5.0 INDIVIDUAL PROTECTION REQUIREMENTS

Section §191.15 of 40 CFR 191 provides that disposal systems "shall be designed to provide a reasonable expectation that, for 10,000 years after disposal, undisturbed performance of the disposal system shall not cause the annual committed effective dose, received through all potential pathways from the disposal system, to any member of the public in the accessible environment, to exceed 15 millirems (150 microsieverts)." The Individual Protection Requirements were addressed by DOE in Chapter 8 of the CCA.

Previous EEG Comments

The DCCA did not provide dose calculations to determine if the individual protection requirements had been met. Consequently, EEG had no comment on this requirement in our review of the DCCA (Neill et al., 1996). EEG has not made any previous written comments to DOE or EPA on Chapter 8 of the CCA.

EPA Response to Chapter 8

In the CCA DOE concluded that the only mechanism for undisturbed releases and a dose to an individual was from migration of brine from the repository in anhydrite marker beds to the accessible environment. This contaminated brine was pumped to the surface and diluted to decrease total dissolved solids to 10,000 milligrams per liter. The individual was assumed to drink 2 liters per day of this diluted water. The realization with the highest concentration of radionuclides (out of 300 realizations) was used for the dose calculation.

EPA requested that DOE provide analyses of other exposure pathways beside the drinking water pathway evaluated in Chapter 8 of the CCA. DOE provided this analysis in their February 27, 1997 response to EPA's request for additional information. The additional pathways scenarios analyzed were: (1) farm family inhalation; (2) farm family ingestion; and (3) cattle rancher. DOE dose estimates for the maximum realization were 0.47 mrem for drinking water and 0.46 mrem from ingestion (the other scenario doses were negligible).

EPA also made their own Dose Verification Evaluation and included this Technical Support Document (U.S. EPA, 1997k) with the proposed rule. Pathways evaluated were drinking water; crop, soil, meat and milk ingestion; inhalation; and direct radiation. EPA calculated doses of 0.49 mrem per year from drinking water and 0.16 mrem for all other pathways.

EPA agreed that the DOE scenario assumptions were conservative and actually unlikely. Also, that the CAG (U.S. EPA, 1996a) requirements were fully met. Therefore, they concurred in the adequacy of DOE's Individual Protection Requirement evaluation.

EEG Evaluation

The EEG checked both DOE's and EPA's dose calculations. Agreement was within 5%.

CCA calculations of the concentration and quantity of radionuclides reaching the accessible environment in the anhydrite interbeds were taken as a given by EPA. EEG has not checked these calculations either but they appear reasonable. Also, the limited quantity of contaminated water calculated to reach the accessible environment (a maximum of 216 m^3) was not invoked by DOE or EPA in their calculations. This limited quantity of contaminated water would preclude EPA's calculated 30-year radionuclide buildup in soil (which contributes less than 1% of the other pathways dose).

We consider two inhalation and soil ingestion pathways to be more likely than those considered by DOE and EPA. These are: (1) resuspension of solids from undiluted brine used for dust control about a residence; or (2) resuspension of solids from a mud pit where the contaminated brine has evaporated. The brine could be in the mud pit as a result of an aquifer pump test, an oil or gas borehole, or as a residue from a water treatment process (such as reverse osmosis). However, these scenarios result in estimated doses that are less that 0.1 mrem/y. So, these scenarios, though perhaps more reasonable, lead to lower doses than calculated by DOE and EPA.

EEG agrees that this requirement has been adequately and conservatively evaluated. We consider this to be a closed issue.

6.0 EVALUATION OF EPA'S RESPONSES TO EEG'S COMMENTS

The EPA has provided responses to some of the EEG comments on the CCA provided to the EPA before the March 17, 1997, deadline. These responses are found at the end of each Compliance Assessment Review Document (U.S. EPA, 1997b). References have been made to these responses in the relevant chapters in this report. For the sake of completeness, the EEG review of these responses are grouped together in this chapter.

Section 194.14 (CARD 14)

Issue 14.T: The probability of encountering a brine reservoir during drilling and the reservoir's potential volume are underestimated.

103. The CCA assumed that the probability of encountering a brine reservoir is a function of reported brine encounters expressed as a percentage of total boreholes drilled. The problem with this assumption is that drillers are not required to report brine encounters; moreover, drillers tend not to report such encounters unless they result in significant delays or cause other problems during operations. Thus, the eight percent brine encounter rate used in the CCA dramatically understates the actual rate, which probably lies somewhere between 50 and 100 percent. (103)

525. The EEG does not find the CCA reservoir volume assumption of 32,000 to 160,000 m^3 to be justified. (525) (II-H-12.4)

EPA response to Issue T:

EPA found that DOE's representation of brine pocket occurrence probability and brine pocket size/volume in the CCA were not consistent with available information. EPA directed DOE in letters dated March 19, 1997 (Docket A-93-02, Item II-I-01, enclosure 3) and April 25, 1997 (Docket A-93-02, Item III-I-27) to conduct new performance assessment modeling that includes modified parameter values. EPA requested that the brine pocket probability be modified to a range from 1 percent to 60 percent, and that this occurrence be sampled rather than a fixed value of 8 percent. In addition, EPA requested that the parameters regarding rock compressibility and porosity (e.g. Castile COMP_RCK), as well as how the brine pocket volume is sampled, be modified in the mandated Performance Assessment Verification Testing (DOE, 1997b and 1997c). This approach effectively modified the sampled brine pocket volume to include more representatively the possibility of higher brine pocket volumes, including that of WIPP-12. As a result of the PAVT, EPA found that the original brine reservoir characteristics were, in fact, acceptable. For more discussion on this topic, also see this CARD, section 14.B.5, EPA's Technical Support Document for Section 194.14: Content of Compliance Certification Application (EPA, 1997a) and the Technical Support Document for Section 194.23: Parameter Justification Report (EPA, 1997e).

EEG assessment of EPA response to Issue 14.T

The Performance Assessment Verification Test has demonstrated that the brine reservoir characteristics have a large effect on predicted repository pressure and brine saturation. The EEG believes that the Performance Assessment Verification Test is a valuable set of calculations that were needed to demonstrate the robustness of the performance assessment calculations.

The characterization of the potential high pressure brine pocket used in the PAVT is much more accurate than the representation used in the CCA calculations. There are two parameters used in the PAVT that are still inaccurate. First, the PAVT uses a sampled pressure range of 11.1 to 16.5 MPa gage for the Castile brine, based on regional occurrences of brine, rather than the 12.6 MPa gage measured at WIPP-12. WIPP-12 brine almost certainly protrudes under the WIPP repository. However, it was found that the pressure range used in the PAVT leads to prediction of more and larger brine releases than the single value of 12.6 MPa (Rucker, 1998).

Secondly, there is poor justification for the 1% lower end of the EPA range for the probability of encountering a pressurized brine pocket. The 60% upper end is based on an electromagnetic survey of the WIPP site (U.S. DOE, 1996c, 2.2.1.2.2) that indicates brine is likely under about 60% of the repository. Most importantly, the probability of hitting brine under WIPP should be based on local WIPP information and not the entire Delaware basin. The calculated size of the WIPP-12 brine reservoir and the existence of boreholes around WIPP-12 that have not encountered brine in the Castile constrain the WIPP-12 reservoir such that the reservoir must extend under the repository (Neill, 1997d). The brine indicated by the electromagnetic survey must be part of the WIPP-12 reservoir. Hence, the probability of encountering brine should be modeled as 60%. Thus, the PAVT under represents the probability of encountering a brine reservoir while overestimating the effect of the reservoir.

Section 194.23 (CARD 23) Models and Computer Codes

ISSUE 23.A: Cuttings/Cavings and Spallings Model

97. The CCA fails to consider cavings that occur as the drill bit passes through the waste, cavings from particle impact, cavings from helical turbulent flow, and radioactive brine ejected before spallings.

EPA Resolution of comment 97

EPA disagrees with the comments. The cavings submodel rigorously considers the impact of helical laminar flow on cavings release by numerically solving a series of non-linear integral equations. Because of complexities in the turbulent flow regime, similar mathematical treatment is not possible and it is necessary to resort to empirical procedures. DOE accounts for the helical flow component in the turbulent regime by using a rotation factor (F) which increases the erosion as compared to that calculated by uniaxial flow (Docket: A-93-02, II-G-1, Volume V, Appendix CUTTINGS_S, WPO #37765, page 47). For radioactive brine to be ejected from an inadvertent human intrusion borehole which penetrates waste, two conditions must be met (Docket: A-93-02, II-G-1, Volume 1, Chapter 6, Section 6.4.7.1.1, page 6-152):

The waste must be under sufficient pressure to drive the drilling mud from the borehole (greater than 8 MPa). Mobile brine contaminated with radionuclides must be present.

The direct brine release conceptual model as implemented with the BRAGFLO_DBR code addresses this issue of ejection of radioactive brine (Docket: A-93-02, II-G-5). The cavings model does not explicitly consider erosion from particle impact as the drill bit passes through the waste. Any such erosion would be of very short duration (about four minutes for fully compacted waste at a drilling rate of 50 ft/h). Borehole enlargement from particle impact would produce lower flow velocities for the drilling mud and reduce the erosion calculated by the cavings model. Consequently, EPA believes that any impact from this process is included within the range of calculated cavings releases.

EEG Assessment of comment 97.

The EEG concurs with EPA's assessment.

98. The spallings model assumes constant pressure, although blow-out is a phenomenon related to pressure differentials. There are several methodological problems with the experiments (e.g., no dimensional analysis, no vent sensitivity analysis, etc.). The model considers only particle dislodgment, not lifting or lofting. Limited parameters are sampled or calculated (e.g., particle diameter, but not waste permeability, cementation strength, drill bit diameter, or radioactive content of waste).

EPA Resolution on comment 98

EPA agrees that the spallings conceptual model was initially inadequate. However, these inadequacies result in higher releases. Since the Conceptual Model Peer Review Panel found the spallings model implemented in the CCA to be inadequate, DOE conducted a significant computational and experimental program as documented in Docket A-93-02, Item II-G-23. These new computational approaches include consideration of pressure transients. On the basis of this new material, the Peer Review Panel determined that the spallings model used in the CCA resulted in the calculation of release volumes which are reasonable and may actually overestimate expected releases (Docket: A-93-02, II-G-22, Conceptual Models Third Supplementary Peer Review Report, April 1997, page 12).

The new computational approach predicts extremely small spallings volumes for all gas pressures below lithostatic pressure. EPA has concluded that, since the spallings model in the CCA considers only particle dislodgement from the waste and not lifting or lofting of dislodged particles up the borehole, the approach taken by DOE is conservative. Larger particles dislodged from the surfaces of radial fractures in the waste will not be lifted 2150 ft to the land surface. In Docket: A-93-02, II-G-23, page 1-3, the tensile strength of saturated surrogates waste was measured to be 0.074 MPa while that of dry waste was 0.15 MPa. This may be compared to a value of 1 Pa used for the cementation strength in the spallings model. Thus the tensile strength in the spallings model was conservatively assumed to be several orders of magnitude lower than determined by tensile tests on waste surrogates. As discussed in detail in Section 1.2.3.2.4. of the '194.23 Technical Support Document- Models and Computer Codes, the use of a single value for the drill bit diameter is reasonable.

In the CCA, DOE chose to treat the radioactivity released by spallings as the average radioactivity in the repository (Docket: A-93-02, II-G-1, Volume 1, Chapter 6, Section 6.4.7.1, page 6-151) and based this position on the fact that the spallings model presumed that waste was eroded from fracture channels extending over a large portion of a waste room. In contrast, radioactive releases from cuttings and cavings were based on randomly sampling three of 569 waste streams for each intrusion. In this case the argument was made that cuttings/cavings removed only a localized volume of waste. Thus, the approach taken by DOE is consistent with the conceptual model in each case (ibid., page 6-189). It may further be noted that the CCDFs for waste volume removed by cuttings/cavings and spallings are about the same magnitude (see Figures 4.2.2 and 4.4.3, right frame, mean in Helton and Jow 1996, pages 4-6 and 4-22, Docket: A-93-02, II-G-07). Thus, if waste stream variability were incorporated into spallings releases, the results would be roughly comparable to those for cutting/cavings which as can be seen in Figure 4.2.3 (ibid., right frame, mean, page 4-6) are well below the EPA release limits. Since the average activity of the CH-TRU and the RH-TRU waste is essentially the same (ibid., page 4-1), and since the spallings model considers removal of waste from throughout an entire room, omission of RH-TRU waste from the spallings model will not have a significant impact on calculated releases.

EEG assessment of comment 97

The newer spallings model (Hansen et al., 1997) and subsequent peer review resolves this comment. However, the issue of an adequate spallings model remains. As shown in Section 2.4 of this report, the newer codes fail to model expected repository conditions.

This is still a major concern.

262b. The CCA fails to consider RH-TRU waste in the spallings scenario.

EPA Resolution on comment 262b

EPA agrees [sic]. EPA believes that combining the RH-TRU waste streams into a single volume-averaged stream is a reasonable modeling simplification. This is supported by the fact that the average activity in the RH-TRU and the CH-TRU waste is about the same while the probability of encountering CH-TRU is about seven times greater. Consequently cuttings releases are dominated by CH-TRU (Docket: A-93-02, II-G-07, Helton and Jow 1996, page 4-1).

DOE Response to issue

669 The conceptual models used to characterize the spallings and direct brine release processes were developed to describe the effects of rapid depressurization of large volumes of interconnected, homogeneous, and relatively permeable waste material. The models do not apply to the effects of rapid depressurization on the relatively small and relatively well isolated volumes anticipated for the RH-TRU waste. RH-TRU waste will be emplaced in boreholes in the halite walls of the waste disposal region. . .The volume of pressurized fluid available within a single RH-TRU canister will be far too small to displace the drilling fluid within the borehole, and therefore intrusions directly into an RH-TRU canister are very unlikely to result in a spall or direct brine release event. Intrusions into CH-TRU, waste near an RH-TRU emplacement borehole will draw spalled material and contaminated brine from the more permeable CH-TRU waste, rather than from the RH-TRU waste. It is therefore correct not to apply the spallings and direct brine release models to RH-TRU waste. (II-H-21.26)

670 DOE chose to model cuttings and cavings releases of RH-TRU waste using a single, average activity level for RH-TRU waste based on consideration of information available

in the Baseline Inventory Report (BIR) Rev. 2 (Appendix BIR of the CCA). Individual waste streams are reported for RH-TRU waste. Most of these waste streams represent small volumes of material, however, and the probability assigned to the penetration of many of these individual categories by an intrusion borehole would have been below the regulatory threshold of 10^{-3} in 10^{4} yr. Rather than neglect these low-probability events, the DOE has included them in the analysis by lumping them, and their activity loads, into a single category with the other, more abundant RH-TRU waste that dominates the volume-averaged activity of RH-TRU waste used in the performance assessment. The activity levels that might be calculated by random combinations of large numbers of waste streams plus backfill would closely resemble the overall average activity. (II-H-21.27)

EEG assessment of EPA comment resolution

The EEG is satisfied that neglecting RH-TRU in spallings calculations and using a single waste stream to represent RH-TRU in the cuttings and cavings model are acceptable modeling approximations. The primary reasons for this assessment are that RH-TRU will be less that 1% by volume of the transuranic inventory of the repository and that the high activity levels in the RH-TRU waste are from fission products that will have significantly decayed in the first two hundred years of burial. While the present activity of RH-TRU waste varies many orders of magnitude, the transuranic content of the waste does not.

535 The spallings model is defined as gas driven entrainment of solid particles. The spallings model should include the effects of brine. (II-H-12.14)

EPA Resolution of Comment

EPA disagrees with the comment. Spallings occurs only if the pressure in the intruded waste panel exceeds 8 MPa. As the gas pressure increases, the brine saturation in a waste panel decreases (Docket: A-93-02, II-G-07, Helton and Jow 1996, page 5-1). Thus, at pressures where spallings can occur, less brine is available for release. In addition, the spallings model uses the average radionuclide concentration in the waste to develop the source term (ibid., page 4-7). If some radionuclides are dissolved in brine which is transported along with solid waste to the surface, this radioactivity will have been accounted for by the solid material since mass must be conserved. The spallings model addresses all the radioactivity as if it remained with the solids rather than partitioned between the solid and the brine. Direct brine releases in which brine flows up the borehole after intrusion are accounted for by the direct brine release model (Docket: A-93- 02, II-G-05). EPA believes that this "double counting" of solid spall releases and waste mobilized by brine overestimates releases from these mechanisms and therefore is adequate for use in PA and is conservative.

EEG assessment of EPA comment 535 resolution

In light of the newer spallings model (Hansen et al., 1997), the inclusion of brine release in the spallings model is a minor concern.

536 With the composition of the waste ranging from large pieces of metal to ash, it is unlikely that the waste will degrade to a uniform grain size. There has been no analysis to show that the releases calculated by sampling for a uniform distribution size bounds the release from a heterogeneous medium. (II-H-12.15)

EPA resolution of comment

EPA agrees that a uniform particle size is not appropriate. The CCA does not assume that waste degrades to a uniform particle size. Waste particle diameters in the spallings model were assumed to be distributed log-uniformly from $4x10^{-5}$ to 0.2 m (Docket: A-93-02, II-G-1, Appendix PAR, page PAR-115). Spallings releases are dominated by transport to the surface of solids of small particle size (see, for example Fig. 4.3.5 in Helton and Jow 1996, page 4-14,Docket A-93-02, II-G-07). Since use of a loguniform distribution biases parameter selection during LHS sampling to smaller (i.e., more conservative) values, releases will be higher with this parameter distribution. In addition, it was deduced from the findings of the Expert Elicitation Panel on waste particle diameters that the particle range was most probably between 1 mm and 10 cm which would reduce the spallings release (Memorandum entitled "Estimate WIPP Waste Particle Sizes Based on Expert Elicitation Results: Revision 1" from Yifeng Wang to Margaret S. Chu and Mel G. Marietta, Sandia National Laboratories, SNL WPO# 46936, June 27, 1997). The use of the mean particle size in determining the shear strength of the waste is a reasonable approach to characterizing the fact that the waste does not have a uniform particle size.

EEG's assessment of the EPA comment resolution

The EPA missed the point of this comment. The spallings model used for the CCA calculations did assume a uniform particle size. The uniform size was assumed to be uncertain and was therefore sampled from a range. However, the issue is no longer pertinent to the CCA because of the development of the newer spallings model.

