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MODELING THE EFFECT OF EXCAVATION-DISTURBED-ZONE POROSITY INCREASE ON GROUNDWATER INFLOW TO AN UNDERGROUND REPOSITORY

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Introduction

The excavation of underground radioactive waste repositories produces conditions where the repository is underpressured relative to the surrounding host rock, resulting in groundwater inflow to the repository. Groundwater, ranging from relatively fresh water in sedimentary and crystalline rocks to highly saline brine in salt formations, has been shown to enhance gas generation from emplaced waste forms, which in turn expedites repository pressurization (NEA, 1992). Repository pressurization from waste-generated gas 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 this 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 also contribute to enhancing potential release pathways away from the repository.

Freeze et al. (1995a; 1995b) describe an enhanced version of TOUGH2 (called TOUGH28W) and its application to model the coupled processes of gas generation, multiphase flow and geomechanical deformation at the Waste Isolation Pilot Plant (WIPP) repository. This paper describes a new application of TOUGH28W that couples time-dependent DRZ property changes with multiphase groundwater flow around an underground excavation at WIPP. The results are relevant not only to other salt repositories, but also to repositories in other geologic formations where groundwater inflow and DRZ effects are a concern.

Brine Inflow to WIPP Room Q

The WIPP is a U.S. Department of Energy (DOE) facility designed for 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

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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, which includes brine accumulation volume, relative humidity, room closure/DRZ deformation, resistivity, barometric pressure, and temperature, are summarized in Jensen et al. (1993a; 1993b). Hydraulic tests were performed to determine permeability and near- and far-field pore pressures.

Darcy flow from the far-field was expected to produce brine inflow to Room Q immediately following excavation (Figure 1). 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 might be 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 5.5 years is due to brine leakage under a test zone seal and does not reflect a change in brine flow behavior. Scoping calculations suggested that evaporation may not be responsible for all of the early-time brine loss. Therefore, a modeling study was performed with TOUGH28W to examine the influence of a time-dependent DRZ porosity on brine inflow to Room Q.

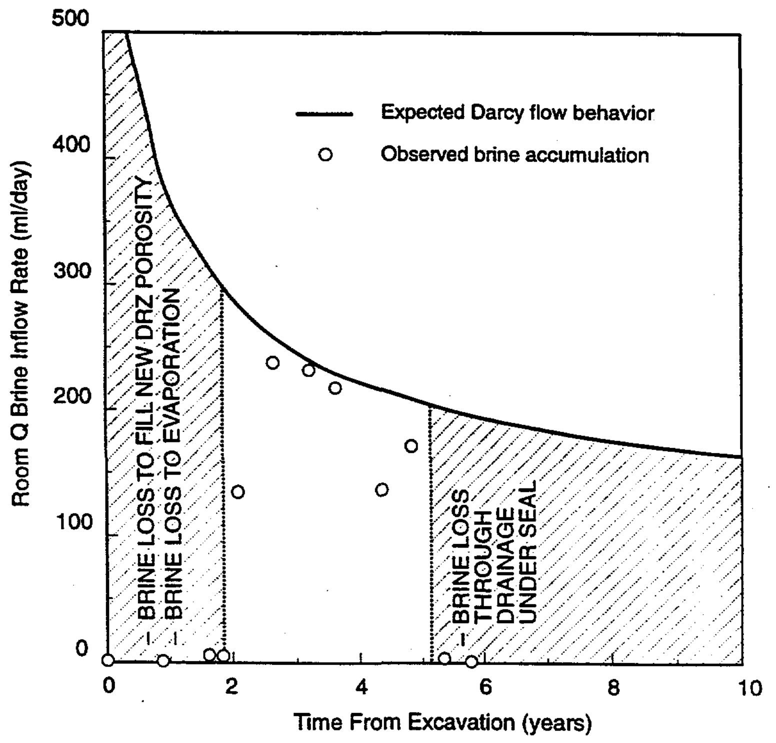

Figure 1. Comparison of expected Darcy flow behavior with observed brine accumulation in Room Q.

Modeling Brine Inflow Coupled With a Time-Dependent DRZ Porosity

Structural and hydrologic data and observations were examined to develop a conceptual model for brine inflow to Room Q that assumes far-field Darcy flow combined with an increasing DRZ pore volume. Numerical simulations were performed with TOUGH28W to examine the influence of a time-dependent DRZ porosity on flow into Room Q. 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 look-up table relationships in TOUGH28W between DRZ porosity, time, and distance from the excavation (Figure 2). At the end of each TOUGH28W iteration, the DRZ porosity was adjusted to match the temporal and spatial SPECTROM-32 prediction of DRZ porosity. TOUGH28W pressures and saturations then equilibrated with the porosity in subsequent iterations.

