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Green element solutions for inverse groundwater contaminant problems

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2016

http://hdl.handle.net/10539/20616

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ABSTRACT

In this work two inverse methodologies are developed based on the Green element method for the recovery of contaminant release histories and reconstruction of the historical concentration plume distribution in groundwater. Unlike direct groundwater contaminant transport simulations which generally produce stable and well-behaved solutions, the solutions of inverse groundwater contaminant transport problems may exhibit non-uniqueness, non-existence and instability, with escalation in computational challenges due to paucity of data.

Methods that can tackle inverse problems are of major interest to researchers, and this is the goal of this work. Basically, the advection dispersion equation which governs the transport of contaminants can be handled by analytical or numerical methods like the Finite element method, the Finite difference method, the Boundary element method and their many variants and hybrids. However, if a numerical method is used to solve an inverse problem the resulting matrix is ill-conditioned requiring special techniques to be employed in order to obtain meaningful solutions. In view of this we explore the Green element method, which is a hybrid technique, based on the boundary element theory but is implemented in an element by element manner. This method is attractive to inverse modelling because of the fewer degrees of freedom that are generated at each node. We develop two approaches, in the first approach inverse Green element formulations are developed, the ill-conditioned matrix that results is decomposed with the aid of the singular value decomposition method and solved using the Tikhonov regularized least square method. The second approach utilizes the direct Green element method and the Shuffled complex evolutionary (SCE) optimization method.

Finally, the proposed approaches are implemented to solve typical problems in contaminant transport with analytical solutions besides those that have appeared in various research papers. An investigation on the capability of these approaches for the simultaneous recovery of the source strength and the contaminant concentration distribution is carried out for three types of sources and they include boundary sources, instantaneous point sources and continuous point sources. The assessment

accounts for different transport modes, time discretization, spatial discretization, location of observation points, and the quality of observation data.

The numerical results demonstrate the applicability and limitations of the proposed methodologies. It is found in most cases that the solutions with inverse GEM and the least squares approach are of comparable accuracy to those with direct GEM and the SCE approach. However, the latter approach is found to be computationally intensive.