537 [DOE argues that] a larger initial spall will be followed by less erosion than a smaller initial spall, resulting in the same final void ration. We find two errors in this argument: 1) The pressure difference between the waste repository and the hydrostatic pressure of the drilling mud can be over 6 MPa, three orders of magnitude above pressure differential need for explosive spall. 2) The second argument presupposes, without justification, that the erosion volume is larger than the initial spall volume and that the cavity caused by the initial spall will be partially filled by the erosion process. (II-H-12.16)

539 The spallings model does not include a sensitivity to scale leading the developers of the spallings model to state extrapolation of release volumes to WIPP, using the parameters evaluated using small scale laboratory models, has the potential for grossly under-predicting such releases. (II-H-12.18)

EPA resolution of comments 537 and 539

The CMPRP was not satisfied with several aspects of the spallings model as implemented in the CCA (see, for example, Docket: A-93-02, II-G-1, Volume XII, Appendix PEER, PEER 1, page 3-88 to 3-93). However, based on additional information subsequently developed by DOE and included in the Spallings Release Position Paper (Docket: A-93-02, II-G-23), the Panel concluded that the model was reasonable and probably conservative (Docket: A-93-02, II-G-22, page 12). EPA agrees with this position and believes this responds to EPA's initial concerns.

538 The model tests the erosion portion of the spallings phenomena for waste with no cohesive strength, but not the initial explosive phase, nor the effect of cohesion. (II-H-12.17)

EPA resolution of comment 538

EPA disagrees with the comment. The spallings model used in the CCA assumed that the cementation strength of the waste was 6,895 Pa or 1 psi (Docket: A-93-02, II-G-10, Appendix PAR, page PAR-190, ID #3245). Testing of surrogate waste mixtures as described in Spallings Release Position Paper (Docket: A-93-02, II-G-23, page 1-6) indicated that the strength of the waste was substantially higher than assumed in the CCA with the average tensile strength of saturated waste being 74,000 ± 40,000 Pa. Thus, the amount of spallings should be reduced as compared to that calculated in the CCA. (see response to comment 537 above.) EPA believes this increased waste strength would mitigate the impact of the "initial explosive phase" and that total releases would be well below the 0.5 to 4.0 m^3 range used in the PAVT calculations.

EEG's assessment of the EPA resolution of comments 537, 538, 539

EPA's assumption that the new spallings model is adequate to answer all spallings' concerns does not address EEGs' concerns. EEG believes that relying solely on the results from the new spallings model may be underestimating the importance of the issue. For example, the new spallings model cannot simulate all expected repository conditions. Locally varying waste permeability or different gas viscosities cause the code to produce erroneous results. It is therefore suggested that the EPA look more closely at the newer model before dissmissing any comment on spallings.

540 The "gas erosion" and the "stuck pipe", considered by the DOE in earlier performance assessments, have been excluded from the CCA spallings model. These two phenomena could cause releases that are over an order of magnitude larger than the largest releases calculated in the CCA. (II-H-12.19)

EPA Response to comment 540

EPA does not believe it is necessary to include gas erosion and stuck pipe processes in the CCA spallings model. Gas erosion and stuck pipe releases occur only if the waste permeability is less than $1x10^{-16}$ m^2 (Docket: A-93-02, II-G-1, Appendix CUTTINGS_S, page 37). In addition, the gas pressure in the intruded panel must exceed 8 MPa for gas erosion and 10 MPa for stuck pipe processes to occur. Based on earlier experimental work, DOE used a value for waste permeability of $1.7x^{-13}$ m^2 (see discussion in Section 1.3.2.7.4 of the TSD for '194.23 - Models and Computer Codes). More recently, DOE measured the permeability of surrogate waste mixtures based on current understanding of waste mixtures and degraded waste characteristics and determined the permeability of waste surrogates to be $2.1x10^{-15}$ to $5.3x10^{-15}$ m^2 on two samples (Docket: A-93-02, II-G-23, page 2-18). Based on the available waste permeability information, EPA concluded that the gas erosion and stuck pipe processes should not occur because permeabilities will be greater than the $1x10^{-16}$ m^2 threshold.

EEG assessment of EPA comment resolution

EEG still considers “stuck pipe” and “gas erosion” as potentially important processes in the calculation of spallings releases. See Section 2.4 of this report.

ISSUE 23.F: Three Dimensional Processes and Boundary Conditions

553 The EEG concludes that the use of a 2-D geometry in the BRAGFLO may introduce significant non-conservatism into the CCA calculations. The FEP S-1 needs to be reexamined with appropriate consideration of the impact of increased brine saturation on calculated estimates. (II-H-25.4)

EPA response to comment 53

EPA disagrees with the comment. The work that is most relevant to this concern is the FEP Screening Analysis titled S1: Verification of 2D-Radial Flaring Using 3D Geometry, WBS No. 1.1.6.3, SANDIA WIPP CENTRAL FILES-A: 1.2.07.3: PA:QA:TSK:S1, ERRATA - February 19, 1996 (SNL WPO #30840). In this work, a simplified version of the two dimensional CCA PA grid was tested against a corresponding three-dimensional (3-D) model. BRAGFLO was used in both two-dimensional (2-D) and 3-D simulations, and TOUGH28W was used to model the 3-D simulations only. Simulation results were compared for cases with an average repository gas generation rate, and a gas generation rate that was double the average. The results of the second case, in which the gas generation rate was doubled, indicates that a combination of pressure induced fracturing and the 1-degree dip cause flow paths which are different for the 2-D and 3-D grids. Once fracturing of the interbeds occurs, the 3-D model displays an immediate migration of gas primarily out of the west side of the repository into the anhydrite layers, accompanied by brine inflow to the repository. This phenomenon is not seen in the results from the 2-D model, in which the west side of the repository is a no flow boundary, which demonstrates that the 2-D and 3-D simulations show local variations. However, the results also show that the predictions of brine flow to the accessible environment are similar for both 2-D and 3-D grids. With respect to increased brine saturation, Figures 7 and 12 of the FEP Screening Analysis referenced above (WPO# 30840), shows the average gas saturations calculated with the 3-D simulations of TOUGH28 and both the 2-D and 3-D versions of BRAGFLO. Simulation results are compared for the base case and twice the base case generation rates, respectively. These curves indicate that gas saturations are higher in the 2-D simulations (WPO# 30840, page 27). Since brine and gas saturations are inversely related a similar trend would be observed for the brine saturations. In the Performance Assessment Verification Test (PAVT) , it was determined that the greatest potential releases could be attributed to those associated with spallings and direct brine releases. Furthermore, these releases are pressure controlled and will not occur if repository pressures are below 8 MPa. The fact that the 2-D model may overestimate gas saturation by underestimating brine saturations will lead to the prediction of higher gas pressures than those that would have been predicted with the 3-D configuration and this will result in more conservative estimates of releases. Based on this, EPA believes that the 2-D geometry used in the BRAGFLO CCA PA calculations is a reasonable simplification and that the predicted results are conservative.

EEG assessment of EPA resolution of comment 553

The EEG does not consider this issue to be resolved. See Section 2.10 of this report

Issue 23.W: CCA Parameters and PAVT Parameter Selection

550 The data and rationale for the sampled distribution of the waste-room residual-brine saturation is presented on pages PAR-27 through PAR-31. . .The non-conservative distribution of 0 to 0.560 reduces the estimated releases of direct brine release [sic].

Appropriate ranges for the waste room residual brine saturation are a constructed distribution using values from the eight unconsolidated materials; a uniform distribution from 0.0783 to 0.277, or a uniform distribution from 0 to 0.277. (II-H-25.1)

DOE Response to the Issue

845 The comment about the distribution of 0 to 0.560 for S [residual brine saturation of wr waste] being non-conservative is not correct because one should not be using a value just because it is more conservative. Instead, the use of a particular distribution or value should be based on how closely it represents the processes being modeled and how accurately it reflects realistic expectations of what will occur in the repository. The range of 0 to 0.560 was therefore chosen on the basis of being both reasonable and realistic. (II-H- 45.6)

EPA's Response to Comment 550 and 845

The residual brine saturation is that value at which no more flow will occur even with further decreases with capillary pressure. The range used for the CCA is based on literature values for unconsolidated materials. EPA agrees with DOE's comment, in that DOE has selected a reasonably representative range value for the wastes. This parameter will change with time, as the wastes gradually compacts, the porosity will become lower and the residual brine saturation will increase due to the increased capillary pressure of the smaller pores. Therefore, the low end on the distribution represents coarse material prior to waste compaction and the high end would be representative of fairly compacted waste. EPA's basic philosophy in dealing with such uncertain parameters has been to be reasonably sure that one or more of the following criteria are true : 1) that the values selected for a parameter in question leads to conservative results; 2) that the results are relatively insensitive to that parameter, or 3) that the selective range is representative of the actual parameter values. In the case of brine saturation, the complexity of the problem does not allow a predetermination to be made regarding whether a certain range or distribution is conservative. A further complicating factor is that the BRAGFLO computer code contains a wicking function that allows gas generation to occur even if the capillary pressures are low (Appendix BRAGFLO). Based on modeling experience EPA believes that residual brine saturation is insensitive and that the selected values does not impact the final results to a significant degree. EPA is confident that the range and distribution placed on the residual brine parameter are reasonably representative of the wastes and are adequate for use in the CCA PA calculations.

EEG assessment of EPA resolution of comment 550

Based on the information presented during the January session of the conceptual model peer review panel and to the particle size expert elicitation panel that some waste may be consolidated, the range of sampled residual brine saturation of the waste in the CCA calculations was appropriate.

551 Even though the parameter ranges recommended by Beauheim are more reasonable than the ones used in the CCA, the EEG disagrees with the recommended values for reservoir volume because the range includes the value derived from testing the ERDA-6 brine reservoir and initial pressure because of the use of data from twelve other brine encounters in the Salado. . . The recommended initial pressure range of 16.5 to 11.0 MPa gage is based on pressure measurements from thirteen Castile brine encounters. At WIPP-12 the measured pressure was 12.6 MPa gage. Therefore, the reservoir pressure should be a constant value of 12.6 MPa gage in the revised CCA calculations. (II-H-25.2)

EPA’s response to comment 551

No response given.

EEG assessment of EPA resolution of comment 551

See resolution to Issue 14.T on page 224.

552 If the samples distributions of parameters used in the CCA calculations are in error, but include the likely values of those parameters, should the CCA calculations be acceptable? The EEG position is that, under the these conditions, the CCA calculations should be repeated with the best estimate of the parameter distributions available. The use of a faulty distribution of one parameter biases the CCDF curves and confuses the assessment of uncertainty. The use of more than one faulty parameter set makes the assessment of uncertainties impossible because of the complex non-linear nature of the performance assessment models. (II-H-25.3)

EPA's general response to Issue 23.W and to comment 552

EPA performed a thorough review of the parameters and the parameter development process (see Section 12.4 on requirement §194.23 (c)(4) above in CARD 23 -- Models and Computer Codes; EPA Technical Support Document for § 194.23: Models and Computer Codes (Docket A-93-02, Item III-B-6); and EPA Technical Support Document for § 194.23: Parameter Justification Report (Docket A-93-02, Item III-B-14)). EPA reviewed parameter packages in general for approximately 1600 parameters used in the CCA Performance Assessment calculations. EPA further reviewed parameters record packages and documentation in detail for more than 400 parameters important to performance of the disposal system. Records reviewed include the Docket: A-93-02, II-G-1, Volume 1, Chapter 6, Tables 6-8 through 6-27, page 101 to page 166, A-93-02, II-G-1, Volume XI, all of Appendix PAR, WIPP parameter entry forms (464 Forms), Parameter Records Packages (PRP), Principal Investigator Records Packages (PIRP), Analysis Packages (AP), and Data Records Packages (DRP). The evaluation included a review of the expectations listed in the "Compliance Review Criteria" for §194.23(c)(4) above in Section 5.4.2. As a result of substantial information gathering at the Sandia Records

Center, EPA was able to uncover on its own substantial necessary documentation supporting most of the parameters used in the CCA PA. EPA first examined the sources of different parametric values used in the computer codes. EPA found that 416 (26.4%) of the 1571 parameters used in the CCA PA calculations are well-established constants found in general literature and general engineering knowledge. EPA discovered that DOE derived 887 (56.6%) of the parameters from experimental data, either from its own experiments or from journal articles. EPA also found that 89 (5.7%) are waste-related parameters derived from the waste inventory report (see docket: A-93-02, II-I-1, Volume III, Appendix BIR). EPA found that DOE selected the values of 149 (5.9%) parameters using professional judgment of its employees. Approximately 194 (12.3%) parameters were "legacy parameters" originally used in DOE's 1992 PA and again incorporated in the CCA PA (see Docket: A-93-02, II-I-31, Comment No. 11).

EPA selected 465 parameters on which to concentrate its analysis. EPA selected parameters to review based on the following criteria:

- parameters that appeared to be important to compliance or seemed to be poorly justified, such as material permeabilities and porosities, particle size, brine reservoir characteristics, pressures, solubilities of actinides, and waste inventory information,

- parameters that control various functions of the CCA PA computer codes that appeared to be important to compliance, such as permeability threshold, and dispersivity characteristics of the Culebra,

- other parameters EPA used to evaluate the overall quality of SNL's documentation traceability, such as reference constants and general reference values.

The purpose of the parameter review was to verify that DOE's documentation includes adequate information to fulfill the compliance review criteria of section 12.2, for §194.23(c)(4) of this CARD. For greater detail about EPA's examination of the specific parameters in each category, see EPA Technical Support Document for Section 194.23: Parameter Justification Report (Docket A-93-02, Item III-B-14).

EPA strongly believes that EPA-mandated Performance Assessment Verification Test was done with the best estimate of the parameter distributions available. EPA did an exhaustive review of the parameters used in the CCA PA and altered those needed and required DOE to repeat the calculation with the necessary changes. See A-93-02, III-B-5, II-G-26 and II-G-28 for documentation of the changed parameters and their impact on potential releases.

EEG assessment of EPA resolution of comment 552

Though the EPA did a thorough job in evaluating the parameters for the PAVT, the EEG believes that the performance assessment evaluation is still incomplete. For example, the EPA studied the evidence carefully when considering the Castile Brine Reservoir parameters and selected relevant values to assign to the parameter. Yet, the solubility of certain actinides in Salado and Castile brines or the partition coefficient of actinides for sorption onto the Culebra Dolomite and the probability of brine reservoir encounter were inadequately addressed. These few examples play an important role in compliance, as studied by the EEG in sensitivity analyses (Section 2.2 of this report). The synergetic effect off all parameters is unknown, and it is important to characterize each parameter carefully. The EEG believes that this has not been done, and perhaps a new performance assessment should be conducted with parameter values that are more easily justified through experimentation.

554 The sampled parameter for the probability of microbial gas generation determines whether cellulose and plastics and rubber will be degraded by microbial action after

closure of the repository. . . It is the opinion of EEG that the numerical value of this parameter constitutes expert judgment. Given the importance of this parameter to the estimates of radionuclide release, this parameter should be demonstrated to be either solidly based on scientific evidence or be conservative. The justification for this parameter presented in support of the CCA does neither of these. (II-H-25.5)

DOE response (II-H-45)

The interaction of gas generation with other processes in the repository is complex. Because of this, an *a priori* determination of a meaningful, conservative selection from the possible processes of gas generation is difficult. The suggestion of the EEG that microbial degradation should always be specified, i.e., a 100% probability, is not necessarily conservative since this would tend to reduce brine inflow. Therefore, to be consistent with the treatment of uncertainty throughout the performance assessment, the DOE assigned probabilities to gas generation processes to ensure that assessment results reflect the uncertainty associated with the occurrence and extent of these processes, i.e., both possible outcomes be sampled.

The conceptual model for gas generation in the WIPP repository includes two dominant generation processes: metal corrosion and microbial degradation of organic material. The probabilities of occurrence of these processes were established through a procedure that included careful review of uncertainty suggested by experiments conducted specifically for the WIPP, literature review, and consideration of local scale processes in the disposal room. Given the presence of brine, it is reasonable to assign a 100% probability to metal corrosion. However, there are considerable uncertainties associated with the occurrence of significant microbial populations. These are:

(1) Whether micro-organisms present in the waste are capable of carrying out the potentially significant processes that generate gas identified by Brush[6].

(2) Whether these microbes will survive for a significant fraction of the 10,000 year period of performance of the repository.

(3) Whether sufficient electron acceptors (oxidants) will be available to any microbes that survive.

(4) Whether enough nutrients, especially N and P, will be available.

Electron acceptors and nutrients will be present in the repository (see Appendix BIR7). Therefore, points (3) and (4) relate to the uncertainty as to whether these materials will be physically and chemically available to any microbes that survive. Brush[8] discussed these issues in more detail.

In addition to uncertainty over the possibility of microbial activity, there is also uncertainty over the amounts and types of biodegradable waste. It is reasonable to assume that readily biodegradable material such as cellulosics will be consumed if microbes are active. However, plastics and rubber are much less biodegradable than cellulosics and may not contribute to the gas generation process. Two factors may potentially increase the biodegradability of those materials: (1) long time scale; (2) co-metabolism. Over a time scale of 10,000 years, the chemical properties of plastics and rubbers may change, possibly resulting in enhanced biodegradability. Furthermore, micro-organisms may co-metabolize plastics and rubbers with cellulosics and other more biodegradable organic compounds. All of these uncertainties precluded the use of experimental and/or modeling studies to quantify the probability of significant microbial gas generation in WIPP disposal rooms and the probability of significant microbial degradation of plastics and rubbers for the performance assessment calculations to support the CCA.

To incorporate the uncertainty about the dominant processes of gas generation, the DOE assigned a value of 50% to the probability of significant microbial gas generation and 50% to the probability of significant microbial degradation of plastics and rubbers in the case of significant microbial gas generation. In other words, steel corrosion alone occurs in 50% of LHS sample vectors, steel corrosion and microbial degradation of cellulosics occurs in 25% of LHS sample vectors, and steel corrosion and microbial degradation of cellulosics, plastics, and rubbers occur in 25% of LHS vectors. This is consistent with the treatment of uncertainty throughout the PA calculations (see Appendix PAR, page PAR-6, Delta Distribution). As the EEG requests, it is also based on scientific evidence as to the likely gas generation processes and ensures that all the possible complex interactions between gas generation and other processes are accounted for.

