Assessing the Regulatory Consequences of Underground Nuclear Weapons Testing with Parameter and Conceptual Uncertainty - Frenchman Flat, Nevada

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Underground nuclear testing via deep vertical shafts was conducted at the Nevada Test Site (NTS) from 1951 until 1992. The Frenchman Flat area of the NTS was used for seven years, with 10 underground nuclear tests conducted. The Underground Testing Area (UGTA) Subproject is currently conducting correction action investigations to ensure the protection of the public. Part of these investigations involves developing a groundwater flow and transport model to be used, in consultation with regulatory authorities, for determining appropriate measures to protect human health.

The metric used for regulatory decision making is the 5% probability of exceeding the U.S. Environmental Protection Agency's *Safe Drinking Water Act* (the groundwater quality standard of the State of Nevada), computed for each of the models. Traditionally, model parameters have been the focus of uncertainty analysis to make regulatory decisions with groundwater modeling. However, significant forecast variations may also arise due to incomplete understanding of the subsurface geologic framework and other conceptual uncertainties. There is a growing understanding that the modeling paradigm should be expanded to include plausible conceptual models of the system and its associated parametric uncertainty in order to better assess forecast uncertainty.

In Frenchman Flat - where the geology includes basin-and-range normal and strike-slip faults, a detachment fault, and Mesozoic-age thrust faults overprinted by extensive Tertiary volcanism - geologic framework uncertainty was directly addressed by developing multiple possible models of the geologic framework that were tested for their ability to match observed hydrologic conditions. Flow model parameter uncertainty for selected frameworks was addressed using

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null-space calibration-constrained Monte Carlo analysis. This suite of flow models was combined with transport parameter uncertainty via Latin Hypercube sampling to provide contrasting views of uncertainty for use in regulatory decision making. Transport model conceptual uncertainty was also found in the radionuclide release processes associated with the shock-altered rocks near the tests.

Examining a simple proxy for contaminant transport, groundwater flow through the source area, for all the models showed that the uncertainty from alternative geologic models was not strongly different from parameter uncertainty. The biggest change in forecast uncertainty resulted from incorporating velocity and flow direction constraints derived from geochemical relationships, local characterization data, and parameter limits based on bounding conceptual models for faults and the relationships among rock properties.

The ensemble of model results is to be used for regulatory decision making. The regulatory strategy calls for the model transport forecasts to be iteratively evaluated using field data collection for consistency of behavior and uncertainty in key areas. Confidence in model results will be developed through initial model evaluation wells and continued ground-water quality monitoring, and the uncertainty in model forecasts will be managed through institutional control of areas of groundwater contamination.

Model development experience from Frenchman Flat suggests that uncertainty analysis, whether parameter or conceptual, that focuses on changes to model outcomes that are not informed only by calibration data may be more useful to decision makers than a general “uncertainty analysis”. So far the approach described above has received favorable regulatory review. However, consideration of more complex forms of uncertainty – conceptual model uncertainty – has created a new problem in that it is not always obvious what uncertainty, permissible with the data, actually has an impact on the decision. Complex analyses with inherent conceptual model uncertainty must be planned with the flexibility to allow exploration of this uncertainty.