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Sensors and Monitoring Techniques for the Deep Unsaturated Zone: Reducing Uncertainty Related to Seepage and Transport in Fractured Rock

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Planning for performance confirmation of hydrologic properties and processes in a potential geologic repository for high-level radioactive waste at Yucca Mountain is a requirement stated in Subpart F of 10 CFR Part 63. An important goal of performance confirmation is to acquire information indicating whether natural and engineered barriers are functioning as intended, and whether the conditions encountered are within the limits assumed during a licensing review. Long-term monitoring of hydrologic properties and processes and in situ confirmation of design assumptions will play a key role in the safe operation of the potential geologic radioactive waste repository and in the decision to close the repository.

Despite remarkable advances in cyberinfrastructure for linking sensors into spatially distributed environmental networks, the extended time horizon (decades to hundreds of years) for long-term monitoring activities, the harsh thermal and radiative conditions in the near-field environment, the deep fractured unsaturated rock environment at Yucca Mountain, the potential scope of observations, and restricted access to observation ports for maintenance and upgrades each present unprecedented challenges to the design of hydro-environmental monitoring networks. Activities for performance confirmation could include the use of pore water samplers and sensors for measuring water content, matric potential, temperature, relative humidity, and water and gas fluxes. Current sensor technology for deep fractured rock systems (i) lags behind environmental observatory network solutions for surface and near-surface processes, (ii) lags behind analogous technology for unconsolidated porous media, (iii) cannot be reliably deployed without ongoing maintenance or replacement at relatively frequent intervals, and (iv) is not designed to withstand harsh thermal and radiative conditions.

Long-term monitoring could require special design considerations, such as measurement redundancy, built-in self-calibration and quality assurance measures, a staged and upgradable monitoring network design, and a focused initiative for development of appropriate technologies. Safe repository operation and long-term stewardship call for concerted efforts to advance sensor technology and for strategic planning to overcome these challenges.