The EEG also states that the gas generation probabilities used should be peer reviewed. In fact the Conceptual Model Peer Review Panel have done this (see Appendix PEER, Section 1). With regard to the gas generation model probabilities, the Panel stated (p. 3-144 to 145):

> "Regarding microbially induced gas generation, the model assumes that the probability of degradation of cellulose and plastics/rubber will be 50% and that in the event that biodegradation occurs there is a 50% probability that plastics and rubbers will also be degraded." [Illustration callout and illustration omitted in this quote]
>
> "This assumption is based on major uncertainties that are described in Section 3.21.2.4 below, and represents a judgement. For performance assessment purposes, this assumption will result in less gas generation than if one were to assume total consumption of all the organic material. There is apparently no scientific evidence that plastics/rubbers degradation will occur at all with certainty,

based on contemporary experience. The possibility that products from microbial degradation of cellulose, and perhaps radiolysis by alpha irradiation, could combine to break down the relatively stable plastics polymers to more consumable fragments suggests the probability should be non-zero. It is difficult to argue for a value higher or more precise than 50%, unless there were more robust long-term data, or experience with plastics degradation in, for example, landfills. Therefore, for performance assessment purposes, the assumption regarding plastics/rubbers appears to be adequate.

With regard to the degradation of cellulose, the long list of uncertainties identified in Section 3.21.2.4 below suggests that less than full probability of significant microbial degradation of this more readily consumable material is a reasonably valid assumption. Also, it does not appear scientifically valid to assume that either all or none of the cellulose will be degraded in light of the significant uncertainties that microbial populations would remain viable to the extent of complete cellulose degradation. DOE is not seeking a worst case in performance assessment. Therefore the 50% probability is a reasonable assumption for modeling purposes."

The DOE believes this excerpt shows that the Conceptual Model Peer Review Panel fully understands the goals of performance assessment in general, the purpose of model and parameter selection, and in particular the basis and reasonableness of the DOE gas generation model.

EPA's response to comment 554

EPA has examined information to support these parameters. See EPA Parameter Justification Report (Docket A-93-02, Item III-B-14), Section 5.25, for detailed discussion of the PU, PROPMIC parameter.

Section 5.33, for detailed discussion of the AM, PROPMIC parameter.

EEG assessment of EPA resolution of comment 552

It appears from the response that EPA did not understand the question. The EPA response in Section 5.25 and Section 5.33 (U.S. EPA, 1997m) addresses concerns of Plutonium and Americium sorption onto microbial colloids and humid colloids.

The sampled parameter for the probability of microbial gas generation determines whether cellulose and plastics and rubber will be degraded by microbial action after closure of the repository. No degradation of cellulose or plastics occurs in the calculations with a 50% probability. Only cellulose degrades in 25% of the sampled vectors. Cellulose, plastics, and rubber degrade with a probability of 25%. The preliminary sensitivity analysis report (Helton, 1996) lists this parameter as the largest influence on the variation of total calculated release from the WIPP repository.

The documentation supporting this parameter does not contain any numerical justification for the probabilities assigned to this parameter. All of the hand calculations performed to calculate the gas generation parameters are included as attachments to the memo of Wang and Brush (1996). Calculations for the degradation probabilities are absent from these attachments. It is the opinion of EEG that the numerical value of this parameter constitutes expert judgment. Given the importance of this parameter to the estimates of radionuclide release, this parameter should be demonstrated to be either solidly based on scientific evidence or to be conservative. The justification for this parameter presented in support of the CCA does neither of these.

The numerical values of the degradation probability parameter should undergo peer review consistent with expert judgment. Otherwise, the parameter should be conservatively set to always specifying microbial degradation of cellulose, plastics, and rubber.

EEG assessment of DOE's response

The parameter used to set the probability of microbial degradation in the CCA calculations is not derived analytically but instead was a result of interpretations that constitute expert judgment. The EEG suggested that the probability of microbial degradation should undergo peer review as parameter obtained using expert judgment. It was suggested that without this peer review the microbial degradation parameter should be set to always specifying microbial degradation of cellulose, plastics, and rubber. The EEG has been convinced by DOE's arguments that setting the parameter to always specifying microbial degradation of cellulose, plastics, and rubber is not appropriate. The central point remains that the probabilities used in the CCA calculations are a result of expert judgment. As such the parameter is required to be peer reviewed using the procedure outlined in 40 CFR Part 194.26. The conceptual model peer review does not meet the requirements outlined in the section.

557 If a single value for the consolidated waste permeability is to be used for direct brine release, then it should be 2.4×10^{-13} m^2 and not 1.7×10^{-13} m^2 . (II-H-25.8)

DOE's response to comment 557

The [waste permeability] value of 2.4×10^{-13} m^2 is both reasonable and is as technically correct as the 1.7×10^{-13} m^2 value. There has been no technical reason offered which would justify using the higher value instead. (II-H-45.5)

EPA's response to comment 557

EPA has examined information to support this parameter. EPA believes that a single value instead of a probability distribution is justified for permeability. See EPATechnical Support Document for Section 194.23: Parameter Justification Report (Docket A-93-02, Item III-B-14), Section 5.19, for detailed discussion of the BLOWOUT, APORO parameter.

EEG assessment of EPA resolution of comment 557

Refer to EEG Chapter 2.4 for full explanation of EEG's concerns and responses.

Section 194.27 (CARD 27) Peer Review

ISSUE 27.A: EPA should look carefully at Peer Review conclusions

2 Our impression is that certain panels have performed a thorough and credible review, while others have not. Our recommendation to the EPA is to review the bases of findings of the panels and subject them to your own critical review by the EPA staff, contractors, or formally assembled peer review groups. (522) (II-H-12.1)

EPA's response to Issue A

EPA's audit of DOE's records did not result in any findings that substantially compromised the credibility of the process used to implement the peer reviews required by Section 194.22(b) or Section 194.27(a) (see "EPA Compliance Review" under 194.27(b) above). As stated in EPA's response to comments received on the proposed compliance criteria, "The Agency does not intend for peer review of DOE's activities to supplant or replace the Agency's review of compliance applications. . . Regardless of the recommendations or judgments made by the peer review groups, all decisions on the adequacy of the compliance application will be EPA's and EPA's alone" (Response to Comments Document for 40 CFR Part 194, pp.9-6 to 9-7). In other words, EPA recognizes that peer review contributes to but does not supplant the Agency's independent review. EPA therefore considered peer review panels' findings in technical areas in conjunction with other information relevant to compliance. EPA's consideration of the scope and findings of the required peer reviews may be found in **CARD 22 – Quality Assurance, CARD 23 -- Models and Computer Codes, CARD 24 -- Waste Characterization, and CARD 44 -- Engineered Barriers**.

EEG assessment to EPA resolution of comment 2

It appears that discussions on several issues dealt by peer review groups may have been made without EPA's own analysis. An example is the new spallings code. The peer review accepted the conceptual model, without an actual testing of the code. The EEG found that after conducting a thorough sensitivity analysis with the codes, variations in several parameters may lead to conclude that the CCA spalled volumes are not conservative. If the EPA had conducted their own analysis, they too would have reached to the same conclusion. The same can be seen with the issue of actinide solubility or actinide partition coefficient (K_d).

Section 194.32 (CARD 32) Scope of Performance Assessment

ISSUE 32.A: The CCA does not adequately address the effect of fluid injection on the repository

12 The DOE has chosen "soon after disposal" to mean 50 years in the context of the fluid injection scenario. However, in the 1991 DOE elicitation of expert opinion on future activities in the vicinity of WIPP, one of the four teams addressed fluid injection and assigned probabilities of waste brine disposal associated with other industrial activities for

the full 10,000 years. Further, the probability of a large number of such injection wells, within the site was predicted to increase with time. (526) (II-H-12.5).

13 The discussion of fluid injection in Appendix SCR of the CCA is incomplete and largely incorrect. For example, Appendix SCR mentions gas injection for natural gas storage in the Morrow Formation but fails to mention natural gas storage in the Salado Formation. It is argued that the differences between the geology at WIPP and the Vacuum Field and Rhodes-Yates Field provide for more potential thief zones below the WIPP horizon in the event of water escaping the injection zone. However, field evidence strongly suggests that brine injection into the Bell Canyon below the WIPP horizon appears to be leaking into the Culebra aquifer above the WIPP horizon. The CCA provides no experimental evidence such as the measurement of water quantities in the anhydrite beds of the Salado Formation to support the CCA speculation. (527)(II-H-12.6)

14 The claim that there will no waterflooding on the scale of Rhodes-Yates is also undermined by field evidence. (528)(II-H-12.7)

15 While the Delaware sands, including those around the WIPP produce large volumes of water, they are nonetheless, technically and economically amenable to waterflooding as well as CO2 flooding. (529)(II-H-12.8).

16 The CCA-SCR notes that state regulations do not allow injection pressures to exceed the rock fracture pressure. However, that portion of the regulation applies to the target injection zone and not any overlying formations. The producing reservoirs near WIPP are greater than 7,000 feet. One consequence of greater vertical distance is that the surface injection pressure is automatically approved for 1,400 psi or 0.2 psi per foot. This corresponds to 2,400 psi at the WIPP horizon which is well in excess of the fracture pressure of the anhydrite beds in the Salado Formation.(531)(II-H-12.10).

17 Stoelzel and O'Brien consider only salt water disposal and assume an injection depth of 260 feet, a surface injection pressure of 850 psi, and a pressure at the WIPP horizon of 1,900 psi. However, pilot water flooding operations near WIPP are underway for reservoirs at 7,000 feet depth and have been approved to inject at a surface pressure of 1,400 psi, which in the event of communication, would exert a pressure of 2,400 psi at the WIPP horizon. Hence, the anhydrite beds in the Salado Formation would fracture, as successfully argued by Hartman and brine would migrate for miles in the inadvertent waterflooding hydro fracture scenario. (532)(II-H-12.11).

EPA's comment to Issue 32.A

DOE evaluated fluid injection in connection with the scope of the performance assessment but rejected the scenario on the grounds of low consequences. EPA evaluated DOE's Hartman Scenario and also performed an independent fluid injection analysis; see EPA Technical Support Document for 194.32: Fluid InjectionAnalysis (EPA 1997b). The results of these studies show that effective permeability in marker beds is probably lower than that used in the PA, and that other factors (such as injection rate, injection interval, etc.) also play a very important role in fluid injection. EPA agrees that under very unrealistic conditions, modeling can show fluid movement toward the WIPP under an injection scenario. These conditions include those modeled by Bredehoeft, such as steady state flow, two well scenarios, and pulsing flow. However, when modeling assumes more realistic but still conservative conditions, fluid movement sufficient to impact disposal performance of the WIPP does not occur.

In addition, EPA believes that geologic and hydrogeologic conditions in the Hartman area are different than in the WIPP area, which also precludes one-to-one comparison of conditions at the WIPP and at the Bates lease. For example, the Castile Formation is not present in the Bates area, but over 1,000 feet of Castile is present in the WIPP area. Also, the present oil well completion practices in the Delaware Basin are substantially improved. Injection rate, pressure, target and fluid volume related regulations are different and are closely monitored by the state agencies. EPA concludes that the model representation in DOE studies, including two-dimensional analysis, appears to be appropriate for the intended use, because the model uses radial flaring in the z direction to capture compatible volume in the 360 o flow to compensate for 3D simulation.

EPA also requested (see Docket A-93-02, Item II-I-17) that DOE consider different factors in its fluid injection modeling (Stoelzel and Swift, 1997). Refer to the discussion in this CARD under 194.32(c). EPA concluded that DOE's initial modeling studies (Stoelzel and O'Brien, 1996) and supplemental modeling studies (Stoelzel and Swift, 1997 and Docket A-93- 02, Item II-I-36), together with EPA's own fluid injection analysis (EPA 1997b) all indicate that DOE's screening of fluid injection from consideration in PA is appropriate. EPA also notes that DOE considered waterflooding for the undisturbed (historical, ongoing, and near future time frame) and screened it from consideration based upon consequence. In so doing, DOE is not required by the Compliance Criteria to evaluate this FEP for the long-term future.

EEG Assessment to EPA Resolution of Issue 32.A

As discussed in Secion of 2.6 of this report, the EEG disagrees with the EPA on this issue.

ISSUE 32.C: The CCA does not adequately consider solution mining of potash

4 The CCA (Appendix MASS, p. 87) claims that the DOE is not aware of any ongoing solution mining in the Delaware Basin. However, that activity has been ongoing for

several decades in southeast New Mexico, including the Delaware Basin, to provide brine for oil field drilling operations. Furthermore, state records show fluid injection for solution mining of halite is expanding into areas closer to the WIPP to meet the needs of drilling activities in that area. (533)(II-H-12.12)

8 The CCA inappropriately eliminates solution mining for potash. DOE relies on current regulations which do not fully cover all scenarios, nor do they prevent solution mining for potash. (751) (II-H-32.12)

DOE's response to Issue 32.C

It is unlikely that potash mine operators in the vicinity of the WIPP will elect to use solution mining in the future, even once Sylvite deposits are fully mined out by conventional excavation methods, because conditions are economically unfavorable, as noted by Heyn (1997), a potash mine operator within the Delaware Basin. Points raised by Heyn (1997) are summarized below: (1) Solution mining requires heat to increase the ambient temperature of the injected water in order to increase the dissolved salt capacity of the brine. This is usually accomplished by taking advantage of geothermal heat found in deep wells or mines. Most solution mines are at depths in excess of 3,000 feet (910 meters). The potash ore bodies in the vicinity of the WIPP are less than 1,740 feet (530 meters) below the surface. Also, the cost of evaporation equipment to recover the potassium salts may be prohibitive. (2) Solution mining of the Sylvite ore bed in the vicinity of the WIPP would result in excessive solution of unwanted minerals and clays because the ore zone is too thin. Solution mining usually requires an ore bed thickness in excess of 10 feet. (3) Unavailability and cost of fresh water in the area would impede implementation of solution mining. (4) Potash ore reserves in the vicinity of the WIPP are too low in potash grade and the life expectancy of the mines is too low to justify the cost of constructing a solution mining refinery. Thus, it is likely that the potash bearing ore zones in the vicinity of the WIPP will continue to be extracted using conventional room and pillar methods, rather than solution mining. (724)(II-H-24.19)

EPA's response to Issue 32.C

EPA agrees that the CCA did not appropriately treat solution mining of potash; however, DOE provided supplemental information concerning solution mining in response to public comments e.g., DOE, 1997i, 1997m, and Docket A-93-02, Items II-H-44 and II-H-45). DOE indicated that the target potash intervals for conventional room and pillar mining are Zones 4 and 10, which would also be the target horizons for solution mining. DOE concluded that the effects of solution mining relative to changes in overlying Culebra hydraulic conductivity are included in the modeled effects of room and pillar mining. The increase in hydraulic conductivity is related to the reduction in confining stress. Unless the mean confining stress is reduced to zero, the increase in hydraulic conductivity will be considerably less than what DOE has considered in PA. However, DOE indicated in supplemental information that solution mining is not likely in the vicinity of WIPP because fresh water for mining is limited and the overall procedure is cost prohibitive. Also, langbeinite, which is the primary target of extraction, is not readily soluble in water.

EPA noted that a permit is being sought for a pilot solution mining venture in the Carlsbad area. However, it is not possible to accurately predict the future possible minable zones if mining techniques are refined. Solution mining is presently not being done and may not take place in the future, and solution mining would likely include those horizons already included in the room and pillar mining modeling assumptions. With the supplemental information, EPA concludes that DOE has sufficiently addressed the potential effects of potash solution mining and that they were addressed within the scope of the PA.

EEG assessment of EPA response to Issue 32.C

EEG's responses to EPA are:

- EPA's conclusion that potash solution mining is not likely at WIPP relies on solicited comments that are factually incorrect and inconsistent with the published scientific literature.

- DOE and EPA maintain that excavation mining captures the effects of solution mining on the hydraulic conductivity of the overlying aquifers. However, based on the scientific literature, the prediction of subsidence above solution mines can be much more complex than the prediction of subsidence due to excavation mining. This issue needs to be reevaluated for the final rule for WIPP.

- Potash is a resource used for the production of food, therefore it appears to be incorrect to calculate a probability of mining based on past potash production which was inherently dependent on past mineral economics and the availability of high grade ore. It also seems reasonable to assume that low grade potash ores will eventually be mined to meet world demand.

ISSUE 32.D Potash reserve assumptions are contradictory and/or inadequate

8 The CCA claims credit for addressing the issue of potash mining. However, the CCA underestimates the areal extent of potash reserves and the potential impact of the excavation mining of potash within the site and on adjacent federal and state properties. The use of only existing releases adjacent to the site does not account for the currently economical potash reserves. . . Further, the Department of Interior notes that potash ore

has been and can be economically mined at ore concentrations less than current lease grade. (560) (II-H-25.11)

EPA's response to Issue 32.D

EPA concurs that the DOE and BLM minable footprints do not coincide. Relative to potash, the CCA indicated that only the 4th and 10th horizons are economic reserves, although remaining ore zones are considered resources that would be mined with advances in thin-seam extraction technologies. However, the minable footprint presented in the CCA on Figure 2-38 does not entirely match or coincide with the locations or information presented by Griswold in NMBMMR 1995. DOE provided supplemental information concerning the minable potash footprints, in response to stakeholder questions (Docket A-93-02, Item II-H-45). Although the minable footprints identified by DOE and Department of Interior differ, DOE concluded that this is due to the difference between the definition of "resources" and "reserves." (Reserves are hose resources that are currently economically recoverable with currently available technology, and resources are mineral deposits that are not currently economical or have not been discovered.) That is, DOE contended that their estimates were based on actual minable reserves, which are less pervasive than resources. However, DOE also contended that this approach is consistent with the intent of Section 194.32(b), which states that DOE must consider resources similar in quality and type to those currently extracted.

EEG assessment of EPA response to Issue 32.D

The EEG has conducted a sensitivity analysis pertaining to the extent of potash reserves within the controlled area. The conclusion is that with current models and the implementation of mining in those models (increase in effective transmissivity of the Culebra), the scenario has little effect. However, simply increasing the transmissivity within the Culebra does not account for all processes involved in subsidence due to mining, and other parameters, such as fracture width, or porosity may be significantly changed. Therefore, the EEG concludes that a more accurate portrayal of mining should be included in the performance assessment, including extent and consequence.

ISSUE 32.I: Justification of FEPs screening

3 Operations involving the screening and other processing of FEPs are inadequately documented. 25% of the original FEPs list was eliminated with no documentation of the process; 70% of the remaining FEPs have essentially no more documentation than what appears in the CCA. The documentation for the other 30% also appears to be incomplete. The rationale for excluding many of the FEPs from the PA is not documented in the CCA. (559) (II-H-25.10)

EPA's response to Issue 32.I

In general, EPA found DOE's screening analyses and justifications for inclusion or exclusion of FEPs to be adequate. However, EPA determined that additional information or justification was necessary regarding certain FEP issues (e.g., dissolution, brine mining, solution mining, and fluid injection). Public comments also identified similar deficiencies in the screening analyses for some FEPs in the CCA. DOE provided supplemental information addressing EPA's questions and public comments (Docket A-93-02, Items: II-I-24, II-I-31, II-I-34, II-I-36, II-I-37). EPA reviewed the information and concluded that DOE's responses have adequately addressed all its concerns regarding FEPs and scenarios.

