Performance Evaluation Using Expert Elicitation and Long Term Environmental Monitoring Optimization for Long Term Stewardship

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Abstract: Long term environmental monitoring is a critical component of stewardship for three reasons: (1) data provide ongoing evidence of environmental compliance and protection of the public and the environment; (2) the monitoring program, in part, determines the life cycle cost and extent of stewardship; and (3) the monitoring program provides a framework to develop trust and agreement between the site steward, stakeholders, and public. Quantitative performance evaluation of the restoration or waste site system over a given compliance period (for example, 30 to 100 years) provides a mechanism for (1) estimating parameter and model uncertainties and sensitivities, (2) establishing long term monitoring objectives and metrics, (3) eliminating or reducing uncertainties in the system model, and (4) knowing when to cease monitoring. Often, the site performance evaluation is risk- and probability-based—a powerful quantitative tool to assess predictions, remedies, and institutional control approaches. For the reasons mentioned, this paper includes a discussion of performance evaluation, using expert elicitation, as a precursor to long term monitoring program design, and later, as an iterative tool to optimize and validate system management.

Federal, State, and local laws and regulations, as well as DOE Order 5400.1, provide the requirements and guidance for environmental monitoring programs. DOE draft stewardship implementation plans offer guidance, and identify the need for technically defensible monitoring programs. Long term environmental monitoring under stewardship will provide new challenges and opportunities. The National Research Council's most recent report on long term stewardship (2000) emphasizes that planning for the "long term" must entail considerations of continual change and system failure. State-of-the-art methods for evaluating long term monitoring effectiveness, cost, and improvement are discussed briefly in this paper, and detailed in a new American Society of Civil Engineers Monograph (Minsker et al. in preparation). Optimization methods fall within four broad categories: (1)

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regulatory and decision-logic, (2) statistically-based, (3) probabilistic and simulation, and (4) mathematical optimization.

A requirement for siting, licensing, operation, and safe closure of radioactive waste disposal sites is the preparation and maintenance of a site-specific performance assessment (PA). A PA is a series of analyses conducted (1) to determine potential radiological risks posed by a waste management system to the public and the environment over an established compliance period (usually 1,000 to 10,000 years), and (2) to compare these risks to established performance objectives. Performance Assessment is the mechanism that integrates the source term, conceptual model(s), release and pathway scenarios, and dose calculations to long term monitoring and maintenance over the compliance period. Technical uncertainties identified in the PA are systematically reduced by data collection, field studies, research and development, etc. to provide greater confidence in iterative results and to ensure long term protection of the public and environment. Results of the PA are used to effect regulatory decisions and facility operation regarding disposal configuration, waste acceptance criteria, safety, site characterization, closure design, long term monitoring and maintenance.

Similar to its application for radioactive waste site management, performance evaluation of remedial sites targeted for closure and stewardship management is a powerful quantitative tool to assess predictions, remedies, and institutional control approaches. Quantitative performance evaluation of the site system over the compliance period provides a mechanism for (1) estimating parameter and model uncertainties and sensitivities, (2) establishing long term monitoring objectives and metrics, (3) eliminating or reducing uncertainties in the system model, and (4) knowing when to cease monitoring

Performance evaluation can be conducted following a deterministic or probabilistic approach, or a combination of both. Under a deterministic approach, a range of standard release and pathway scenarios are constructed by the analyst, then doses are calculated under the assumption that the scenarios will occur without consideration of the likelihoods of the scenarios. This approach is characteristically conservative, worst case, and tends to overestimate dose exposures to the receptors. On the other hand, a probabilistic approach to scenarios takes the likelihood of occurrence into account, allowing a mechanism to differentiate between site characteristics and accessability. Projection of impacts from remedial and disposal sites can go far into the future. Long term processes and events are highly site-specific, so each site should choose to include only those that are pertinent to the individual site. Along the same line of reasoning as scenario development, site-specific mathematical models allow an accurate representation of the facility.

In determining realistic scenarios for future site use and disturbance (i.e. intrusion), the effectiveness of institutional controls, and to document stakeholder/public input, expert elicitation has proven to be an effective tool (Black et al. 2001). Elicitation is the process of formally capturing judgement or opinion from a panel of recognized experts regarding a well-defined problem, relying on their combined training and expertise (Meyer and Booker 1991). An important ingredient of the process is the development of models and assumptions, and the sharing of information among all participants to ensure that the results are credible. Expert judgement has proven to be very useful for evaluating rare or poorly understood phenomena and for forecasting future events; those that are not readily predictable by conventional means of data reduction. For example, uncertainty exists in defining the values and practices of future societies, volcanic events that may put a repository at risk, and hydrogeologic processes that may determine land use or desertification.

Expert elicitation can be used by federal agencies, state regulators, advisory boards, stakeholders and the public to address challenging policy issues associated with environmental stewardship and long term monitoring, especially over extended time periods. As an example, Black et al. (2001) convened a stakeholder workshop and Subject Matter Expert (SME) panel to determine: (1) site-specific scenarios for inadvertent (i.e. unknowing and unplanned) human intrusion into radioactive waste disposal sites at the Nevada Test Site, and (2) the effectiveness of management controls to eliminate or reduce the probability of human intrusion. The SMEs determined that inadvertent human intrusion was most likely to occur through water well drilling atop the waste site. The SMEs also concluded that institutional control and site knowledge may be important factors in deterring intrusion for the first several hundred years. However, surface barriers, designed properly, could be very effective in preventing the siting of a drill rig atop the waste site for the long term. Subsurface barrier, placards, and markers were judged to be less effective in preventing intrusion. These conclusions of the SME panel were forwarded to DOE Management for integration in the PA, for consideration in closure cap design, and long-term monitoring.

The first recommendation of the authors of this paper is to use performance evaluation in an iterative approach to guide long term monitoring activities. In this way, the residual source term, conceptual model(s), release and pathway scenarios, and dose/exposure calculations are linked to long term site monitoring and maintenance over the compliance period. The second recommendation is to use subjective elicitation, where possible and practical, to capture the judgement and opinion of third-party experts regarding events (i.e. scenarios) and processes (i.e. management control factors) that are not readily determined by conventional methods. Very often, site-specific scenarios and forecasted future events, bear heavily on the outcome of dose and exposure calculations; they also indirectly determine priorities for monitoring media, parameters, site locations, and frequencies. The final recommendation is to integrate state-of-the-art methods for evaluating long term monitoring effectiveness, cost, and improvement, as detailed in a new American Society of Civil Engineers Monograph (Minsker et al. in preparation). Optimization methods fall within four broad categories: (1) regulatory and decision-logic, (2) statistically-based, (3) probabilistic and simulation, and (4) mathematical. These four categories cover the range of simple regulatory approaches for monitoring, such as “one upgradient, three downgradient,” to more complex deterministic and stochastic optimization methods.

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