S-6: DYNAMIC ALTERATION OF THE DRZ/TRANSITION ZONE
Summary Memo of Record

Date: September 28, 1995

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Subject: FEP Screening Issue S-6

STATEMENT OF SCREENING DECISION

FEP Screening Issue S-6 need not be included in future system-level performance assessment calculations.

STATEMENT OF SCREENING ISSUE

This screening effort evaluates the need for including dynamic alteration of the disturbed rock zone (DRZ) and transition zone (TZ) in future system-level performance assessment calculations. The DRZ and TZ will have dynamic (time-varying) porosity and permeability properties due to room consolidation, possible room expansion, and fracturing caused by high pressures. Previous performance assessment calculations modeled the DRZ and TZ with a constant porosity equal to those of the intact halite units and a constant high formation permeability. However, the DRZ and TZ may fracture in response to high, time-dependent gas generated pressures. There will be a dual effect from the formation alterations. With pressure build-up due to gas generation and creep closure within the waste, the increased porosity within the DRZ and transition zone may offer more fluid storage and resulting lower pressures. The increase in formation permeability may enhance the flow of fluid away from the DRZ and TZ. As a consequence, the constant properties used for the DRZ and TZ may not be conservative with respect to gas and brine outflow. An associated screening issue is uncontrolled fluid flow to the surface (blowout) during an intrusion into the repository. The volume of uncontrolled releases to the surface due to cuttings, spalling, and blowout during drilling is influenced by the prevailing pressure, permeability, and saturation conditions in the disposal room at the time of intrusion.

APPROACH

The DRZ and TZ will have dynamic (time-varying) porosity and permeability properties due to three processes: (1) room consolidation, (2) possible room expansion, and (3) fracturing caused by high pressures. The first two processes are addressed using reasoned arguments, while the third process is addressed using a sensitivity analysis. These approaches are summarized in this section.

<u>Time-Dependent Properties of the DRZ/TZ During Room Closure</u>

Observations to date indicate that the development of a dilational DRZ around room openings is time-dependent, i.e., both he geometric extent and amount of dilation within the DRZ increase with time, up to some limit. To the extent that dilation is significant, it would tend to allow increased brine storage between the boundary of the far-field domain and room wall. That is, it would tend to decrease observed brine inflow into the room itself. At long times, however, the DRZ (with the probable exception of the anhydrites) will largely heal and its porosity (of the halites) will return to approximately the initial porosity under lithostatic loading. Therefore, assuming that fluid pressures within the repository are relatively low at the time of final structural closure, the process of structural healing of any halite DRZ could potentially release "additional" brine into the waste disposal room.

The present model implementation assigns increased permeabilities and fixed porosities (equal to the far-field porosity values) to the DRZ and TZ. Therefore, no "additional" brine storage in the DRZ is allowed. This approach of combining elevated permeabilities with no additional brine storage has the following impacts: a) brine volumes estimated to enter the room directly are essentially those crossing the DRZ/far-field boundary as a function of time (since enhanced DRZ storage is not allowed); b) prior to the time of effective structural closure, brine inflow volumes should be overestimated (since enhanced DRZ storage is not allowed); c) the amount of additional brine that flows into the repository during the DRZ healing period is bounded and included in the brine inflow calculations. (This is because enhanced DRZ storage is not allowed and brine which would actually be retained in the DRZ is discharged directly into the repository. As long as DRZ healing does not result in porosities less than intact levels, the current treatment bounds brine inflow.); and d) after the time of structural closure, estimated brine inflow volumes should be realistically estimated or slightly overestimated (because an elevated permeability of the DRZ is retained).

Effective room closure is expected to occur (on average) within approximately 100-400 years, i.e., very early in the 10,000 year time frame of regulatory interest. Since: a) any impact of a time-dependent DRZ on fluid inflow is expected to occur very early in the regulatory timeframe; b) brine inflow volumes up to and through the time of room closure should be realistically captured by the present modeling implementation; and c) since no meaningful impact of any short-term increase in brine inflow rate during the process of final room closure can be identified, it can be concluded that it is not necessary to include numerical modeling of a time dependent DRZ at the repository horizon in long-term system-scale calculations during the room closure process.

<u>Time-Dependent Properties of the DRZ/TZ During Room Expansion (Prior to Formation/Propagation of New Fractures)</u>

Assuming that "final" room closure occurs while fluid pressures within the waste-emplacement rooms are still below lithostatic, and that far-field formation-propagation of fractures occurs only at pressures near the lithostatic load, there is the possibility of time-dependent DRZ/TZ properties at fluid pressures ranging from sub-lithostatic pressures to that required for the initiation of fracturing. Any dilational behavior within the DRZ/TZ over this pressure interval would be expressed in terms of increased permeability and local increases in porosity. The present modeling approach assumes steady-state maintenance of increased permeability, but does not include increases in porosity. The available limited experimental data base indicates approximately a four-fold increase in permeability of anhydrite interbeds at pressures below lithostatic, with extremely small increases in porosity. Due to its ability to creep structurally at rates exceeding the rate of volumetric response to internal pressurization, halite dilation over this pressure interval would not occur.