EEG assessment of EPA response to Issue 32.I

The EEG does not agree that the screening of FEPs in the CCA were adequate. The fluid injection scenario (Section 2.6 of this report), for example, addresses several concerns of the inadequacy by the DOE and EPA in their analysis. Also, arguments can be made on the Air Drilling Scenario (Section 2.5) and issues surrounding production well ERDA-9 (Section 2.14).

Section 194.33 (CARD 33) Consideration of drilling events in performance assessment

ISSUE 33.B: The Performance should incorporate lower plug permeabilities

555. Borehole lifetime should be a sampled parameter in the CCA calculations or else the DOE should provide demonstration that variations in borehole lifetime do not effect [sic] the release estimates. (555)(II-H-25.6)

EPA response to Issue 33.B:

EPA reviewed natural borehole degradation processes and the subsequent effect of these processes on borehole permeability. Based on available information (e.g., WPO# 41131 and Appendix PAR, p. 192), EPA found that a constant value of permeability 10^{-14} m^2 throughout the regulatory period would not be conservative because of pressure buildup in the repository. The Agency believes that, primarily due to the solidification of drilling muds within the borehole in time, variations in the permeability of borehole plugs will occur and that a lower value of permeability would be more realistic than the constant and relatively high permeability value that DOE used.

EPA agrees that DOE gave little credit to factors that could sustain or enhance the potential effectiveness of plugs. Although DOE provided a combination of site-specific and theoretical justifications in support of plug parameter assignments, the assumed value of the plug permeabilities is subject to uncertainty and EPA determined that a modification of DOE borehole plug permeability values was necessary. EPA required that EPA-mandated PA simulations be conducted using lower permeability values (parameters used in model- CONC_PLG maximum of 10^{-19} m^2, BH_SAND maximum of 5 x 10^{-17} m^2) to account for possible cases in which complete degradation does not occur throughout a well, or natural materials and mud provide additional layers with sealing properties.

EEG assessment of EPA resolution of Issue 33.B

The EEG suggested the borehole plug lifetime should be a sampled parameter based on two observations. 1) It is likely that the performance assessment calculations are sensitive to the assumed borehole plug lifetime. 2) Borehole plug lifetime is an uncertain parameter. The use of a constant value for borehole plug lifetime in all the calculations is inconsistent with DOE's guidelines for sampled parameters. Contrary to the assertion in the DOE response (II-H-46), the EEG did not argue that the estimate of 200 years is unreasonable.

The DOE (II-H-45) claims that borehole plug lifetime uncertainty is accounted for by assuming that two percent of the plugs are continuous (long-lived) and hence do not degrade (II-H-46). This claim is wrong.

The EEG recognizes that sampling borehole plug lifetimes would be impractical using the present performance assessment design. The DOE should investigate the influence of borehole plug lifetimes on repository conditions and assess the potential impact on CCDF calculations.

The EPA mandated verification test used a range of permeabilities of degraded boreholes that extended lower than the range used in the CCA calculations. The lowest permeability effectively limits flow through the borehole. The effect may have similar consequences to the effect on the repository conditions of long lived borehole plugs. Thus, the EPA mandated verification test may, in conjunction with the CCA calculations, provide a bound on the influence of variable borehole lifetimes. This, however, is speculation and needs to be confirmed.

Issue 33.D: The estimated probability of intersecting a pressurized brine reservoir is adequately/inadequately justified, and E1 intrusions will not necessarily affect disposal system performance.

219. EEG finds no justification for assuming only eight percent probability of intercepting a pressurized brine reservoir in the Castile Formation, 800 feet below the repository. (219)(A-50 [II-H-12])

EPA response to Issue 33.D:

EPA found that DOE's representation of brine pocket occurrence probability in the CCA was not consistent with available information. EPA requested that the brine pocket probability be modified to range from 1 percent to 60 percent, and that it must be a sampled value rather than a fixed value of 8 percent. These values were used in the PA verification test (PAVT). Results of the PAVT indicated that the modified Castile Brine Pocket parameters increased releases (DOE 1997a, 1997b). However, the resulting PAVT CCDF curves, while closer to the EPA limit than PA CCDF curves, are still well below the EPA limits. EPA agrees that the E1 scenario does not always enhance radioactive releases in all instances. Refer to **CARD 14-- Content of Compliance Application** for further discussion of brine pocket probability.

EEG assessment of EPA resolution to Issue 33.D

There is poor justification for the 1% lower end of the EPA range for the probability of encountering a pressurized brine pocket. The 60% upper end is based on an electromagnetic survey of the WIPP site (US. DOE, 1996c, 2.2.1.2.2) that indicates brine is likely under about 60% of the repository. Most importantly, the probability of hitting brine under WIPP should be based on WIPP, not the entire Delaware basin. The WIPP-12 brine reservoir is of sufficient size to protrude under the repository. The existence of boreholes around WIPP-12 that have not encountered brine in the Castile constrain the WIPP-12 reservoir so much that it is almost certain that the reservoir extends under the repository (II-H-25). The brine indicated by the electromagnetic survey must be part of the WIPP-12 reservoir. The probability of encountering brine should be modeled as 60%. The PAVT thus underrepresents the probability of encountering a brine reservoir.

Section 194.41 (CARD 41) Active Institutional Controls

ISSUE 41.B: DOE should provide specific commitments preventing human intrusion for 100 years

1 EEG recommends that EPA should require DOE to provide specific commitments on how they will prevent human intrusion for the first 100 years. As part of building a credible argument, the CCA should also take into account the pessimism of its own expert elicitation on the limited effectiveness of active institutional controls. (562) (II-H-25.13)

EPA response to Issue 41.B:

Upon preliminary review of the CCA, EPA requested that DOE provide specific commitments concerning AICs for the WIPP site, including fencing, signs, and site patrols (Docket A-93-02, Item II-I-01). DOE provided the requested information (Docket A-93-02, Item II-I-07, Enclosure 1c). DOE also described legal prohibitions on resource extraction and other activities at the WIPP site that function as AICs, such as the erection and testing of passive institutional controls and the implementation of the site monitoring plan.

DOE did not conduct an expert elicitation for the purpose of determining how long the proposed AICs specifically are expected to be effective. As EEG noted, an expert elicitation conducted prior to the promulgation of the final Compliance Criteria resulted in predictions of AICs' effectiveness generally (see A-93-20, Item II-H-25). However, DOE did not rely on these predictions in proposing that AICs will be completely effective for 100 years. EPA believes that it is fully within DOE's capacity to maintain the proposed controls for 100 years after disposal, is discussed under EPA Compliance Review for Section 194.41(a) above.

EEG assessment of EPA resolution to Issue 41.B

Title 40 CFR 191.14 (a) requires maintenance of active institutional controls for as long a period of time as is practicable after disposal, but the credit in performance assessment may not be taken for more than 100 years. The DOE has proposed controls for 100 years and has assumed no drilling in the repository for that period. The EEG agrees with the EPA's finding for this requirement, but recommends that if in the final rule EPA finds WIPP to be in compliance with the standards and proposes to grant certification, oversight by the federal (other than DOE) and state authorities should be required to ensure vigorous implementation of the active institutional control.

Section 194.43 (CARD 43) Passive Institutional Controls

ISSUE 43.B: DOE's proposal for PICs credit is or is not acceptable

5 Based on DOE's experience with institutional controls in the recent past, a claim of 99% credit for passive institutional controls for 700 years does not appear justifiable. (561) (II-H-25.12)

EPA response to Issue 43.B

EPA proposes to deny DOE's application for PICs credit for two reasons. First, DOE did not employ expert judgment to derive the credit. EPA stated in the preamble to 40 CFR Part 194 that "the degree to which PICs might reduce the future drilling rate can be reliably determined only through expert judgment" (61 FR 5232). Instead, DOE developed a proposal and submitted it to a peer review panel of three experts. EPA does not view peer review as equivalent to expert judgment. The Agency laid out explicit requirements for the conduct of expert judgment in Section 194.26.

Second, EPA found that DOE's analysis does not account persuasively for the uncertainty associated with the forecasting the effectiveness of PICs. EPA does not concur with the conclusion of the PICs peer review panel that DOE's proposed credit is reasonable. Among other issues, EPA considers DOE's assertion that every aspect of the PICs design is virtually certain to endure and be understood for the proposed period to be contrary to EPA's specification in Section 194.43(c) that "[i]n no case. . . shall passive institutional controls be assumed to eliminate the likelihood of human intrusion entirely" (61 FR 5243). This topic is discussed in greater detail in EPA Compliance Review for Section 194.43(c).

EEG assessment of EPA resolution of Issue 43.B

The EEG agrees with this determination of denying credit for PICs for reasons stated by the EPA in U.S. EPA (1997c), as well as for reasons that EEG has previously submitted to the EPA (see Appendix 8.2-Passive Institutional Controls).

Section 194.44 (CARD 44) Engineered Barriers

ISSUE 44.A: Borehole plugs, shaft seals, panel closure, and backfill should/should not be considered engineered barriers.

5 Shaft seals are at best an attempt to undo the damage done to the natural environment when the shafts were excavated, and therefore cannot be an engineered barrier as distinct and complementary to the natural barriers. (545) (II-H-12.24)

6 Like the shaft seals, panel closure systems (separation of waste panels by engineered structures) cannot be considered to be engineered barriers because they too can at best be imperfect attempts to restore the original natural system. Panel seal is not included in the examples of engineered barrier in EPA definition (Section 191.12). (546) (II-H-12.25)

7 The fact remains that the purpose of including MgO in the WIPP repository is to control the chemical conditions in the WIPP repository to allow assumption of lower actinide solubility values. It may therefore satisfy a need for the Containment Requirement of the Standards, but does not provide complementary added assurance visualized by the Assurance Requirements (40 CFR 191.14). (547) (II-H-12.26)

8 Since the stated requirements for plugging the boreholes (Section 3.3.4 and Figure 3-10 of the CCA) are much less stringent than the shaft seals, the borehole plugs have a lesser claim as engineered barriers. The NRC specifically excludes borehole seals as part of an engineered barrier system. Hence, the borehole plugs should not be considered to be an engineered barrier. (548) (II-H-12.27)

EPA response to Issue 44.A

Section 194.14(b)(1) required DOE to include in the description of the disposal system information about engineered barriers, i.e., "any material or structure that prevents or substantially delays movement of water or radionuclides toward the accessible environment," as defined at Section 191.12. The CCA treated panel seals, shaft seals, and borehole plugs as features of the disposal system design, and EPA evaluated them in that context. For a discussion of these features, see Section 194.14(b)(1) and Response to Comments in **CARD 14 – Content of Compliance Certification Application.**

For the purpose of complying with the assurance requirements at Section 194.44, DOE proposed to implement one engineered barrier -- magnesium oxide (MgO) backfill. EPA believes that DOE adequately demonstrated in the CCA and supplementary information that MgO will serve to prevent or substantially delay movement of water or radionuclides toward the accessible environment. For more discussion of the effectiveness of MgO backfill, see Section 194.44(a) above in this CARD, as well as Response to Issue C below.

EEG assessment to EPA resolution to Issue 44.A

Title 40 CFR 191.14 (d) requires use of both engineered and natural barriers in the repository design. The CCA proposed a chemically-buffering magnesium oxide backfill as the only engineered barrier, and the EPA has accepted in the proposed rule the DOE (U.S. DOE, 1996c) proposal to satisfy this assurance requirement. The EEG view is that while there are still some questions about the efficacy of the chemical buffer aspect of the magnesium oxide (MgO) backfill (see Appendix 8.4, section 2.3 of this report), this engineered feature has been selected primarily to enable DOE to use numerical values of certain parameters in the containment requirement calculations. The MgO backfill may not therefore be considered to satisfy this assurance requirement in a strict sense of the philosophy of these requirements. Incorporation of backfill in the WIPP design is nevertheless a good idea and the EEG has been recommending a salt/clay mixture as backfill for years. A pure MgO backfill does not have the benefit of the chemical retardation of radionuclides that clays afford, but may help keep the repository chemical environment stable. The EEG would prefer addition of clays such as commercially available bentonite to the backfill, but is willing to accept emplacement of MgO backfill for the sake of operational ease and efficiency.

As to the distinction between “engineered barriers and “engineered features”, it is not based on the standard (40 CFR 191), or its criteria (40 CFR 194). The CCA (U.S. DOE, 1996c) included these “features” in the section on “engineered barriers”, hence the EEG comment.

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ACRONYMS

AEC	U.S. Atomic Energy Commission
ALARA	As Low As Reasonably Achievable
BIR	Baseline Inventory Report
CAG	Compliance Application Guidance
CAO	Carlsbad Area Office
CARD	Compliance Assessment Review Document
CCA	Compliance Certification Application
CCDF	Complimentary Cumulative Distribution Function
CH-TRU	Contact-Handled Transuranic
CRP	Cellulosics, Rubber and Plastics
DCCA	Draft Compliance Certification Application
DLR	Dewey Lake Redbeds
DOE	U. S. Department of Energy
DQC	Date Quality Characteristics
DRZ	Disturbed Rock Zone
EEG	Environmental Evaluation Group
EMP	Environmental Monitoring Plan
EOR	Enhanced Oil Recovery
EPA	U. S. Environmental Protection Agency
ERDA	Energy Research and Development Authority
HI	Human Intrusion
INEEL	Idaho National Engineering and Environmental Laboratory
IRG	International Review Group
IRT	Independent Review Teams
LANL	Los Alamos National Laboratory
LWB	Land Withdrawal Boundary

M&O	Management and Operations
MCLs	Maximum Concentration Limits
MMP	Minimum Miscibility Pressure
NAS	National Academy Science
NRC	National Research Council
NMOCD	New Mexico Oil Conservation Division
NEA/IAEA	Nuclear Energy Agency/International Atomic Energy Agency
OECD/IAEA	Organisation for Economic Cooperation and Development/International Atomic Energy Agency
OECD/NEA	Organisation for Economic Cooperation and Development/Nuclear Energy Agency
PA	Performance Assessment
PAVT	Performance Assessment Validation Test
PIC	Passive Institutional Controls
QA	Quality Assurance
QAPD	Quality Assurance Program Document
QED	Qualification of Existing Data
RTR	Real Time Radiography
RH-TRU	Remote-Handled Transuranic
SNL	Sandia National Laboratory
SWND	Southwestern Nash Draw
STP	Standard Temperature Pressure
SPM	System Prioritization Method
TRU	Transuranic
TWBIR	Transuranic Waste Baseline Inventory Report
USDW	Underground Source of Drinking Water
U.S. NRC	United States Nuclear Regulatory Commission
VE	Visual Examination
WID	Waste Isolation Division

WIPP	Waste Isolation Pilot Plant
WQSP	Water Quality Sampling Program
WWIS	WIPP Waste Information System

ENVIRONMENTAL EVALUATION GROUP

AN EQUAL OPPORTUNITY / AFFIRMATIVE ACTION EMPLOYER

7007 WYOMING BOULEVARD, N.E.
SUITE F-2
ALBUQUERQUE, NEW MEXICO 87109
(505) 828-1003
FAX (505) 828-1062

February 7, 1997

Mr. Frank Marcinowski, Director
Center for the Waste Isolation Pilot Program
U.S. Environmental protection Agency
Office of Radiation and Indoor Air
401 M Street SW
Washington, DC 20460

Dear Mr. Marcinowski:

At our January 21, 1997 meeting, you requested our comments on the WIPP Compliance Certification Application (CCA) now, because the end of the 120 day comment period on March 17 may be too late for you to seriously consider our comments in your deliberations on the CCA. We are therefore submitting our partial comments on the CCA at this time for your consideration.

The EEG has identified many specific issues in its evaluation of the WIPP-CCA. These issues can be grouped in the following broad categories:

- Lack of sufficient justification in disqualifying several features, events, and processes (FEPS) from consideration.
- Insufficient basis for selecting certain conceptual models and rejecting others.
- Incorrect estimation of probabilities of certain events.
- Insufficient justification or erroneous assumptions in assigning values for several input parameters.

The EEG has attended most of the meetings of the WIPP/CCA Peer Review Panels that were organized as required by 40 CFR 194.27. Our impression is that certain panels have performed a thorough and credible review, while others have not. Our recommendation to the EPA is to review the bases of findings of the panels and subject them to your own critical review by the EPA staff, contractors, or formally assembled peer review groups.

In reviewing the CCA, the EEG does not accept the arguments of "no consequence" to delete the otherwise plausible features, events and processes, and to justify incorrect values for certain input parameters. Such arguments, made on the basis of piecemeal, limited sensitivity analyses, may be misleading in projecting the relative importance of scenarios, conceptual models and input parameters for CCDF calculations. We strongly recommend that the EPA reject all such "no consequence" arguments and demand that a fresh set of calculations be performed after the EPA has examined the robustness of all the CCA assumptions regarding FEPs, conceptual models, numerical models, probability assignments, and input parameter values, and has provided alternative models and numbers to the DOE. This comment also applies to the recommendations of the peer review groups. The Conceptual Model Peer Review Group, for example, provides solid technical arguments for not accepting certain conceptual models advocated and used in the CCA, but then has found them acceptable on "no consequence" basis without providing sufficient explanation for such acceptance.

Comments on specific issues are enclosed. These are arranged as brief papers that can be read as stand-alone documents. We plan to submit additional comments to you in this format, as they are developed in the next few weeks.

Sincerely,

Robert H. Neill
Director

RHN:LC:js
Enclosures: EEG Reviews of the WIPP-CCA,
Plutonium Solubility
Chemical Retardation
Spallings Model
Fluid Injection
Brine Reservoir Assumptions
Engineered Barriers

cc: Ms. Jennifer Salisbury, NMEMNRD
Mr. Lindsay Lovejoy, Jr., NMAG
EPA docket for WIPP (A-9302)

CHEMICAL RETARDATION VALUES FOR THE CULEBRA

In the event of a borehole intrusion, the Culebra Aquifer, which lies 400 meters above the WIPP horizon, is one possible groundwater pathway for release of radionuclides to the accessible environment. Chemical retardation is expected to slow the transport of radionuclides through the fractured dolomite of the Culebra Aquifer. However, the DOE application has used values for estimating retardation coefficients that appear to lack justification.

Faced with a lack of field data and limited column test data for WIPP, the DOE CCA used retardation values from crushed rock samples in the laboratory to represent field conditions. Justification by the DOE is based on the following observations.

