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# Design and Use of Intermediate Scale Physical Model Experiments for Validation of Stochastically Based Subsurface Flow and Transport Theories and Models

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Considerable knowledge exists on the use of stochastically based theories and methods to model subsurface processes in naturally heterogeneous formations. Hydrologic and environmental applications of these models involve flow and transport of water and dissolved contaminants in unsaturated and saturated zones of aquifers and multiphase flow as applied to subsurface remediation. Past validation of theories and models developed for these applications primarily relied on data from field sites such as Borden aquifer in Canada, MADE site in Columbus, Mississippi, Cape Cod in Massachusetts and few others. Even though these sites are much better characterized using high resolution bore hole data than regular field sites where limited data on aquifer characteristics, water flow, soil moisture distribution and transport is available, it can be argued that extending these theories or modeling methods to other sites may have limitations as the parameters that characterize both physical and chemical heterogeneities are expected to vary drastically from site to site. In addition, in field situations when adequate data on characterization needed at all relevant scales is not available, unrealistic assumptions are made to meet the constraints of the theory or the model being tested or validated. An alternative we have pursued in our research is to use synthetic aquifers created in intermediate scale test systems. Even though all the complexities that are inherent in field systems cannot be captured exactly, laboratory systems at the intermediate scale provide the capability to incorporate necessary controls to create desired heterogeneous configurations with known geo-statistical and other relevant flow, transport and reactive process parameters to generate accurate and comprehensive data sets. These types of test systems have the added advantage that the characterization information can be obtained at any scale varying from macroscopic to the length scale of the test system. Observations can also be made using precision sensors at any observation scale without being limited such as in field systems where the data generally comes from sparsely distributed monitoring wells. The synthetic aquifers can be packed and experiments could be designed to simulate the critical processes that are fundamental to the theory or the model being tested or validated. This paper presents several past studies that used two and three-dimensional intermediate scale synthetic aquifers on water flow, tracer methods, reactive transport, multiphase flow, assimilation of soft and hard data for model calibration and up-scaling of mass transfer. How intermediate scale test systems could be used for such investigations will be discussed. Proposed use of similar testing methods for applications in near surface soil moisture affected by land/atmospheric boundary conditions and carbon sequestration and leakage will be discussed.