Therefore, the baseline modeling approach, which assigns increased permeability to the DRZ at all times, is conservative (overestimate fluid flow) regarding fluid flow through the DRZ over this pressure interval. Since time-dependent increases in porosity occur only in the anhydrite over this pressure interval, the baseline model is also conservative (underestimates storage) regarding potential brine and/or gas storage within the DRZ. Therefore, it can be concluded that inclusion of a time-dependent DRZ in system-scale performance calculations is not warranted for this time/pressure interval.

Time-Dependent Properties of the DRZ/TZ During Potential Far-Field Fracturing

A model for treating fracturing within the DRZ and TZ was implemented in BRAGFLO. Except for parameter values, this model is identical to the existing anhydrite interbed alteration model employed for the interbeds. In this model, formation porosity and permeability are dependent on brine pressure as described in Appendix 2 of the records package entitled "FEPs Screening Analysis for FEPs DR2, DR3, DR6, DR7, and S6". This treatment permits the representation of two important formation alteration effects. First, pressure build-up due to gas generation and creep closure within the waste will slightly increase porosity within the DRZ and TZ and offer additional fluid storage with resulting lower pressures. Second, the accompanying increase in formation permeability will enhance the flow of fluid away from the DRZ and TZ. Since an increase in porosity has a tendency to reduce outflow into the far field, parameter values are selected so that the DRZ/TZ alteration model greatly increases permeability while only modestly increasing porosity.

A series of BRAGFLO simulations were performed to determine if dynamic formation alteration of the DRZ and TZ have the potential to enhance contaminant migration to the accessible environment. Effects of all other FEP issues were turned off in the simulations. Two basic scenarios were considered in the screening analysis, undisturbed performance and disturbed performance. Both scenarios included a 1.0 degree formation dip downward to the south. Intrusion event E1 is considered in the disturbed scenario and consists of a borehole that penetrates the repository and pressurized brine in the underlying Castille Formation. Two variations of intrusion event E1 are examined, E1 Up-Dip and E1 Down-Dip. In the E1 Up-Dip event the intruded panel region is located on the up-dip (north) end of the repository, whereas in the E1 Down-Dip event the intruded panel region is located on the down-dip (south) end of the repository. These two E1 events permit evaluation of the possibility of increased brine flow into the panel region due to higher brine saturations down-dip of the borehole and the potential for subsequent impacts on contaminant migration. To incorporate the effects of uncertainty in each case (E1 Up-Dip, E1 Down-Dip, and undisturbed), a Latin hypercube sample size of 20 was used resulting in a total of sixty simulations. To assess the sensitivity of system performance on formation alteration of the DRZ and TZ, conditional complementary cumulative distribution functions (CCDFs) of normalized contaminated brine releases to the Culebra via human intrusion and shaft system, as well as releases to the subsurface boundary of the accessible environment, were constructed and compared to the corresponding baseline model CCDFs. In the baseline model calculations, the effects of all FEP issues are turned off. These comparisons provide direct information about how the inclusion of formation alteration in the DRZ and TZ may influence repository performance. In addition, blowout, cuttings, and spalling performance measures are examined. Drivers for potential releases to the surface by these mechanisms are brine pressures, brine saturations, and permeability in the waste disposal area.

RESULTS AND DISCUSSION

The DRZ and TZ are located near the repository as illustrated in Figure 1 of Appendix 1. These zones provide enhanced permeability regions that tend to increase fluid mobility near the repository and potentially enhance flow between the disposal room, borehole, shaft, and marker beds. This increase in fluid mobility may result in increased releases to the accessible environment.

CCDFs for releases to the Culebra and subsurface boundary of the accessible environment for E1 Up-Dip, E1 Down-Dip, and undisturbed cases are provided in Figure 8 of Appendix 1. Each figure compares CCDFs of normalized releases predicted by the baseline model and normalized releases predicted with formation alteration. Note that releases to the Culebra via the shaft and intrusion borehole are shown on the left side of the figure, whereas releases to the subsurface boundary of the accessible environment are presented on the right side of the figure. In each case, the curves are almost identical for most of their lengths. Note that any differences in releases are minor with the baseline CCDFs consistently above the dynamic alteration CCDFs. These results indicate that the DRZ and TZ are modeled adequately in the baseline model with a constant porosity equal to that of intact halite and a constant high permeability.

Blowout, spalling, and cuttings metrics including maximum, mean, medium, and minimum values of volume averaged brine pressures, brine saturations, porosity, and permeability in the waste region for undisturbed conditions at 100, 1000, and 10000 years are given in Table 7 of Appendix 1. Comparison of these table values with the baseline values given in Table 2 indicate that all metrics (drivers) are essentially equivalent between the two cases. Therefore, dynamic alteration of the DRZ/TZ has a negligible effect on waste room conditions relevant to releases due to blowout, cuttings, and spalling.

BASIS FOR RECOMMENDED SCREENING DECISION

Based on the CCDFs, the inclusion of dynamic alteration of the DRZ/TZ in BRAGFLO results in computed releases to the accessible environment that are essentially equivalent to the baseline case. In addition, dynamic alteration of the DRZ/TZ has an insignificant effect on waste room conditions relevant to blowout, cuttings, and spalling releases. Therefore, dynamic alteration of the DRZ and TZ need not be included in system level PA calculations.