1) Sorption can occur in pores of various scales.

2) The surface area to volume ratio in crushed rocks sorption tests are similar to in-situ Culebra dolomite.

3) For long flow paths and long flow times radionuclides have sufficient time to diffuse into these pore spaces and sorb.

While EEG agrees that there appears to be a reasonable theoretical basis for using crushed rock, the EEG disagrees with the final data used in the CCA. Empirical sorption tests were done for all permutations of four types of brine; CO_2 levels of 0.033%, 0.24%, 1.4%, or 4.1%; and no, low, intermediate or high levels of organics. Because DOE plans to add M_gO as backfill, the fugacity of CO_2 in the repository is expected to be 10^{-7}. Thus, EEG discarded the results for CO_2 levels of 0.24%, 1.4%, and 4.1%. EEG also discarded results that did not meet DOE's own quality control criteria, and the results from a set of mechanistic sorption experiments because the dolomite was not from the Culebra. The average of the batch results formed the upper end of a uniform distribution.

Results from flow-through experiments using rock cores formed the lower end of the uniform distribution. In some cases, there was no radionuclide breakthrough at 300 days, so a minimum estimated K_d, assuming breakthrough at 300 days was used.

The DOE did not include the influence of organics on K_d values. In batch tests, even low concentrations of organics dramatically reduced K_d values. The impact of organics are included in the Kd values recommended by EEG.

The following tables show the Kd values used in the CCA, and the values suggested by the EEG using the criteria described above.

Table 1. K_ds used by DOE in CCA.

Oxidation State	Am	Pu	U	Th	Np
III	20 - 500	20 - 500			
IV		900 - 20000	900 - 20000	900 - 20000	900 - 20000
V					1 - 200
VI			0.03 - 30		

Table 2. K_ds recommended by EEG.

Oxidation State III, IV, V, VI	Am	Pu	U	Th	Np
	73 - 314	83 - 270	0.35 - 5	0.15 - 1.5	1.0 - 21

PLUTONIUM SOLUBILITY-EXPERIMENTAL MEASUREMENTS VERSUS CCA CALCULATED VALUES

Where brine has dissolved waste in the repository, direct drilling provides a vertical pathway for the long-lived actinides to return to the environment. Plutonium constitutes 87% of the initial radioactivity in the performance assessment calculations. Oxidation state is a factor that has an impact on the plutonium solubility. The DOE CCA assumes that the plutonium in the repository will be either at Pu(III) or Pu(IV), with 50% probability of one or the other. However, the solubilities are not measured for Pu(III) or Pu(IV). Rather, the solubility of Pu(III) is calculated using thermodynamic data for Nd(III) and the solubility of Pu(IV) is calculated using thermodynamic data for Th(IV).

While solubility experiments show that regardless of the initial oxidation state, Pu (VI) dominates at steady state conditions, it is not included in the performance assessment calculations. Pu(VI) has a high solubility in the conditions anticipated for the WIPP repository by the CCA.

The magnesium oxide backfill is anticipated to keep the repository at a pH of 10 and reducing. Reed et al. (1996) reported, that for brine at pH of 8 to 10, and reducing conditions, Pu(VI) is stable with an apparent solubility of 10^{-4} M. While it has been argued that corrosion of the steel drums would result in a reducing environment, Rao (1996) found that it was not possible to reduce Pu(VI) below Pu(V) despite adding more iron per unit mass of plutonium than could be expected in the repository, even assuming complete dissolution of the steel containers. Clark and Tait (1995) also concluded that Pu (VI) is stable in WIPP brines. Table 1. compares the calculated values used in the CCA and the measured values reflective of conditions anticipated in the repository.

Table 1. Solubility of plutonium as determined by calculations and experiments

Source of Brine	CCA calculations	Experiment, Reed et al.
Castile	5.7×10^{-9} M	8×10^{-5} M
Salado	4.4×10^{-6} M	9×10^{-5} M

The experimental evidence leads to the following conclusions:

1) Pu(VI) will be stable in the WIPP repository.

2) There is no support for the assumption that plutonium will stabilize in either oxidation state Pu(III) or Pu(IV).

3) The calculated results used in the DOE CCA are significantly different from experimental results for WIPP brines under anticipated repository conditions.

The EEG therefore recommends using the experimental values determined by Reed et al. (1996) shown in Table 1, for the CCA calculations.

References

1. D. L. Clark and C. D. Tait, 1995. LANL Progress Report. December 12, 1995. CCA Additional References No. 134.

2. L. F. Rao, 1996. PNNL Progress Report, April 1, 1996.

3. D. T. Reed, D. G. Wygmans, M. K. Richmann, 1996. "Stability of Pu(VI), Np(VI), and U(VI) in Simulated WIPP Brine," ANL Interim Report, CCA Additional References No. 539.

SPALLINGS MODEL

1. Critique of the Model Used in the CCA

For the purposes of the WIPP Compliance Certification Application (CCA) calculations, spallings refers to the entrainment of solid waste during the venting of high pressure gas from the repository in the event of a drilling intrusion. Spallings will occur when the roof of a waste room is penetrated by a drill, if the pressure in the room is sufficient to overcome the hydrostatic pressure of the drilling mud, about 8 MPa. Visual inspection of gas pressures calculated by the BRAGFLO code[1] indicates that over 80% of the undisturbed repository calculations predict pressures over 8 MPa after 10,000 years, with roughly 25-30% reaching this level in less than 1,000 years. The highest pressure calculated was nearly 16 MPa. The CCA calculations predict spallings to be a very important release mechanism. Spallings contributes to over 50% of the release estimates for human intrusion and was the largest form of release in over 10% of the calculated histories. The largest calculated release was less than, but within a factor of five, of the EPA normalized release limit for the 10% probability level.

The EEG finds the spallings model as used in the CCA to be inappropriate on three counts; 1) exclusion of brine from the spallings scenario, 2) the conceptual model of the spallings process, and 3) the experimental basis of the model validation. The spallings model is defined as gas driven entrainment of solid particles. The effect of brine in the waste panel is ignored. Brine may effect the spallings process in three ways. Capillary forces from low saturation may provide a binding force that inhibits spall which is conservatively ignored. Brine may also increase the effective driving force of the spall process increasing the amount of spall. In addition, the brine would contain radionuclides in solution. The CCA does include brine release from the penetration of the repository as a separate, longer term, two-phase flow calculation using repository conditions that are unmodified by the spall process. The spallings model should include the effects of brine.

For the spallings calculations, waste is assumed to be composed of uniform sized granules held together by a cohesive strength of 1 psi (0.007 MPa). The grain size is a sampled parameter in the CCA analysis. With the composition of the waste ranging from large pieces of metal to ash, it is unlikely that the waste will degrade to a uniform grain size. There has been no analysis to show that the releases calculated by sampling for a uniform distribution size bounds the releases from a heterogeneous medium.

Spalling can be viewed as a two step process. First, the explosive depressurization of the waste near the drill puncture, lasting a few seconds, followed by the erosion of channels through the waste by gas further from the puncture location, lasting hundreds of seconds. However, the spallings model includes only the second process. Two justifications are presented for ignoring the first process: 1) The pressure drop increase resulting from ejecting the drilling mud from the drill string is a relatively slow process, 2) the erosion process will proceed to a stable void configuration independent of the initial entrainment. In other words, a larger initial spall will be followed by less erosion than a smaller initial spall, resulting in the same final void ratio. We find two errors in this argument: 1) The pressure difference between the waste repository and the hydrostatic pressure of the drilling mud can be over 6 MPa, three orders of magnitude above the pressure differential needed for explosive spall. 2) The second argument presupposes, without justification, that the erosion volume is larger than the initial spall volume and that the cavity caused by the initial spall will be partially filled by the erosion process.

The spallings model was validated by DOE using a set of bench scale experiments. A four inch high cylindrical cavity of 20 inches in diameter was supplied with high pressure gas through a plenum around the circumference. A vent of variable diameter was placed in the center of the top of the cylinder. The cylinder was filled with silica sand. The experiments were run by stepping the pressure maintained at the plenum. The pressure was held constant until no more material was entrained, then stepped to a higher value. These essentially steady state experiments do not encompass the highly transient spallings phenomena. The model tests the erosion portion of the spallings phenomena for waste with no cohesive strength, but not the initial explosive phase, nor the effect of cohesion. The inclusion of cohesive strength in the spallings model reduces the calculated spall mass by as much as two orders of magnitude. The attached figure shows the sensitivity of the model to waste strength assumptions. The figure presents plots of mass removed by spallings as a function of sampled particle diameter. Each plot represents the mass removed for an assumed waste strength. The waste strength is varied from 0 to 2 psi.

The experiments indicated increasing spall with increasing diameter of the vent. The spallings model does not include a sensitivity to scale leading the developers of the spallings model to state "Extrapolation of release volumes to WIPP, using the parameters evaluated using small scale laboratory models, has the potential for grossly under-predicting such releases[2].

In their initial review, the conceptual model peer review panel deemed the spallings model to be inadequate.[3] Subsequently, the DOE has reconvened the peer review panel twice to reassess the spallings model among others. The DOE presented additional information intended to demonstrate both the validity of the spallings model and the conservatism of the calculations. The peer review panel still considers both the model and the case for conservatism to be inadequate[4,5].

The EEG therefore recommends that further development of the spallings model be pursued. The spallings model should be validated by a set of experiments that adequately simulate the expected processes of spalling in the event of human intrusion into the waste repository. These experiments should include:

a) the effects of varying the brine saturation
b) investigation of the effects of heterogeneity
c) both the rapid depressurization and longer term erosion through channels
d) the effects of varying the waste strength

e) investigation of scale influences

2. Exclusion of Two Processes from the Spallings Model

Two potentially important processes, viz., the "gas erosion" and the "stuck pipe", considered by the DOE in earlier performance assessments[6], have been excluded from the CCA spallings model. These may occur if the gas flows into the drilling mud because the pressure in the repository exceeds the hydrostatic pressure of the drilling mud but the flow rate is insufficient to expel the mud from the drill string. These two phenomena could cause releases that are over an order of magnitude larger than the largest releases calculated in the CCA.

Waste permeability has a strong influence on the gas flow rate through the waste. At lower flow rates, the drilling mud may be able to wash the spall material from the drilling cavity. This is termed gas erosion. In the SPM-2 report[6], releases from 44 to 356 m^3 were considered possible from gas erosion. Compare this to the maximum calculated release of 4 m^3 in the CCA calculations[7]. If the amount of spall is above the carrying capacity of the drilling mud, then the spall will press against the drilling string, slowing the rotation of the drill bit. The normal response of a drilling crew in such circumstances is to raise and then lower the bit in order to clean out the cavity. In the SPM-2 report[6], releases from 43 to 238 m^3 were considered possible from stuck pipe type spall.

Gas erosion and stuck pipe have been excluded from the spallings model because the waste permeability assumptions of the CCA calculations are above the threshold for ejection of the drilling mud from the drill string. The SPM-2 report[6] assumed 10^{-16} m^2 to be the threshold permeability. However, this threshold is not well defined. It certainly is related to the pressure in the repository.

The CCA (Chapter 6, p. 6-100) states that simulated waste compacted under a lithostatic load yielded waste permeability in the range of 10^{-12} m^2 to 10^{-16} m^2. The CCA assigns the waste permeability as a constant at 1.7×10^{-13} m^2, as "representative of the average value of compacted waste." There is no indication that the effects of neglecting the permeability uncertainty on the CCA spallings model were considered[8].

The permeability of the waste is a critical parameter in determining the plausibility of these processes occurring. The value of the permeability should therefore be carefully chosen to reflect, as accurately as possible, the future conditions in the repository. If the potential cementation of the waste by magnesium chloride cement and salt precipitates is considered, the waste permeability may be even lower than the 10^{-16} m^2 lower band assumed in the SPM-2 report[6].

The Engineered Systems Peer Review Panel did not consider these processes or the validity of their deletion from the spallings model. They considered the waste permeability to be adequately determined for the BRAGFLO calculations, but did not consider its potential effect on these processes, or the effect of MgO backfill in reducing waste permeability.

The EEG recommends that a more realistic value or a range of values should be assumed for the waste permeability parameter and potential for the "gas erosion" and the "stuck pipe" processes be included in the spallings scenario with a better defined permeability-pressure threshold.

References

1. Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant, SAND96-2226, Figure 2.3.1, December 1996.

2. L.R. Lenke, J.W. Berglund, and R.A. Cole, Blowout Experiments Using Fine Grained Silica Sand in an Axisymetric Geometry, NMERI 1996/7/32250 - Draft, March 1996.

3. C. Wilson, D. Porter, J. Gibbons, E. Oswald, G. Sjoblom, and F. Caporuscio, Conceptual Model Peer Review Report, DOE, July 1996.

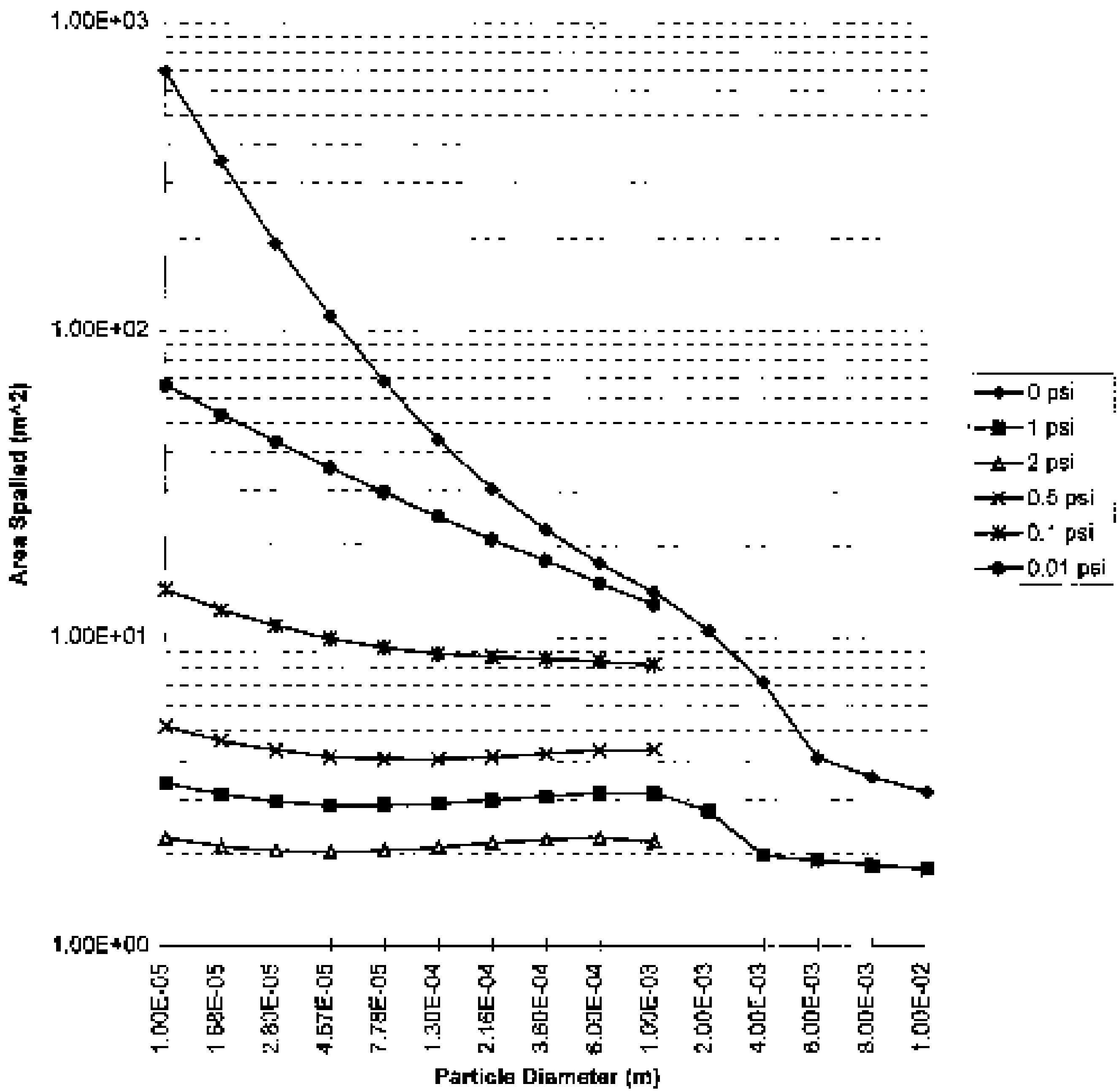
4. C. Wilson, D. Porter, J. Gibbons, E. Oswald, G. Sjoblom, and F. Caporuscio, Supplementary Conceptual Models Peer Review Report, DOE, December 1996.

5. C. Wilson, D. Porter, J. Gibbons, E. Oswald, G. Sjoblom, and F. Caporuscio, Conceptual Models Second Supplementary Peer Review Report, January 1997.

6. B.M. Butcher, S.W. Webb, J.W. Berglund and P.R. Johnson, Systems Prioritization Method — Iteration 2 Baseline Position Paper: Disposal Room and Cuttings Models, Volume 1, March, 1995.

7. J. Helton, Memo: Preliminary Summary of Uncertainty and Sensitivity Analysis Results in Support of the 1996 Compliance Certification Application for the Waste isolation Pilot Plant, December 23, 1996.

8. Form 464 for cuttings waste permeability, WPO 37102, Nov. 28, 1995, and referenced source B.M. Butcher memo to M.S. Tierney, QAP 9-2 Documentation of the Overall Waste Permeability and Flow Property Values for the CCA, January 29, 1996.



Spall area as a function of particle diameter and cementation strength
(Unpublished EEG Calculations Using CUTTINGS_S; Version PA96)

BRINE RESERVOIR ASSUMPTIONS IN THE CCA

The EEG sees no justification for assuming only 8% probability of intercepting a pressurized brine reservoir in the Castile Formation 250 meters below the repository. The fatal flow in the CCA argument for 8% is the assumption that the oil and gas wells that did not report encountering brine did in fact not encounter a brine reservoir. The fact is that the drillers are not required to report brine encounters to the state or federal authorities and no mention would be found in the records unless undue delays or hazardous conditions are encountered.

