Using electrical resistivity to characterize the unsaturated zone and monitor infiltration for improving managed aquifer recharge

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Managed aquifer recharge (MAR), the intentional act of storing water in aquifers for later use, is becoming a more relied upon instrument for balancing water supply and demand that has many benefits over traditional surface storage systems. Current MAR projects that recharge water via infiltration from the surface, however, are experiencing problems with infiltrating all of the water that they are permitted to use and having that water reach and stay in storage. At our field site, the Harkin Slough recharge pond, near Watsonville, California, the management agency is entitled to recharge 2000 acre-feet per year, but is only capable of infiltrating half of that and recovering just 15 percent for later use. These issues arise in great part due to the lack of adequate unsaturated zone characterization and clogging of the pond bottom. Electrical resistivity imaging (ERI) is a tool that can be used to help solve these problems because it can provide in-situ information about the saturation and structure of the soil on better spatial and temporal scales than traditional hydrologic counterparts.

This research is motivated by the recent development of direct push probes, which have been used for the past four years to make electrical resistivity measurements at an MAR pond near Watsonville, CA (Mitchell et al., 2011; Pidlisecky et al., 2012). The latest generation of these resistivity probes, built at the University of Calgary, consist of 25-35 electrodes, capable of inducing current and measuring potential difference for 96 different voltage pairs, with measurements made in the subsurface and in the pond water. Using the inversion methods described in Pidlisecky et al. (2007) and Pidlisecky et al. (2012), these probes provide electrical conductivity data with spatial resolution on the order of centimeters and temporal resolution on the order of a half-hour. This form of data provides a promising new way to characterize and monitor properties and processes below an MAR pond. The goal of this research is to use this data to obtain quantitative hydrologic information from this electrical resistivity data.

We first develop an inversion algorithm, which uses a vertical electrical conductivity profile and auxiliary hydrologic data to estimate the van Genuchten constants and saturated hydraulic conductivity. Using a synthetic case, we analyze the methods accuracy and sensitivity to temporal and spatial resolution in the electrical conductivity profile. We then test the use of this parameterization as a way to directly estimate infiltration rates. We find, in our numerical examples, that sufficient parameterization is attained with varying temporal and spatial samplings and that we could monitor infiltration rates and clogging of a pond bottom with a level of accuracy appropriate for use in modeling and management decisions. Results show that this method can be applied to a homogeneous domain or to the top layer of a vertically layered domain. This method can be used for a perfectly run infiltration test.

We then look at the case, such as in our field data, where there is uncertainty in the Archie parameters that were assumed estimable in the previous method. Here we develop and perform a stochastic inversion for the Harkin Slough recharge pond field data using a rejection sampling method to obtain a probability distribution of the subsurface properties. We use this distribution to analyze the confidence intervals on the infiltration estimation technique that was discussed earlier. We also use these results to analyze the correlation between the geophysical and hydrologic parameters to be able to reduce the inversion in future.

References

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