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Large-Scale Transport Model Uncertainty and Sensitivity Analysis: Distributed Sources in Complex, Hydrogeologic Systems

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The Underground Test Area (UGTA) Project of the U.S. Department of Energy, National Nuclear Security Administration Nevada Site Office is in the process of assessing and developing regulatory decision options based on modeling predictions of contaminant transport from underground testing of nuclear weapons at the Nevada Test Site (NTS). The UGTA Project is attempting to develop an effective modeling strategy that addresses and quantifies multiple components of uncertainty including natural variability, parameter uncertainty, conceptual/model uncertainty, and decision uncertainty in translating model results into regulatory requirements. The modeling task presents multiple unique challenges to the hydrological sciences as a result of the complex fractured and faulted hydrostratigraphy, the distributed locations of sources, the suite of reactive and non-reactive radionuclides, and uncertainty in conceptual models. Characterization of the hydrogeologic system is difficult and expensive because of deep groundwater in the arid desert setting and the large spatial setting of the NTS. Therefore, conceptual model uncertainty is partially addressed through the development of multiple alternative conceptual models of the hydrostratigraphic framework and multiple alternative models of recharge and discharge. Uncertainty in boundary conditions is assessed through development of alternative groundwater fluxes through multiple simulations using the regional groundwater flow model. Calibration of alternative models to heads and measured or inferred fluxes has not proven to provide clear measures of model quality. Therefore, model screening by comparison to independently-derived natural geochemical mixing targets through cluster analysis has also been invoked to evaluate differences between alternative conceptual models.

Advancing multiple alternative flow models, sensitivity of transport predictions to parameter uncertainty is assessed through Monte Carlo simulations. The simulations are challenged by the distributed sources in each of the Corrective Action Units, by complex mass transfer processes, and by the size and complexity of the field-scale flow models. An efficient methodology utilizing particle tracking results and convolution integrals provides in situ concentrations appropriatefor Monte Carlo analysis. Uncertainty in source releases and transport parameters including effective porosity, fracture apertures and spacing, matrix diffusion coefficients, sorption coefficients, and colloid load and mobility are considered. With the distributions of input uncertainties and output plume volumes, global analysis methods including stepwise regression, contingency table analysis, and classification tree analysis are used to develop sensitivity rankings of parameter uncertainties for each model considered, thus assisting a variety of decisions.

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