The 8% probability also ignores the data from WIPP-12 and the TDEM survey over the repository. The borehole WIPP-12 is located north of the repository within the WIPP site. It was drilled to the bottom of the Salado Formation in 1978 and deepened in 1981 at the EEG's suggestion. The DOE contractor (Popielak et al., WIPP-TME-3153, 1983) estimated the volume of the reservoir to be 2.7 million m^3 (17 million barrels). For the maximum possible reservoir thickness of 24 meters, the surface footprint of a cylinder containing this volume would have a diameter of more than 3 km. As the attached figure shows, the WIPP repository is most likely underlain by the brine reservoir encountered by WIPP-12. In addition, the TDEM survey (SAND 87-7144) gives an indication of the presence of brine at the upper Castile horizon. To try to assign specific areas of the presence of brine from this geophysical survey would be over-interpretation of the geophysical data. Combination of the WIPP-12 data and the results of the TDEM survey indicate the existence of brine under the repository. Any borehole drilled into Castile under the repository should therefore be assumed to encounter brine.

The EEG does not find the CCA reservoir volume assumption of 32,000 to 160,000 m^3 to be justified. This is based on the assumption of depletion of reservoirs by future drillers - 100% probability of encounter for the depletion assumption, while only 8% for releases!

The attached table shows the comparison between the characteristics of the WIPP-12 brine reservoir and the CCA assumptions.

The WIPP site was moved twice; in 1975 after the borehole ERDA-6 encountered a brine reservoir, and again in 1982, after WIPP-12 encountered brine. The CCA assumptions of probability should be realistically based on the site specific information, and the characteristics should be based on the WIPP-12 experience.

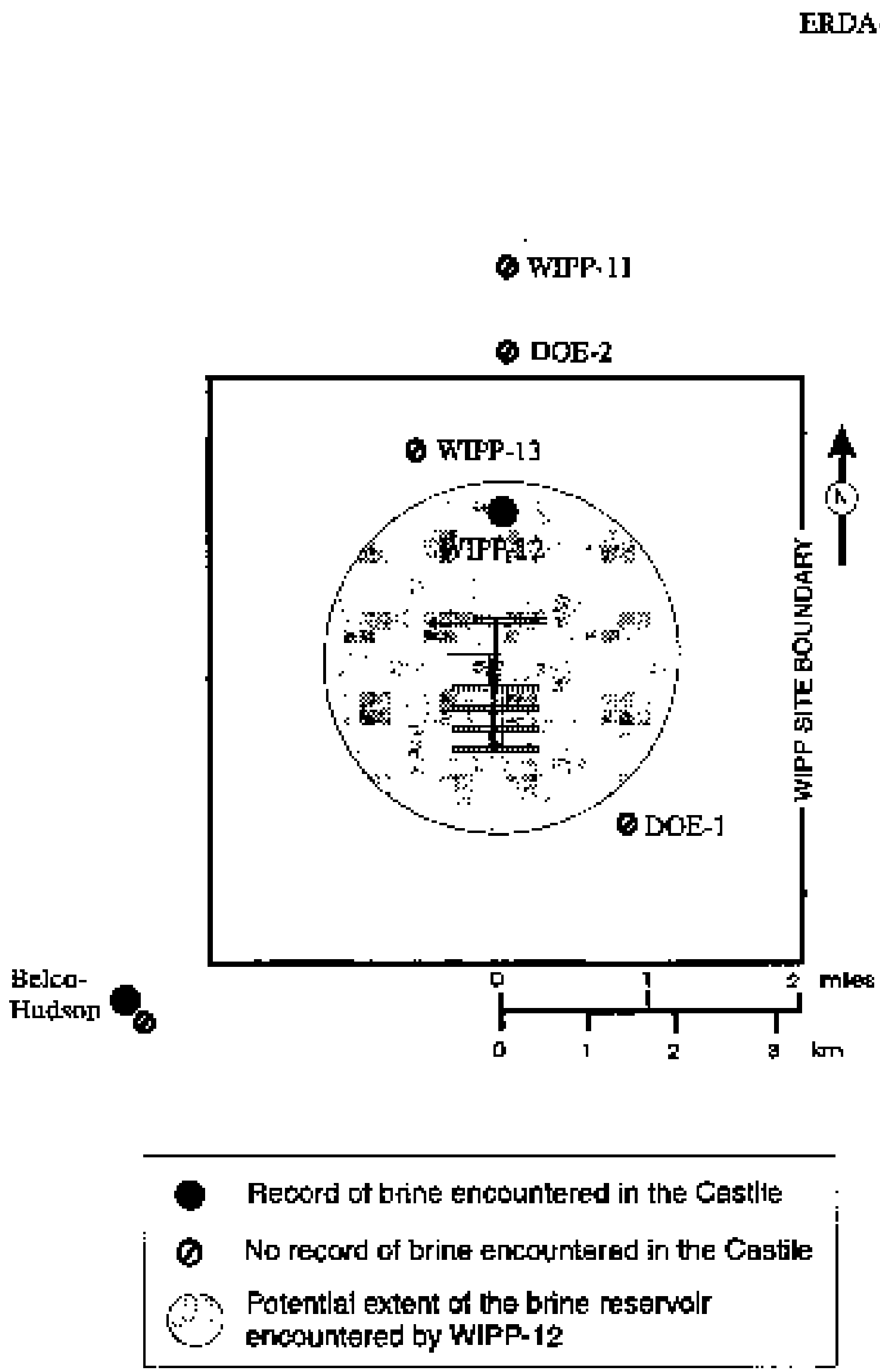
The DOE Conceptual Model Peer Review Panel, in their December 1996 report, essentially agrees with the EEG position, but has accepted the DOE position that there is no significant consequences of the probability and volume assumptions.

The EEG does not accept the "no consequence" argument that is based on piecemeal, partial sensitivity analyses.

Comparison of WIPP-12 Brine Reservoir and the CCA Assumptions

Parameter	WIPP-12 (m^3)	CCA (m^3)
Total Reservoir Volume	2.7×10^6 (a)	32,000 to 160,000 (d)
Projected Max. Artesian Flow	55,821 (b)	5,200 (e)
Flow to Surface During Drilling	4,306 (c)	400 to 2,100 (f)

(a) WIPP/TME-3153, p. H-54
(b) WIPP/TME-3153, p. H-55
(c) WIPP/TME-3153, p. H-9; Actual "unavoidable" flow
(d) DOE/CAO-1996-2184, Table 6-26
(e) CMPRR-Suppl., 12/1996, p. 42; To the Culebra, after 6 encounters
(f) CMPRR-Suppl., 12/1996, p. 42; In 10,000 years



Potential extent of WIPP-12 brine reservoir using WIPP-12 pressure recovery data, rock compressibility of $1x10^{-10}Pa^{-1}$, and reservoir thickness of 24 meters.

ENGINEERED BARRIERS FOR WIPP

The EPA regulations require engineered barriers to be included in the repository design as an Assurance Requirement (40 CFR 191.14d and 40 CFR 194.44). The philosophy of the Assurance Requirements is clearly stated in the "Overall Approach of the Final Rule" (Federal Register v. 50, no. 182, p. 38072), as follows:

> In contrast to the containment requirements, the assurance requirements were developed from that point of view that there may be major uncertainties and gaps in our knowledge of the expected behavior of disposal systems over many thousands of years. Therefore, no matter how promising the analytical projections of disposal system performance appear to be, these materials should be disposed in a cautious manner that reduces the likelihood of unanticipated types of releases. Because of the inherent uncertainties associated with these long time periods, the Agency believes that the principles embodied in the assurance requirements are important complements to the containment requirements that should insure that the level of protection desired is likely to be achieved.

With respect to the engineered barriers as an assurance requirement, the "Overall Approach of the Final Rule" states:

> Designing disposal systems to include multiple types of barriers, both engineered and natural, reduces the risks if one type of barrier performs more poorly than current knowledge indicates.

The CCA (Sec. 3.3) describes four types of engineered barriers in the design of the WIPP disposal system: (1) Shaft Seals, (2) Panel Closures, (3) Backfill around the waste, and (4) borehole plugs. EEG does not consider either of these to be engineered barriers, for the following reasons:

Shaft Seals

Shaft seals are at best an attempt to undo the damage done to the natural environment when the shafts were excavated, and therefore cannot be considered to be an engineered barrier as distinct and *complementary* to the natural barriers.

Note that the 40 CFR 191.12 definition of a "Barrier" includes the following examples of engineered barriers, but does not include "shaft seals".

> ... A canister, a waste form with physical and chemical characteristics that significantly decrease the mobility of radionuclides, or a material placed over and around waste, provided that the material or structure substantially delays movement of water or radionuclides.

The repository standards for the high-level nuclear waste repository (10 CFR 60) specifically exclude shaft seals from engineered barrier system. "Engineered Barrier System" is defined in 10

CFR 60.2 as:

> *Engineered barrier system* means the waste packages and the underground facility.
>
> and
>
> *Underground facility* means the underground structure, including openings and backfill materials, but excluding shafts, boreholes, and their seals (underline added).

Panel Closures

Like the shaft seals, panel closure systems (separation of waste panels by engineered structures) cannot be considered to be engineered barriers because they too can at best be imperfect attempts to restore the original natural system. Panel seal is not included in the examples of engineered barrier in the EPA definition (40 CFR 191.12).

The Marker Bed 139 lies directly below the WIPP repository and is connected to the floor of the waste rooms through extensive fractures, floor upheaval and milling of the floors. Water (with anomalous lead content acting as a tracer) seeping down from the exhaust shaft has moved 400 ft through the marker bed from the base of the air exhaust shaft to the waste handling shaft in a short period of time during 1995-96. This pervasive marker bed would not allow effective separation of the panels unless the entire floor of the repository is dug down 10 ft and grouted.

According to the CCA (p. 3-27, lines 19-20), "The panel closure system was not designed or intended to support long-term repository performance." How then can it be considered an engineered barrier for the long-term performance?

Backfill Around the Waste

The DOE plans to put sacks of magnesium oxide (MgO) over and around the waste drums to try to control the future chemical conditions in the repository. The expectation is that MgO will react with the carbon dioxide (CO_2) that is produced from microbial action in the repository. Removal of CO_2 will result in alkaline conditions in the repository. Since the experimentally determined solubilities of radionuclides are lower in alkaline (high pH) conditions, the emplacement of MgO and its postulated effect allows assumption of lower solubility values in the CCA. This assumption results in lower postulated releases to the accessible environment and thus helps in showing compliance with the Containment Requirements (40 CFR 191.13) of the EPA Standards.

Since the publication of the CCA, the DOE has argued that the MgO is not needed for showing compliance with the Containment Requirements because the mean CCDF without MgO, although showing higher releases than "with MgO", still is within the compliance limits. Such an argument is based on a partial calculation without altering other assumptions and input parameters, and therefore appears meaningless. The fact remains that the purpose of including MgO in the WIPP repository is to control the chemical conditions in the WIPP repository to allow assumption of lower actinide solubility values. It may therefore satisfy a need for the Containment Requirement of the Standards, but does not provide *complementary* added assurance visualized by the Assurance Requirements (40 CFR 191.14).

Borehole Plugs

Since the stated requirements for plugging the boreholes (Section 3.3.4 and Figure 3-10 of the CCA) are much less stringent than the shaft seals, the borehole plugs have a lesser claim as engineered barriers than the shaft seals. The EPA Standards (40 CFR 191.12) do not include borehole plugs as an example of engineered barriers. The NRC specifically excludes borehole seal as part of an engineered barrier system (see the quote under Shaft Seals section above). Hence, the borehole plugs should not be considered to be an engineered barrier.

Incidentally, Figure 3-9 ("Approximate Locations of Unplugged Boreholes") does not include two deep abandoned oil and gas wells that are located within the WIPP site: Badger Unit Federal in Section 15 (between WQSP-3 and H-5 in the northwest part of the WIPP site), and Cotton Baby Federal in Section 34 (east of H-11 in the southeast corner of the WIPP site).

Recommendation

The EEG has recommended a multi-barrier approach for WIPP since the beginning of the project. The EPA regulations also require such an approach as "assurance requirements". According to the WIPP Safety Analysis Report (App. A), 88% of the WIPP bound waste is planned to be processed. At the least, the DOE should take credit for such reprocessing in the WIPP performance assessment and the CCA. EPA should encourage DOE to process the waste to make it insoluble.

<u>Enclosure</u>:
Information from the draft 1996 WIPP SAR

Information from the draft 1996 WIPP SAR
Appendix A, page A-4 to A-15
Data is from final row of cumulative values for each waste form

Stored Drum Equivalents

Final Waste Form	**Not Processed**	**To Be Processed**	
Combustible	4194	23570	
Filter	976	72	
Graphite	616	1845	
Heterogeneous	6355	104300	
Inorganic Non-metal	1168	12911	
Lead/Cadmium Metal	83	31	
Salt Waste	34	68	
Soils	95	1862	
Solidified Inorganics	15651	30670	
Solidified Organics	1077	3311	
Uncategorized Metals	3348	48751	
Unknown	129	188	
Various	0	20105	
Subtotal of column	**33726**	**247684**	Total stored **281410**
Percent of Total Stored	**11.98%**	**88.02%**	

Notes from the 1996 draft SAR
Final SAR Expected late Jan. 1997
W.T. Bartlett 1/21/97

FLUID INJECTION AND SOLUTION MINING

The EPA Requirement and the CCA

The EPA criteria (40 CFR 194.32 c) requires an analysis of the effects of fluid injection activities on the disposal system, prior to disposal and soon after disposal. The CCA has screened out the fluid injection scenario within the site on a "regulatory basis" and adjacent to the site on the basis of "no consequence" and has provided a number of arguments why it should not be considered in the performance assessment for WIPP. This paper is a critique of the CCA arguments contained in Chapter 6 and Appendix SCR. The EEG has reviewed the Stoelzel and O'Brien[1] assumptions (discussed in the CCA and later in this paper), and finds the critique by John Bredehoeft[2] (enclosed) to provide additional compelling arguments for not accepting that analysis to be valid. A copy of a consequence analysis by John Bredehoeft[3] is also enclosed. This preliminary analysis clearly establishes the importance of considering the fluid injection scenario in predicting the near-term and long-term integrity of the WIPP repository.

How Long in the Future?

The DOE has chosen "soon after disposal" to mean 50 years in the context of the fluid injection scenario. However, in the 1991 DOE elicitation of expert opinion[4] on future activities in the vicinity of WIPP, one of the four teams addressed fluid injection and assigned probabilities of waste brine disposal associated with other industrial activities for the full 10,000 years. Further, the probability of a larger number of such injection wells, within the site, was predicted to increase with time (Ref.4, Table IV-16).

With respect to natural resource recovery activities surrounding the WIPP, the surrounding public lands are managed by either the Federal Government or the State of New Mexico. In addition to federal law, state and federal agencies know that this is a resource rich area and have developed additional policies for the effective recovery of these resources consistent with federal and state law. The Federal Land Management and Policy Act[5] states that public lands and resources are utilized to "meet the present and future needs of the American people" and take into account the "long term needs of future generations." This federal law does not limit consideration of natural resources on public lands to "near future" nor to "existing leases." On the contrary, federal agencies such as the Bureau of Land Management have explicitly argued that lessees can plan and submit plans for resource recovery activities outside their actual leases[6].

Review of Appendix SCR Arguments

The discussion of fluid injection in Appendix SCR of the CCA is incomplete and largely incorrect. For example, Appendix SCR mentions gas reinjection for natural gas storage in the Morrow Formation but fails to mention natural gas storage in the Salado Formation. It is argued that the differences between the geology at WIPP and the Vacuum Field and Rhodes-

Yates Field provide for more potential thief zones below the WIPP horizon in the event of water escaping the injection zone. However, field evidence strongly suggests that brine injection into the Bell Canyon below the WIPP horizon appears to be leaking into the Culebra aquifer above the WIPP horizon (see the discussion in Ref.7, section 3.1.6). Further, the CCA provides no experimental evidence such as the measurement of water quantities in the anhydrite beds of the Salado Formation to support the CCA speculation.

The claim that there will be no waterflooding on the scale of Rhodes-Yates is also undermined by field evidence. The proposed waterflood at the Avalon Unit will recover 8.2 million barrels of oil by injecting 141 million barrels of water for forty years through nineteen injection wells into the Cherry Canyon and Brushy Canyon members of the Delaware Mountain Group. At Rhodes-Yates, approximately 41 million barrels of water were injected through eighteen injectors over a 26 year period. Further, the pressure maintenance wells at the Cabin Lake Unit, at the northwest corner of the WIPP Site are injecting 1.4 million barrels of water per year compared to 200,000 bbls water that were injected per year through the two pilot pressure maintenance wells at Rhodes-Yates.[7]

The CCA Appendix SCR argues that waterflooding on the same scale as the Vacuum or the Rhodes-Yates Field is unlikely because oil pools in the vicinity of the WIPP are characterized by channel sands with thin pay zones, low permeabilities, high irreducible water saturations, and high residual oil saturations. However thin pay zones tend to maximize vertical sweep efficiency and have a history of successful waterflooding throughout the United States, including the Delaware Basin. "Low" reservoir permeabilities of oil reservoirs near the WIPP area has not detered waterflooding in the mature oilfields of the Delaware Basin. Further, mature oil fields in the Delaware Basin have responded favorably to carbon dioxide flooding. The observation of high irreducible water saturations is irrelevant. A waterflood is not designed to reduce the water saturation. A waterflood designed to reduce the oil saturation and increase water saturation in the reservoir by producing the oil. The CCA comment on high residual oil saturations does not speak to the economics of waterflooding. While the Delaware sands, including those around the WIPP, produce large volumes of water, they are, nonetheless, technically and economically amenable to waterflooding[7,8] as well as CO_2 flooding[7,9,10,11,12].

The CCA-SCR cites New Mexico state regulations as also protecting the WIPP. However, the emplacement of a salt isolation string is not intended to address the needs of a 10,000 year nuclear waste repository. It is required to meet the near term safety concerns of the potash industry[13]. Further, even oil and gas wells equipped with a salt isolation string are restricted from drilling through potash reserves or near potash mining operations. With respect to brine injection wells, the potash companies and oil companies have documented their concerns[14,15,16].

The CCA-SCR notes that state regulations do not allow injection pressures to exceed the rock fracture pressure. However, that portion of the regulation applies to the target injection zone and not any overlying formations. The producing reservoirs near WIPP are greater than 7000 feet. One consequence of greater vertical distance is that the surface injection pressure is automatically approved for 1400 psi or 0.2 psi per foot. This corresponds to 2400 psi at the WIPP horizon which is well in excess of the fracture pressure of the anhydrite beds in the Salado Formation.

As to state regulations in general, state regulations for fluid injection have been in place for decades. Documented problems with fluid injection projects throughout southeast New Mexico identifies the limitations of state regulations. In the case of waterflood brine migrating through the Salado and damaging another oil company property, there is litigation and monetary compensation[17,18]. In the case of a nuclear waste repository, there are performance assessment calculations. However, the CCA does not include this scenario in the performance assessment calculations.

