging routine that improves on existing methods used with two dimensional electrical resistivity data and the soil moisture data. A statistical analysis was subsequently undertaken to explore the effects of spatial variability of the electrical resistivity-moisture relation on the interpretation of the change in water content in the Vadose zone, using the change in electrical resistivity.

The experimental field setup was laid along a profile of 96 m with the electrode spacing of 2 m at site S1 at NGRI campus (www.ngri.res.in). The Wenner-Schlumberger array was used to survey the profile. A total number of 529 datum points were measured at 23 data levels, which lead to the plotting of a pseudosection by the observed data sets.

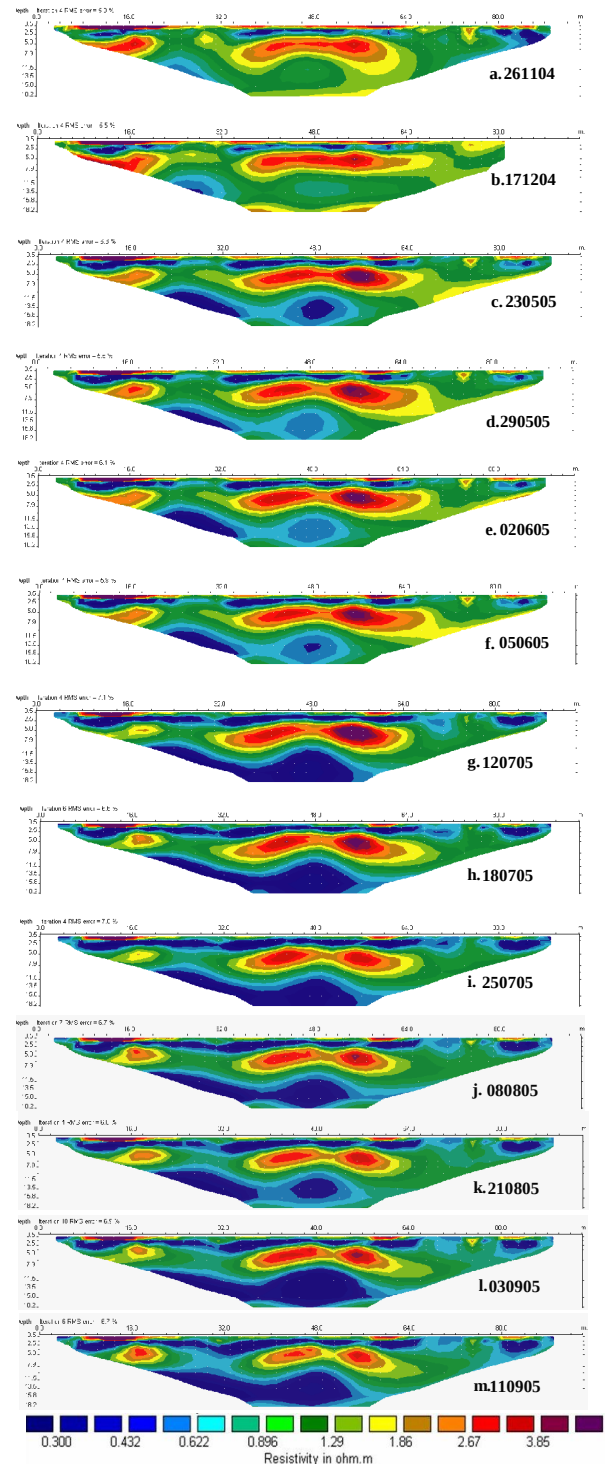


Figure 1 The tomograms after the rainfall events at Site S1.



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The acquired TLERT data (Figure 1) and soil moisture data was collected from the field sites S1 within the NGRI campus to investigate the spatial variability of the electrical-resistivity moisture relation, which is the outcome of the study. The Variography and block kriging approach was developed as a practical solution to improve the level of interpretation possible from measured TLERT data.

The present application adds to an improved procedure of estimating the variogram for determining the variability of any parameter and calculation of the experimental variograms with the desired number of pairs for each lag is much more useful to the sparse datasets commonly found in the field of groundwater hydrology. Experimental variograms plot the average difference of pairs of measurements against the distances interval (lag) separating the pairs. This new invention takes care of the number of pairs formed as a result of the distribution of measurement points. The calculation of variograms by present approach provides a reliable variogram as compared to the classical approach. The entire calculation and plotting is done in MS-Excel environment that is easily and globally accessible (Figure 2).

A key factor that is fostering these calculations is the use of Excel and spreadsheet analysis. We have embraced and accepted the use of Excel to perform these above-mentioned calculations. It has been customary to use the spreadsheets for the analyses of hydrological datasets especially for the pumping test data and for the analysis of ground water problems. We have accepted the applicability of Excel for calculating these experimental variograms with the new approach of obtaining the ensured number of pairs. All the calculations performed can be easily implemented.