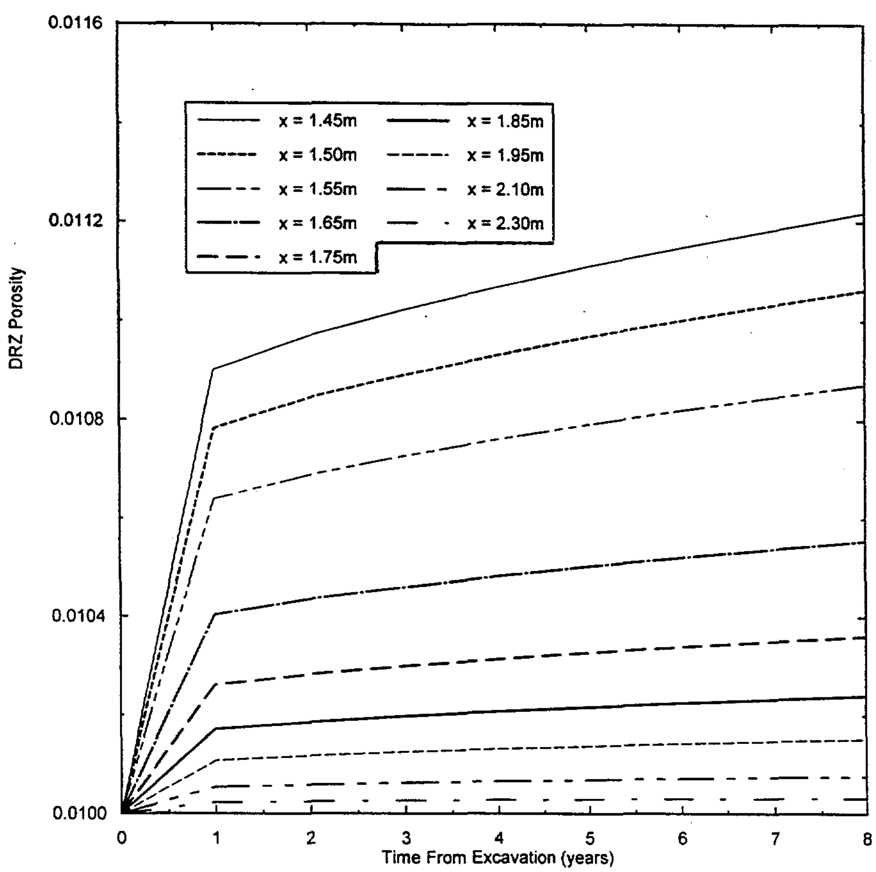

Figure 2. Room Q DRZ porosity as a function of time predicted with SPECTROM-32.

TOUGH28W simulation results of brine inflow to Room Q were compared with measured brine accumulation in the room. Simulation results (Figure 3) 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.

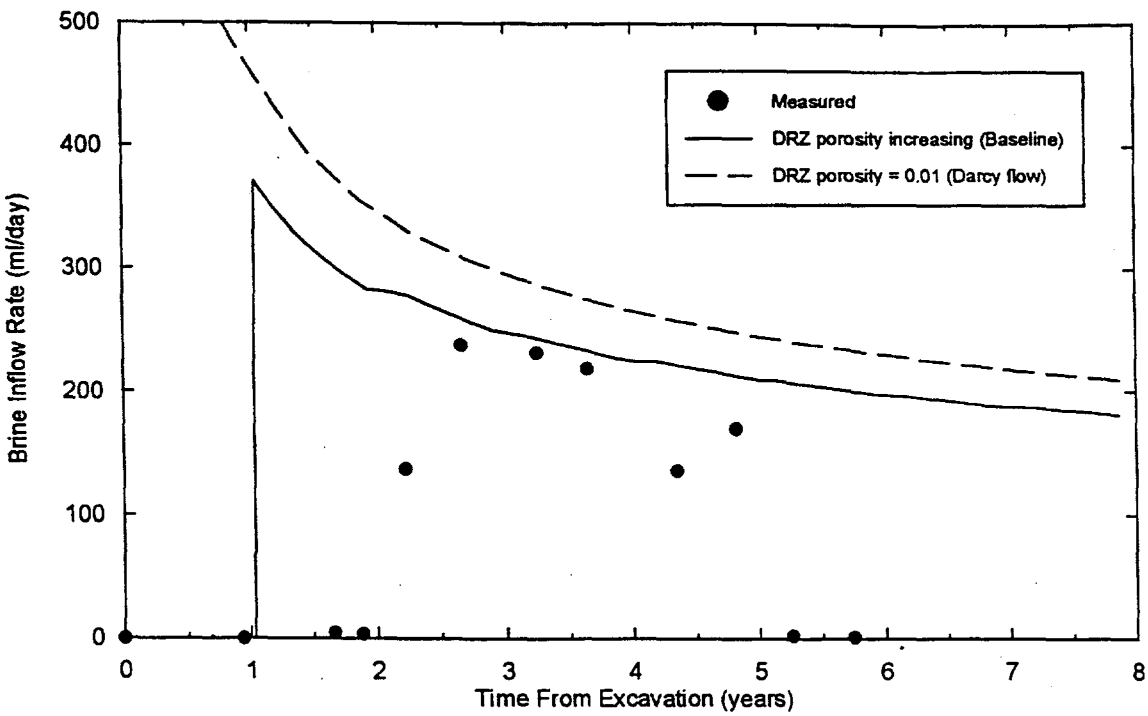

Figure 3. TOUGH2 simulated brine inflow to Room Q combining far-field Darcy flow with time-dependent DRZ porosity increases.

Summary and Conclusions

The proposed model, which uses far-field Darcy flow and a time-varying DRZ porosity, reproduces the measured Room Q brine accumulation data. Early-time brine inflow to Room Q can be reduced to zero if the DRZ porosity increases with time in a manner consistent with room closure/rock mechanics calculations. This type of flow behavior, demonstrated using an example from the WIPP repository 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 can limit gas generation and reduce the pressure buildup in a repository.

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