Stoelzel and O'Brien Model

The fluid injection scenario on adjacent properties for the near future has been screened out by the DOE citing low consequence as determined from calculations by Stoelzel & O'Brien[1]. It should be noted that a two dimensional, vertical model was used. Further, the assumptions used in the calculations (DOE SCR) either underestimate or fail to consider hydraulically fractured Salado anhydrite permeability, permitted surface injection pressures in the vicinity of WIPP, injection pressure gradients, the volume of disposal brine that is typically injected by oilfield operations, and the anticipated time of fluid injection activities.

The model assumes a total of $7x10^5$ cubic meters of brine was injected during a fifty year period. This is equivalent to 4.4 million barrels of brine. The David Ross AIT Federal #1 salt water disposal well, which is less than a mile from WIPP, alone has injected more than 5 million barrels brine in five years of operation. And there is no basis for assuming that industrial fluid injection will not continue for the full 10,000 years.

Stoelzel and O'Brien consider only salt water disposal and assume an injection depth of 4260 feet, a surface injection pressure of 850 psi, and a pressure at the WIPP horizon of 1900 psi. However, pilot waterflooding operations near WIPP are underway for reservoirs at 7000 feet depth and have been approved to inject at a surface pressure of 1400 psi, which in the event of communication, would exert a pressure of 2400 psi at the WIPP horizon. Hence, the anhydrite beds in the Salado Formation would fracture, as successfully argued by Hartman[17] and brine would migrate for miles in the inadvertent waterflooding hydrofracture scenario.

Solution Mining

In 1979 the EEG recommended[19] that the DOE consider solution mining for salt as an intrusion scenario. The CCA (Appendix MASS, p. 87) claims that the DOE is not aware of any ongoing solution mining in the Delaware Basin. However, that activity has been ongoing for several decades in southeast New Mexico, including the Delaware Basin, to provide brine for oilfield drilling operations. Furthermore, state records show that fluid injection for solution mining of halite is expanding into areas closer to the WIPP to meet the needs of drilling activities in that area.

As to future mining of potash, solution mining is the only method that can be reasonably predicted for the Carlsbad District[20]. In Canada and the United States, solution mining is used for recovery of sylvite. Langbeinite is not readily soluble. So if solution mining is employed in the vicinity of the WIPP Site, it will be to recover only sylvite. While no specific plans have yet been formulated,

all mines in the Carlsbad area have held open the option of using solution mining once their sylvite deposits are fully mined out. The concept would rely on the fact that the open spaces left over from mining would allow ore remaining in pillars to be recovered[20].

How can the CCA reject the solution mining scenario, if private companies surrounding the WIPP site are holding the option of using solution mining?

EEG Recommendations

Based on a technical analysis of available information, the EEG recommends that the CCA include the effect of fluid injection and all other resource recovery activities for future and existing wells drilled within the site and adjacent to the site. These activities should include:

- Waterflooding for enhanced oil recovery.
- Carbon dioxide flooding for enhanced oil recovery.
- Salt water disposal from oil production and other industrial activities.
- Solution mining for halite and sylvite.

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Enclosure:

Bredehoeft Memoranda dated January 10, 1997 and January 14, 1997

The HYDRODYNAMICS Group
studies in mass and energy transport in the earth

JOHN BREDEHOEFT *PhD, NAE*
principal

January 10, 1997

MEMORANDUM

To: **Lindsay Lovejoy, Jr.**

From: **John Bredehoeft**

Subject: **Hartman Scenario**

Hartman Scenario—Introduction

The so-called Hartman Scenario is based upon a law suit in the Delaware Basin. In 1991, Hartman, an independent oil operator, attempted to drill a well on the Bates lease approximately 2 miles from the Rhodes Yates water-flood project operated by Texaco. The Hartman #2 Bates well encountered brine at a depth of 2240 feet; the drilling had to be terminated at 2280 feet. In 1953, the Bates #1 well was drilled without encountering pressurized brine.

Water flooding was started in the Rhodes oil field in 1959. Texaco initiated a pilot water flood in 1964. The water flood was extended in the Rhodes field in 1974. There are several active water flood projects in the Rhodes Yates area.

I reanalyzed the Hartman Scenario. In doing so, I first estimated the transmissivity of the Bates # 2 well that flowed extensively. From the transmissivity, I estimated the permeability. This should be obvious, but we are not totally sure what constituted the permeable zone in the Bates # 2 well. I then: 1) compared this estimate of permeability with those measured at WIPP, and 2) estimated the inflow to WIPP should the permeabilities at the Bates # 2 site apply in the vicinity of WIPP.

Transmissivity & Permeability

The Bates # 2 well flowed 840 gpm, or 1.9 cubic feet per second (cfs). The shut-in pressure at the land surface was 1000 psi—approximately 2000 feet of head at the land surface (Van Kirk, 1994). Knowing both the flow rate and the well-head, shut-in pressure there are several methods that can be used to estimate permeability. I first used the Theim, steady-state solution for radial flow to a well and solved for transmissivity, T. I then compared this result to results from two other estimating procedures.

The difficulty with the Theim approach is that we do not know how far out the cone of depression for the Bates # 2 well extended. (We can define the other boundary of the cone as the point where the drawdown caused by flow to the well is negligible.) I assumed several different radial distances for the extent of the cone (r_2), and make the calculations. The differing radial distances bracket the cone. As we see, the estimates do not vary a great deal—by a factor of only two which is small in estimating transmissivity.

$$T = 2.3\, Q \log (r_2/r_1) / [\, 2\, \pi\, (s_2 - s_1)]$$

where T = transmissivity

Q = well production rate

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r_2 and r_1 are selected radial distances from the center line of the well bore. I chose r_1 at the wall of the borehole approximately 0.5 ft (1 foot diameter well bore—slightly larger than the drill bit). I let r_2 be the radial extent of the cone of depression—the distance at which the drawdown is negligible.

$(s_2 - s_1)$ is the total drawdown within the cone of depression caused by the well—1000 psi. (Perhaps I need to amplify this explanation. When the well is flowing the pressure at the well head is atmospheric—which is generally defined as 0. The well head, shut-in pressure gives a us an indication of what the formation pressure would be without the well flowing. The total pressure drop when the well is flowing is 1000 psi. It could be smaller due to friction losses in the well bore —a smaller pressure drop gives a higher estimate of permeability. The total pressure drop across the cone of depression is also 1000 psi.)

I assume the brine produced a pressure of 0.5 psi per foot of brine. (Van Kirk, 1994, reports the normal pressure gradient for saturated salt water as 0.525 psi per foot; I simplified the calculation by rounding to 0.5 psi / ft.)

With r_2 = 1,000 ft.

$T = 2.3 \times 1.9 \times \log(1{,}000.0 / 0.5) / (2\pi \times 2000.0) =$ 0.0011 ft²/sec

With r_2 = 10,000 ft

$T = 2.3 \times 1.9 \times \log(10{,}000.0 / 0.5) / (2\pi \times 2000.0) =$ 0.0015 ft²/sec

With r_2 = 100,000 ft

$T = 2.3 \times 1.9 \times \log(100{,}000.0 / 0.5) / (2\pi \times 2000.0) =$ 0.0018 ft²/sec

With r_2 = 1,000,000 ft

$T = 2.3 \times 1.9 \times \log(1{,}000{,}000.0 / 0.5) / (2\pi \times 2000.0) =$ 0.0022 ft²/sec

We can also estimate the transmissivity using estimating procedures suggested by Theis et al. (1963) for pumped wells, and by Bredehoeft et al. (1983) for flowing wells. The specific capacity is 0.4 gpm per foot of drawdown, or 0.00089 ft² / sec per foot of drawdown. The Theis estimate yields:

T = specific capacity x 2000 (in units of gallons per day per foot)

T = 0.4 x 2000 = 800 gallons per day per foot = 0.0012 ft²/sec.

Bredehoeft et al (1983) produced a graphical type curve; use of the Bredehoeft et al. method yields:

T = 0.0015 ft²/sec

The estimates compare favorably; the values vary by only a factor of two. Since transmissivity can vary over 15 orders of magnitude, a factor of two variation (100%) in the estimates is considered quite good.

The permeability is less clear, only because we do not know through what vertical thickness of rock brine flowed. The drilling encountered brine at a depth of 2240 feet, and was stopped by too much flow at 2280. Assuming the entire 40 feet was permeable, the

	k = T/ thickness = 0.001 / 40.0 =	0.000025 ft/sec
or	k =	0.00075 cm/sec
	k =	0.75×10^{-12} m^2

Implications of the Analysis—Comparison to WIPP

It should be remembered that these numbers are estimated by applying a model for radial flow to/from a well. The estimate is some kind of an average permeability that applies to the entire cone of depression for the well. In other words, it is an estimate of the regional permeability within the assumed cone of depression.

The permeability of the Anhydrite marker beds was measured in-situ at WIPP. The range in anhydrite marker bed permeability data used in PA is

k anhydrite– undisturbed	7.94×10^{-19} m^2 to 10^{-21} m^2
k anhydrite—hydro-fracture maximum value (PA)	10^{-9} m^2
Hartman—Bates # 2	7.5×10^{-13} m^2

The permeability encountered in the Bates # 2 well almost surely represents hydro-fractured anhydrite in the Salado Formation. The shut-in pressure of the Bates well was 1000 psi at land surface. There were reports of oil field brine injection activities in the area with 1000 psi land surface pressures and higher (Van Kirk, 1994). Dennis Powers reported: *"For the Rhodes Yates water flood, the injection pressure at the surface ran 1200 psi and above. Some injection pressures approached 2,000 psi at the surface." (Silva, 1996, p. 67)* A pressure of 1000 psi at land surface is approximately lithostatic at a depth of 2000 feet.

The consensus interpretation of what happened in the Rhodes Yates area is that water injection at high pressure caused massive hydraulic fracturing within the Salado Formation. Numerous wells have encountered flows of water in the Salado (Van Kirk, 1994). The hydraulic fracturing has increased the Salado permeability on a regional scale. Hartman won his law suit on the basis of this hypothesis. This interpretation is consistent with our analysis of the permeability encountered in the Bates # 2 well.

Potential Flow to WIPP

It is of interest to calculate the flow to WIPP through the anhydrite marker beds. I will do two calculations with 1) unfractured anhydrite, and 2) hydro-fractured anhydrite. I will use a simplified model for analysis. I make a number of assumptions

1. two-dimensional, areal flow (x, y) in combined marker beds 139, A and B.
2. good connection between the marker beds and WIPP,
3. single-phase, liquid flow only;
4. steady flow (not transient),

5 that fluid is injected with a pressure at a land surface of 1000 psi (68 atmospheres)—pressures like that measured at the surface in the Bates # 2 well; (This is lower than the 1200-2000 psi pressures reported for surface pressures of injection wells in the Texaco Rhodes Yates water flood. As we will see, 1000 psi poses problems.)

6 that the casing of the injection well fails, and 1000 psi surface pressure is imposed on marker beds 139, A and B:

7 in the hydro-fractured case that the marker beds have a regional permeability equal to that at the Bates # 2 site—7.5×10^{-13} m^2 ; (This assumption deserves more explanation. I suggested above that the hydraulic fracturing in the vicinity of the Texaco Rhodes Yates water flood increseased the permeability on a regional scale. I am assuming that similar, regional scale hydraulic fracturing occurs in the vicinity of WIPP.)

8 the repository is at hydrostatic pressure and remains at hydrostatic pressure; (Early in the history of the repository the pressure could be more nearly atmospheric. As the repository receives significant flow the pressure will increase. For this analysis, I neglect both the early pressure history below hydrostatic, and the later potential pressure build-up above hydrostatic. If one examines the pressure histories of WIPP computed by PA, hydrostatic pressure is the dominate mode.)

9. since the region of the model is finite, I assume no flow boundaries at the edge of the modeled region. (These boundaries force the flow to go to WIPP where the head is held hydrostatic. Ideally, we would like no head build-up at the boundaries; as one can see below there is some build-up at the model boundaries. This condition can be relaxed by extending the model outward. In the hydro-fractured case the permeability is increased in a restricted area; therefore the outer, no-flow boundary may not be as bad an assumption as might appear at first glance. The region model is fairly large; and the boundaries are somewhat removed from the area of principal interest.)

The results are summarized in the following table:

Table I Flow to WIPP

	Distance from well to WIPP	Well-head pressure (psi)	Permeability m^2	Flow rate m^3 / sec	Flow rate m^3 / day
Model 1	2 km	1000	10^{-18}	7×10^{-9}	0.0006
Model 2	2 km	1000	7.5×10^{-13}	5×10^{-3}	430.0 (157,000 / yr)

Note--the approximate total pore volume of the repository, after the salt deforms, is 30,000 m^3.

It is of interest to examine the head distribution produced by this models. The head is the same for each permeability distribution; even though, as Table I shows, the flows are quite different. The attached Figure is an isometric projection of the head. One can picture the flow if you remember that flow is directly down the gradient in head—it is analogous to a marble rolling down hill.

Concluding Remarks

Injection fluid pressures in the vicinity of the Bates lease were high. It seems clear from the data that the pressures were sufficiently high to produce massive hydraulic fracturing over a large area that included the Bates # 2 well. The permeability, as estimated from the well, is five orders of magnitude higher than the highest undisturbed measurements at WIPP. On the other hand, the Bates # 2 well permeability is three orders of magnitude lower than the maximum hydro-fracture permeability used in Performance Assessment.

Fluid injection in the vicinity of WIPP has the potential to quickly fill the repository with brine should the operation be similar to that which occurred in the vicinity of the Bates lease. The Hartman Scenario is not easily dismissed.

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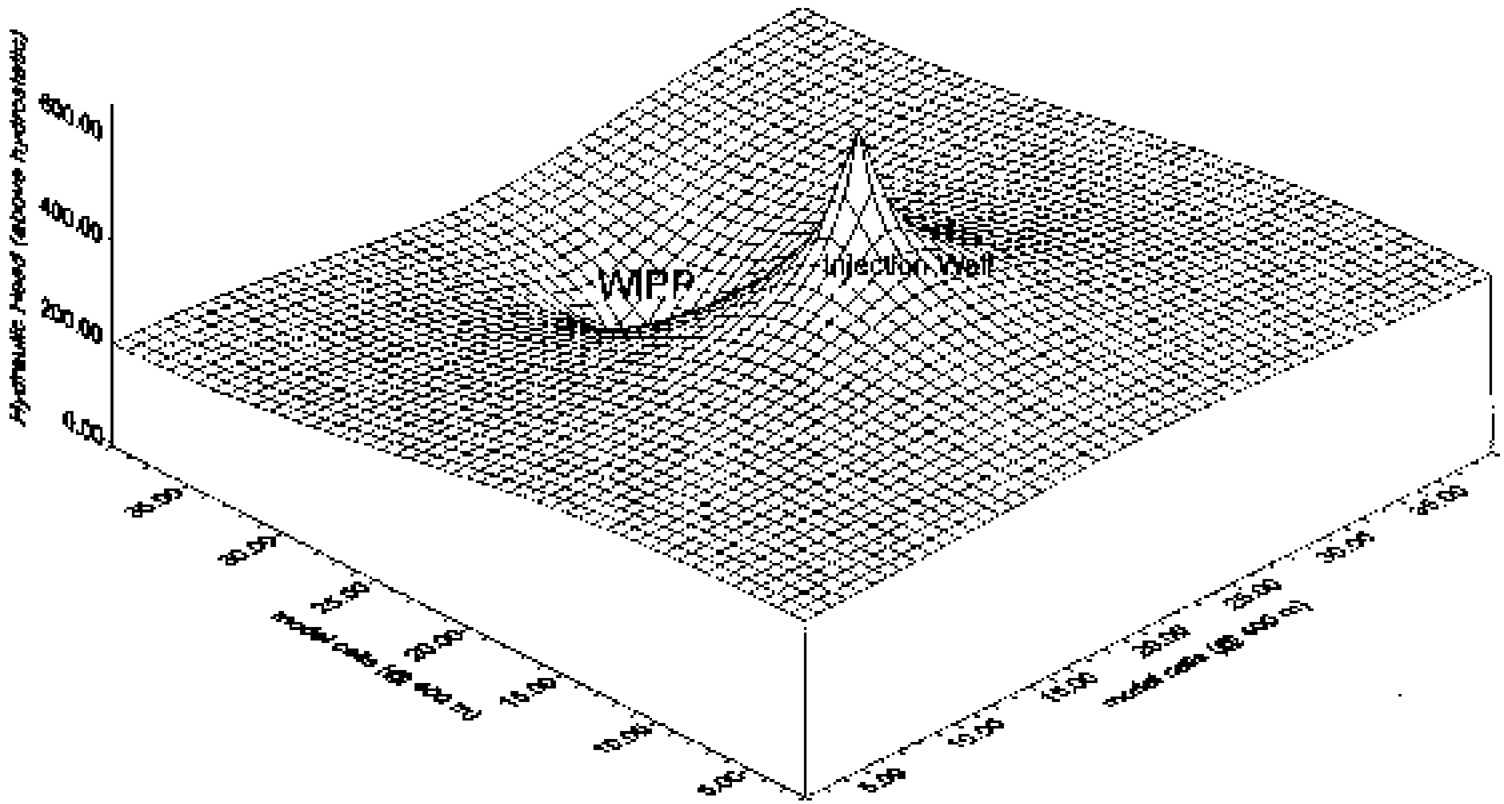
WIPP--Hartman Scenario
(head above hydrostatic)



The HYDRODYNAMICS Group
studies in mass and energy transport in the earth

JOHN BREDEHOEFT *PhD, NAE*
principal

January 14, 1997

MEMORANDUM

To: **Lindsay Lovejoy, Jr.**

From: **John Bredehoeft**

Subject: **Hartman Scenario—Stoezel-O'Brien Analysis**

Introduction

Stoezel-O'Brien did a cross-sectional analysis. I modeled a cross-sectional to compare with our areal analysis and show you the difference.

Analysis

I selected a cross-section strip that is two model cells in width—a total width of 800 meters. This is approximately as wide as the smaller dimension of the repository foot print As before, I placed the injection well 2 km from the repository. I used the permeability estimates from the Hartman # 2 Bates well. I assumed an injection pressure of 1000 psi at land surface; held the repository at hydrostatic head; and did a steady-flow calculation.

This analysis is analogous to our previous analysis except that we now have flow only in the cross-sectional strip. Enclosed is an isometric plot of head for comparison.

