The Dynamics of Vadose Zone Transport: A Field and Modeling Study Using the Vadose Zone Observatory

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Research Objectives

A stated need of the DOE EM program is a better understanding of basic vadose zone fluid flow and contaminant transport processes for the purpose of making improved estimates of contaminant release rates and fluxes across the vadose zone to the water table at DOE sites such as the tank farms at Hanford. We propose to investigate details of the modes of contaminant transport with the aid of infiltration experiments designed to elucidate how vadose zone characteristics such as preferential pathways, heterogeneities, and relative permeabilities influence the transport of contamination in liquid, gas and colloidal phases to the water table. Beyond enhancing our basic understanding of vadose zone transport processes, this proposed effort would result in a vadose-zone-transport-characterization methodology that can be generalized to other DOE sites. To accomplish this, we will use the newly developed Vadose Zone Observatory (VZO) at Lawrence Livermore National Laboratory (LLNL) to carry out a partially subsidized, highly cost-effective study of multiphase fluid flow and colloidal transport in a heterogeneous unsaturated zone bearing dynamic resemblance to one type of Hanford vadose regime. The observatory consists of almost twenty instrumented boreholes and monitoring wells which traverse the 70-foot unsaturated zone including eight wells containing electric resistance tomography (ERT) arrays, four wells for electromagnetic induction tomography (EIT) and water table sampling, and four boreholes with multilevel gas-sampling ports, soil temperature sensors, gypsum blocks, tensiometers and lysimeters. The observatory uses several multichannel data loggers to continuously store information about surface barometric pressure, subsurface gas-phase pressure, subsurface temperature, capillarity and water-table levels that is downloaded into computers for later analysis. Using the capabilities of the VZO, we will continuously monitor the progress of an infiltration event simultaneously using both geophysical volumetric imaging techniques as well as more conventional hydrologic measurements (e.g., subsurface temperature, gas-phase pressure, tensiometry and lysimetry) that involve making observations at discrete points throughout the infiltration volume. An advantage of this approach is that volumetric imaging provides a context for interpreting the discrete observations, while discrete measurements provide a more detailed picture of changes in the vadose zone that cannot be obtained from the volumetric imaging observations themselves. Beyond this, the VZO permits samples of moisture and gases to be taken from many different depths in the vadose zone and from the water table. This ability to sample is critical to our infiltration experiments, which include a variety of chemical and isotopic gas- and liquid-phase tracers and colloidal particles. The release of chemical and isotopic tracers during infiltration events is an important feature of these proposed experiments since such tracers permit evaluation of the potentially complicated relationship between actual chemical transport and fluid flow in the unsaturated zone as determined by ERT or other imaging methods. With the goal of providing a comprehensive picture of multiphase vadose zone flow and transport, LLNL's NUFT (Non-isothermal Unsaturated Flow and Transport) computer program will be used to develop diagnostic models that serve as a framework for interpreting the wide variety of observations obtained during an infiltration experiment. With support from a hydrogeologist at Hanford, modeling will also provide the basis for applying our enhanced understanding of contaminant transport at the VZO to addressing transport issues at Hanford. Finally, by carrying out some infiltration experiments jointly with other LLNL principal investigators and a geophysical instrumentation company, we will leverage our effort as well as collaborate with them in developing improved subsurface imaging interpretations and technologies based upon the ERT and electromagnetic induction methods. In support of DOE educational programs, this proposal involves the participation of an MS-level student intern as well as a postdoctoral researcher.