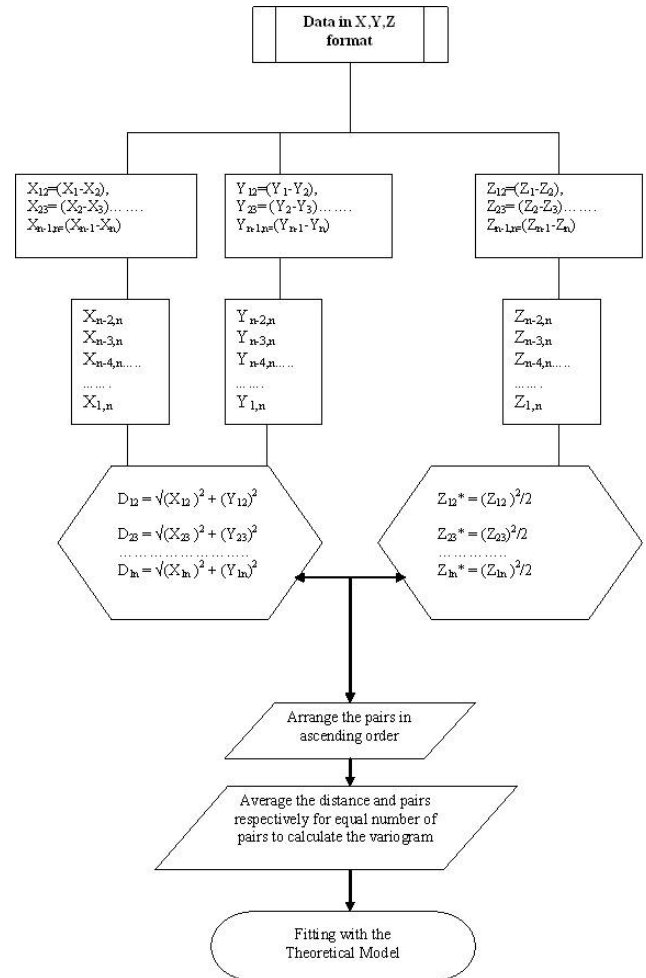


Figure 2 Showing the Flowchart for the calculation of the variograms for the TLERT datasets

On the basis of the above flowchart (Figure 2), the vaiograms for each acquired dataset of resistivity (Figure 1) were calculated. Figure 3 shows the calculated variograms for the respective datasets of resistivity.



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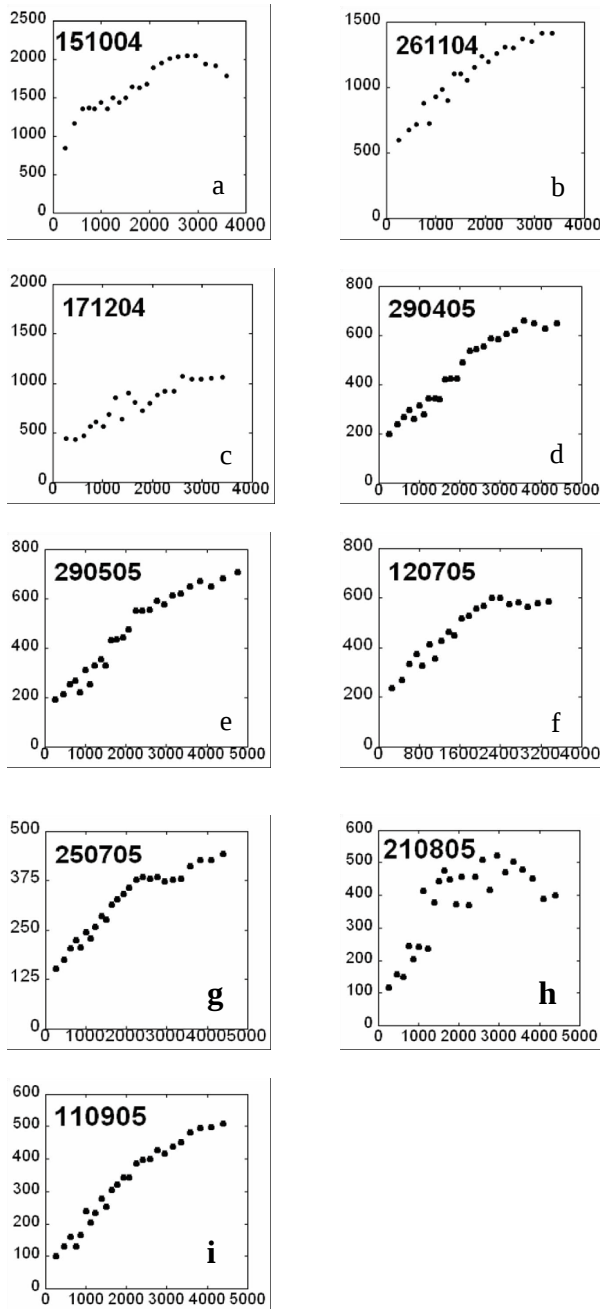


Figure 3 Showing the calculated variograms for the resistivity data acquired on the respective date as mentioned in the insat of the figure. These correspond to the resistivity data (Figure 1) for the site S1

Conclusion

From the variographic analysis of the resistivity datasets, obtained after the time lapse electrical monitoring of the unsaturated zone, it may be concluded that

1. The decrease in the Nugget effect is observed. At site S1 the nugget effect decreases to 30% and finally after comparing the two data sets with a gap of 8 months.
2. There is decrease in the variance percentage also, at S1 the variance decreases by 67 %.
3. Prior to recharge there is no continuity of moisture, but after the rainfall there exists the continuity.
4. Presence of nugget effect shows that the distribution of moisture, as observed with the resistivity and moisture profiles, is not continuous with depth. There exists some gaps and moisture exists in patches.
5. But after the rainfall and the infiltration the gaps are filled and the distribution of the moisture becomes continuous.

The first finding of the present study shows clearly that the assumption of piston flow for the recharge process is not valid in such aquifer condition of hard rock areas. Although the negligible change in the total sill indicates the high variability of formation parameter, reduction in the nugget effect signals the increase in the continuity of moisture present that was more random before the rainfall. Secondly the repeated ERT could support estimation of rainfall recharge at least qualitatively.



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