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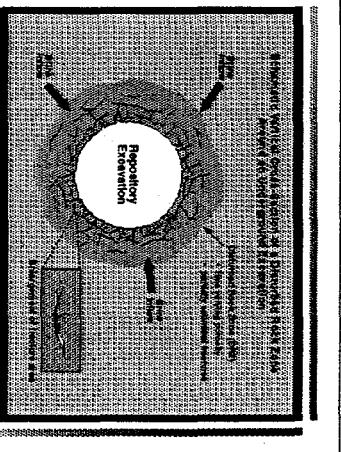
Considerations In Modeling Groundwater Inflow To Underground Repositories

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Introduction

Groundwater in and around underground radioactive waste repositories has several potential effects on repository performance. Repository excavation produces conditions where the repository is underpressured relative to the surrounding host rock, resulting in groundwater inflow to the repository. The presence of groundwater has been shown to enhance gas generation from emplaced waste forms, which in turn expedites repository pressurization. Repository pressurization results in an increased driving force for dissolved radionuclide movement away from the repository.

Repository excavation also produces a zone surrounding the repository having disturbed hydrologic and geomechanical properties. Within the disturbed rock zone (DRZ), intrinsic permeability and porosity change over time due to the formation of microfractures and grain boundary dilation. Additionally, elastic and inelastic changes in pore volume, driven by excavation-related stress redistribution, may cause variations in the near-field fluid pressure and fluid saturation distributions that influence groundwater flow toward the repository excavation. Increased permeability, decreased pore-fluid pressure, and partially saturated conditions within the DRZ contribute to enhancing potential release pathways away from the repository. It is important for a repository performance assessment to consider chemical processes (gas generation), hydrologic processes (multiphase groundwater and gas flow), and geomechanical processes (time-dependent DRZ changes) as well as the complex coupling between these processes.



Brine Inflow to WIPP Room Q

An approach to include time-dependent DRZ property changes in a numerical model of multiphase groundwater flow is demonstrated with an application to brine flow around the Waste Isolation Pilot Plant (WIPP) repository. The WIPP is a U.S. Department of Energy (DOE) research and development facility designed to demonstrate the safe underground disposal of transuranic (TRU) waste from U.S. defense-related activities. The WIPP is located in southeastern New Mexico in the bedded salts of the Permian-age Salado Formation at a depth of approximately 655 m below land surface. Room Q is an experimental room designed to gain insight into the flow processes around the WIPP repository. It is a 109 m long cylindrical room with a 2.9 m diameter that was drilled horizontally in the WIPP underground.



Following excavation, Room Q was sealed to try to prevent evaporative losses. Data were collected from inside the sealed room over a six-year period to characterize and quantify brine inflow to the room. Measured Room Q data includes brine accumulation volume, relative humidity, room closure/DRZ deformation, resistivity, barometric pressure, and temperature. Hydraulic tests were performed to determine permeability and near- and far-field pore pressures.

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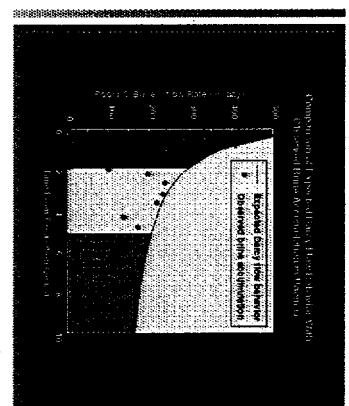
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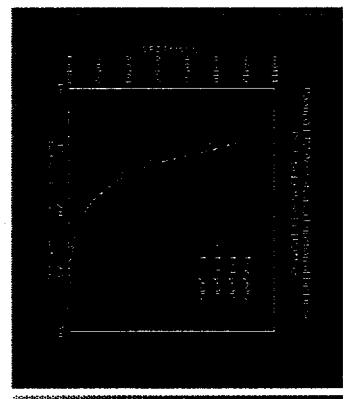
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Darcy flow from the far-field was expected to produce brine inflow to Room Q immediately following excavation. However, brine accumulation was not observed in Room Q for the first two years following excavation. The lack of measured brine accumulation in the room for the first two years following excavation is attributed to (1) far-field brine flowing into newly created DRZ porosity, and (2) evaporation of brine from the walls of the room due to ineffective seals. Measured brine accumulation in the room from 2.5 years following excavation is consistent with Darcy flow from the far-field. The lack of measured brine accumulation after 5 years is due to a problem with brine collection and does not reflect a change in brine flow behavior.

Modeling Brine Inflow With a Time-Dependent DRZ Porosity

Structural and hydrologic data and observations were examined and correlated to develop a conceptual model for brine inflow to Room Q. Numerical simulations were performed with an enhanced version of the multiphase flow code TOUGH2, capable of simulating far-field Darcy flow combined with time-dependent increases in DRZ pore volume. The time-dependent DRZ porosity changes were based on observed room closure and deformation and on simulation results from the geomechanical code SPECTROM-32. A constitutive model for salt deformation, implemented in the SPECTROM-32 code, was used to predict room closure and DRZ formation around Room Q. The SPECTROM-32 simulations calculated damage stress, total volumetric strain, and inelastic strain. Inelastic strain is representative of increased interconnected porosity of the salt. The calculated inelastic strain was used to construct relationships in TOUGH2 between DRZ porosity, time, and distance from the excavation.



TOUGH2 simulation results of brine inflow to Room Q were compared with measured brine accumulation in the room. Simulation results show that early-time brine inflow to the room can be reduced to zero if an increasing DRZ porosity with time is simulated. Reasonable assumptions about the DRZ pore volume can produce enough new DRZ porosity in the first 2 years such that brine inflow to the room is zero. This behavior is consistent with the lack of observed early-time brine accumulation in Room Q. Simulation results also show good agreement with observed brine inflow from 2.5 years following excavation. Sensitivity simulations indicated that early-time brine inflow to the room was very sensitive to the DRZ pore volume. It is therefore important to obtain good estimates of inelastic strain before applying this methodology.

Summary and Conclusions

The proposed model, which uses far-field Darcy flow and a time-varying DRZ porosity, reproduces observed brine inflow to WIPP Room Q. This type of flow behavior, demonstrated using an example in bedded salts, should be expected in any geologic formation where a significant DRZ forms around a repository excavation. This flow behavior is important, because a delay or reduction in groundwater inflow may impact operational phase planning and can limit gas generation and reduce the pressure buildup in a repository.