Results

The results are summarized in the following table:

Table 1 Flow to WIPP

	Distance from well to WIPP	Well-head pressure (psi)	Permeability m^2	Flow rate m^3 / sec	Flow rate m^3 / day
Model 1 (areal)	2 km	1000	10^{-18}	7×10^{-9}	0.0006
Model 2 (areal)	2 km	1000	7.5×10^{-13}	5×10^{-3}	430.0 (157,000 m^3/yr)
Model 3 (strip)	2 km	1000	7.5×10^{-13}	1×10^{-3}	86.4 (31,600 m^3/yr)

Note—the approximate total pore volume of the repository, after the salt deforms, is 50,000 m^3.

As you can see, restricting the flow to a cross-sectional strip reduces it to approximately 1/5 of the amount in areal model. This is the conceptual difficulty with the Stoezel-O'Brien approach.

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WIPP Analysis

Flow to/from WIPP is three dimensional. Sandia claims, perhaps correctly, that analyzing the full 3D flow problem is much too computer intensive to be practical for PA. For this reason the problem is idealized currently into a plane—a cross-section in the case of WIPP. (Two dimensional analyses, either areal—x, y; or cross-sectional—x ,z; or radial—r, z, are the rule in analyzing flow problems.) Any of 2D geometry is an approximations for the 3D problem. The simplification is a compromise—sometimes good, and sometimes not so good. You can see that the Stoezel-O'Brien cross-section was not very good for analyzing flow to WIPP.

In previous PA analyses a radial formulation was used in which radial distances were measured out ward from the disposal room. This formulation did not handle the connection between the disposal panel and the rest of the repository very well. This was changed to a cross-section in an effort to improve this portion of the modeling. The new cross-section will not do well in handling flow outward in the marker beds, the radial model was better in this instance.

I know that Chuck Byrum is concerned about the 2D approximations used in WIPP PA. EPA has had HydroGeologic looking into these approximations.

My gut reaction is that most of the approximations associated with the cross-sectional analysis used in BRAGFLOW are probably okay—assuming a 2D analysis is the only one practical. As I suggested to Sandia when it was presented, the Stoezel-O'Brien cross-section concept used for analysis was poor, at best.

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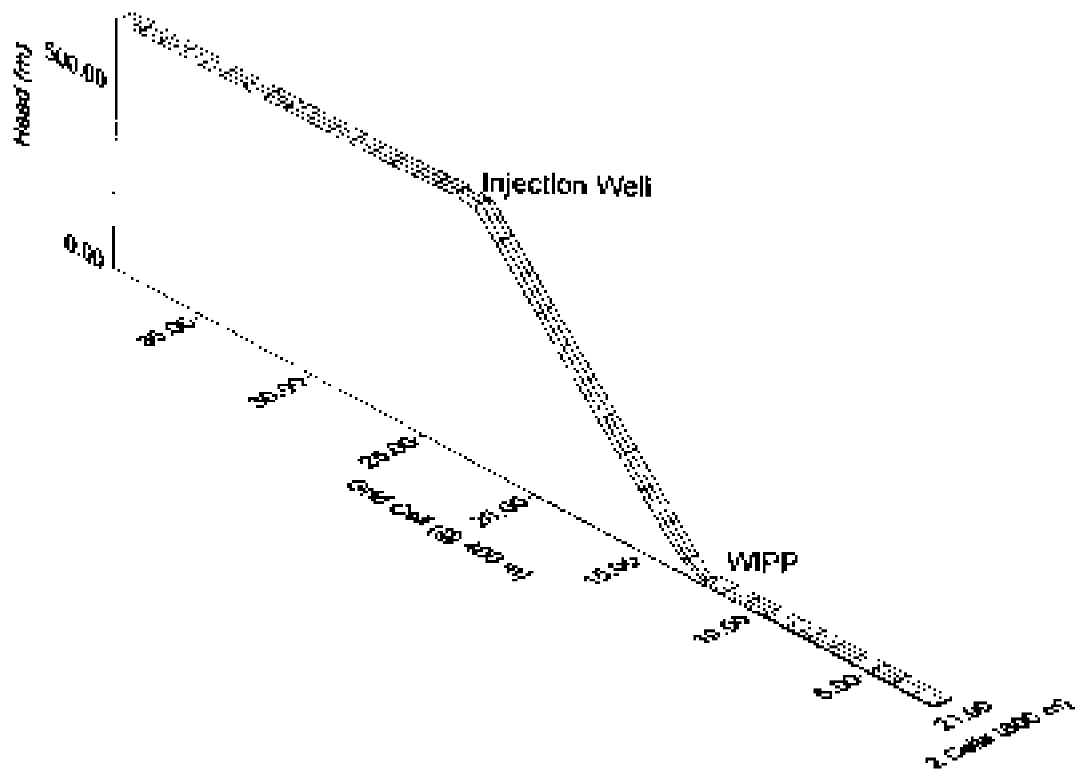
Head (m)
500.00
0.00
Injection Well
WIPP
25.00
21.00
10.50
5.00

ENVIRONMENTAL EVALUATION GROUP
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7007 WYOMING BOULEVARD, N.E.
SUITE F-2
ALBUQUERQUE, NEW MEXICO 87109
(505) 828-1003
FAX (505) 828-1062

March 14, 1997
Director,

Center for the Waste Isolation Pilot Plant Program
U.S. Environmental Protection Agency
Office of Radiation and Indoor Air
401 M. Street S.W.
Washington, D.C. 20460

Dear Mr. Marcinowski:

Enclosed please find the EEG's additional comments on significant issues arising from our review of the WIPP Compliance Certification Application (CCA). This package of 14 papers complements the package of 6 papers submitted to you on February 7, 1997, following the same format.

Please note that as we continue to explore deeper into the assumptions, professional judgements, calculations, conceptual and numerical models, and secondary documentations related to the CCA, we are bound to come up with additional issues to be sesolved. We do not view the March 17, 1997 deadline as a bounding date for communicating additional concerns to the EPA. Given the significance of the decision that the EPA has to make, and the time that the DOE has taken to prepare this application since EPA originally promulgated 40 CFR 191 in 1985, 4 months of review time is not enough. Actually, the review time was much shorter since many of the issues that we have identified required a review of the Sensitivity Analysis Report that was provided to the EEG on January 20, 1997, and additional materials that have only recently been added to the Records Packages at the Sandia National Laboratories.

A detailed review of the July 1995 DOE draft CCA (DCCA) was provided by the EEG to the DOE in February 1996 and later published as the EEG report, "Review of the WIPP Draft Application to Show Compliance with EPA Transuranic Waste Disposal Standards", EEG-61, March 1996. The EEG has not received comments on that review from the DOE to date, and we have found no changes between the draft and the final CCA as a result of the EEG review (EEG-61). In our additional comments on the CCA to be provided in a report that we plan to publish this year, we will analyze our comments on the DCCA and how they have been treated in the CCA. At this time, we are formally submitting a copy of EEG-61 to you and to the Docket as part of our comments on the CCA.

The issues identified in EEG-61, our letter and encloserues date 2/7/97, and this letter and the enclosures, should therefore be considered to be our formal comments on the CCA submitted to you before 3/1797 deadline. As you can see, we have concentrated our efforts so far on reviewing the Containment Requirement related issues of the CCA. We will provide comments on the other parts of the 40 CFR 191 subpart B compliance as we review the compliance with them.

The overall EEG recommendation to the EPA at this point is to require the DOE to include consideration of additional scenarios like water-flooding and solution mining, with corrected conceptual models and parameter values in showing compliance with the Containment Requirements of the EPA Standards, 40 CFR 191. EPA should also require robust engineered barriers as part of the Assurance Requirement of 40 CFR 191.

Sincerely,

Robert H. Neill
Director

RHN:LC:pf
Enclosures: EEG Reviews of the WIPP CCA

Brine Reservior Assumptions in the CCA (Revised)
Faulty Sapling Ranges
Brine Inflow from Salado: 2D versus 3D Geometry in BRAGFLO
Probability of Microbial Degradation
Borehole Plug Lifetime
Inconsistency Between Direct Brine Release and Spallings Geometry
Waste Permeability Values
Random Emplacement of the Waste in the Repository
Residual Brine Saturation of Waste
Compendum of Direct Brine Release Problems
Active Institutional Controls
Passive Institutional Controls
Potash Mining
Documentation of FEPs and Parameters

cc: Ms. Jennifer Salisbury, NMEMNRD
Mr. Lindsay Lovejoy, Jr., NMAG
EPA Docket for WIPP (A-9302)

BRINE RESERVOIR ASSUMPTIONS IN THE CCA (Revised)

This section updates EEG's previous submission of 2/7/97 to the EPA on brine reservoir assumptions. A new section, "Revisions to Parameters" has been added to address issues raised in the January 16, 1997 memo of Rick Beauheim to Palmer Vaughn[1]. No other changes have been made to the original submission.

The EEG sees no justification for assuming only 8% probability of intercepting a pressurized brine reservoir in the Castile Formation 250 meters below the repository. The fatal flaw in the CCA argument for 8% is the assumption that the oil and gas wells that did not report encountering brine did in fact not encounter a brine reservoir. The fact is that the drillers are not required to report brine encounters to the state or federal authorities and no mention would be found in the records unless undue delays or hazardous conditions are encountered.

The 8% probability also ignores the data from WIPP-12 and the TDEM survey over the repository. The borehole WIPP-12 is located north of the repository within the WIPP site. It was drilled to the bottom of the Salado Formation in 1978 and deepened in 1981 at the EEG's suggestion. The DOE contractor (Popielak et al., WIPP-TME-3153, 1983) estimated the volume of the reservoir to be 2.7 million m^3 (17 million barrels). For the maximum possible reservoir thickness of 24 meters, the surface footprint of a cylinder containing this volume would have a diameter of more than 3 km. As the attached figure shows, the WIPP repository is most likely underlain by the brine reservoir encountered by WIPP-12. In addition, the TDEM survey (SAND 87-7144) gives an indication of the presence of brine at the upper Castile horizon. To try to assign specific areas of the presence of brine from this geophysical survey would be over-interpretation of the geophysical data. Combination of the WIPP-12 data and the results of the TDEM survey indicate the existence of brine under the repository. Any borehole drilled into Castile under the repository should therefore be assumed to encounter brine.

The EEG does not find the CCA reservoir volume assumption of 32,000 to 160,000 m^3 to be justified. This is based on the assumption of depletion of reservoirs by future drillers - 100% probability of encounter for the depletion assumption, while only 8% for releases!

The attached table shows the comparison between the characteristics of the WIPP-12 brine reservoir and the CCA assumptions.

The WIPP site was moved twice; in 1975 after the borehole ERDA-6 encountered a brine reservoir, and again in 1982, after WIPP-12 encountered brine. The CCA assumptions of probability should be realistically based on the site specific information, and the characteristics should be based on the WIPP-12 experience.

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[1] Beauheim, R., Revisions to Castile Brine Reservoir Parameter Packages, memo to P. Vaughn, in WPO 31084, Sandia National Laboratory, January 16, 1997.

The DOE Conceptual Model Peer Review Panel, in their December 1996 report, essentially agrees with the EEG position, but has accepted the DOE position that there are no significant consequences of the probability and volume assumptions.

The EEG does not accept the "no consequence" argument that is based on piecemeal, partial sensitivity analyses.

Revisions to Parameters

On January 16, 1997, Rick Beauheim of Sandia National Laboratories recommended revising five parameters describing the Castile brine reservoir conditions[1]. The reasons for these changes are presented in the parameter record packages WPO 31070, 31072, 31082, 31083, and 31084. Even though the parameter ranges recommended by Beauheim are more reasonable than the ones used in the CCA, the EEG disagrees with the recommended values for reservoir volume because the range includes the value derived from testing the ERDA-6 brine reservoir and initial pressure because of the use of data from twelve other brine encounters in the Salado. The combination of the TDEM survey and the estimates of the areal extent of the WIPP-12 brine reservoir provides a strong evidence that the WIPP-12 reservoir and the brine under the repository are one and the same. Therefore, only the WIPP-12 brine reservoir characteristics should be used to define the parameters used in the CCA performance assessment.

Beauheim points out that the parameters should be constrained by what he terms the productivity

$$PR = V \frac{C_r}{f}$$

ratio (PR), given by:
Where V is the sampled reservoir volume, C_r is the rock compressibility and ϕ is the porosity. Beauheim's recommended range for this constraint is $7x10^{-4}$ to $4x10^{-2}$ m^3/Pa, in which the $7x10^{-4}$ m^3/Pa value is from ERDA-6 data and $4x10^{-2}$ m^3/Pa is consistent with the WIPP-12 data. The constraint PR should be fixed at $4x10^{-2}$ m^3/Pa in order to agree with the WIPP-12 data, and the ERDA-6 data should not be used because it is irrelevant to the present WIPP site. Thus, with porosity fixed, the reservoir volume (V) should be inversely correlated with the sampled value of rock compressibility so that PR equals $4x10^{-2}$ m^3/Pa. Attached is a figure from an October 3, 1996 memo from Rick Beauheim to Les Shephard[2] showing PR calculated from the sampled parameters of the CCA calculations. The figure has been modified to point out the $4x10^{-2}$ m^3/Pa value determined for WIPP-12. Only five out of 300 samples were as large as the WIPP-12

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[2]Swift, P.N., K.W. Larson, and R.L. Beauheim, Treatment of Castile Brine Reservoir in the 1996 CCA Performance Assessment, Memo to L.E. Shephard, WPO 41885, Sandia National Laboratory, October 3, 1996.

measurements. This figure clearly demonstrates the inappropriateness of the Castile brine parameters used in the CCA calculations.

The recommended initial pressure range of 16.5 to 11.0 MPa gage is based on pressure measurements from thirteen Castile brine encounters. At WIPP-12 the measured pressure was 12.6 MPa gage. Therefore, the reservoir pressure should be a constant value of 12.6 MPa gage in the revised CCA calculations.

Comparison of WIPP-12 Brine Reservoir and the CCA Assumptions

Parameter	WIPP-12 (m^3)	CCA (m^3)
Total Reservoir Volume	2.7×10^6 (a)	32,000 to 160,000 (d)
Projected Max. Artesian Flow	55,821 (b)	5,200 (e)
Flow to Surface During Drilling	4,306 (c)	400 to 2,100 (f)

(a) WIPP/TME-3153, p. H-54
(b) WIPP/TME-3153, p. H-55
(c) WIPP/TME-3153, p. H-9; Actual "unavoidable" flow
(d) DOE/CAO-1996-2184, Table 6-26; Beauheim (1/16/97 Memo to Vaughn) revised the estimate to 100,000 to 1,700,000 m^3
(e) CMPRR-Suppl., 12/1996, p. 42; To the Culebra, after 6 encounters
(f) CMPRR-Suppl., 12/1996, p. 42; In 10,000 years

BR 'OL Chart 4

Reservoir Production vs. Reservoir Volume-Compressibility Product, First CCA Replicate F1 at 1000 Years

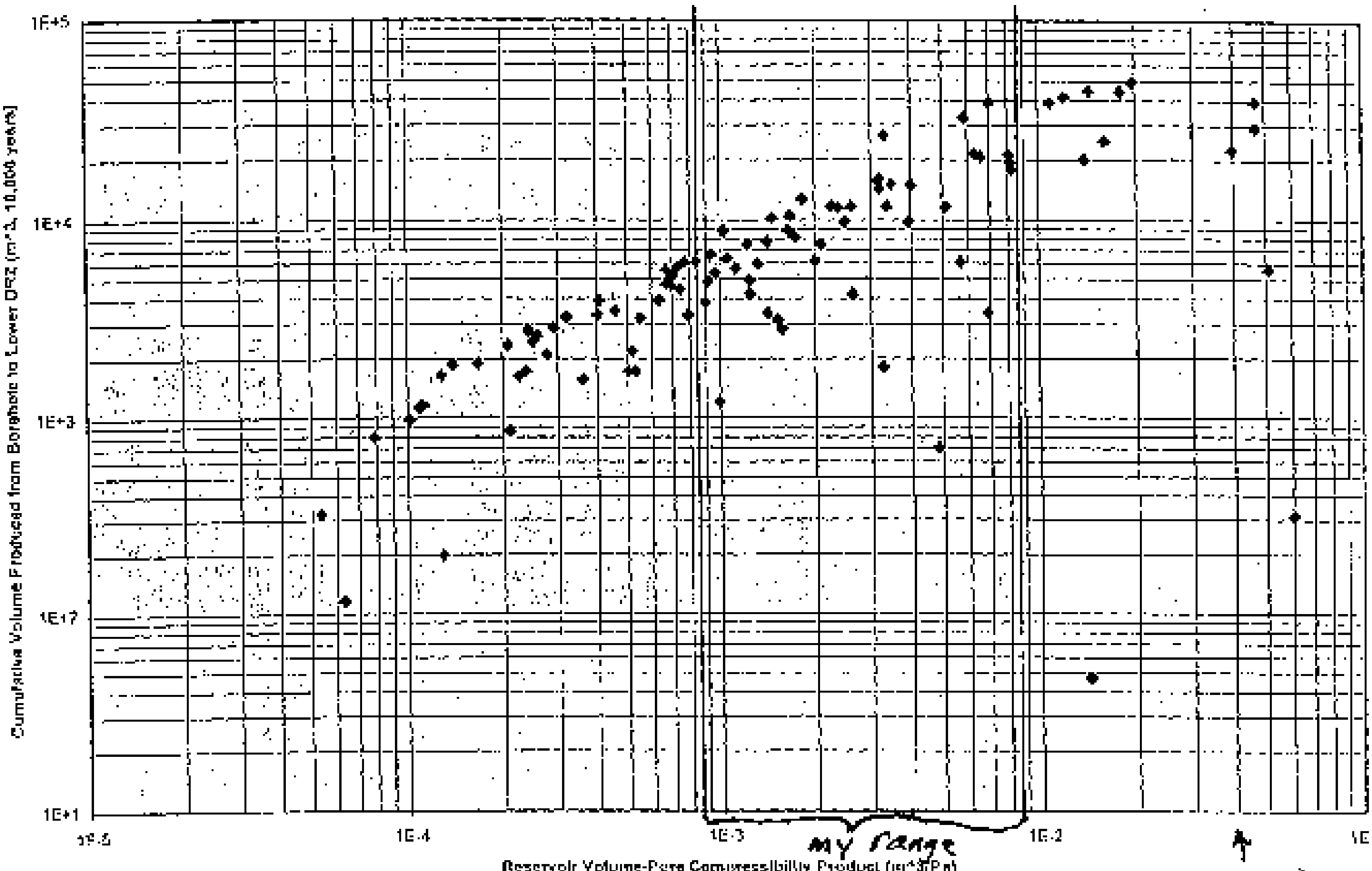
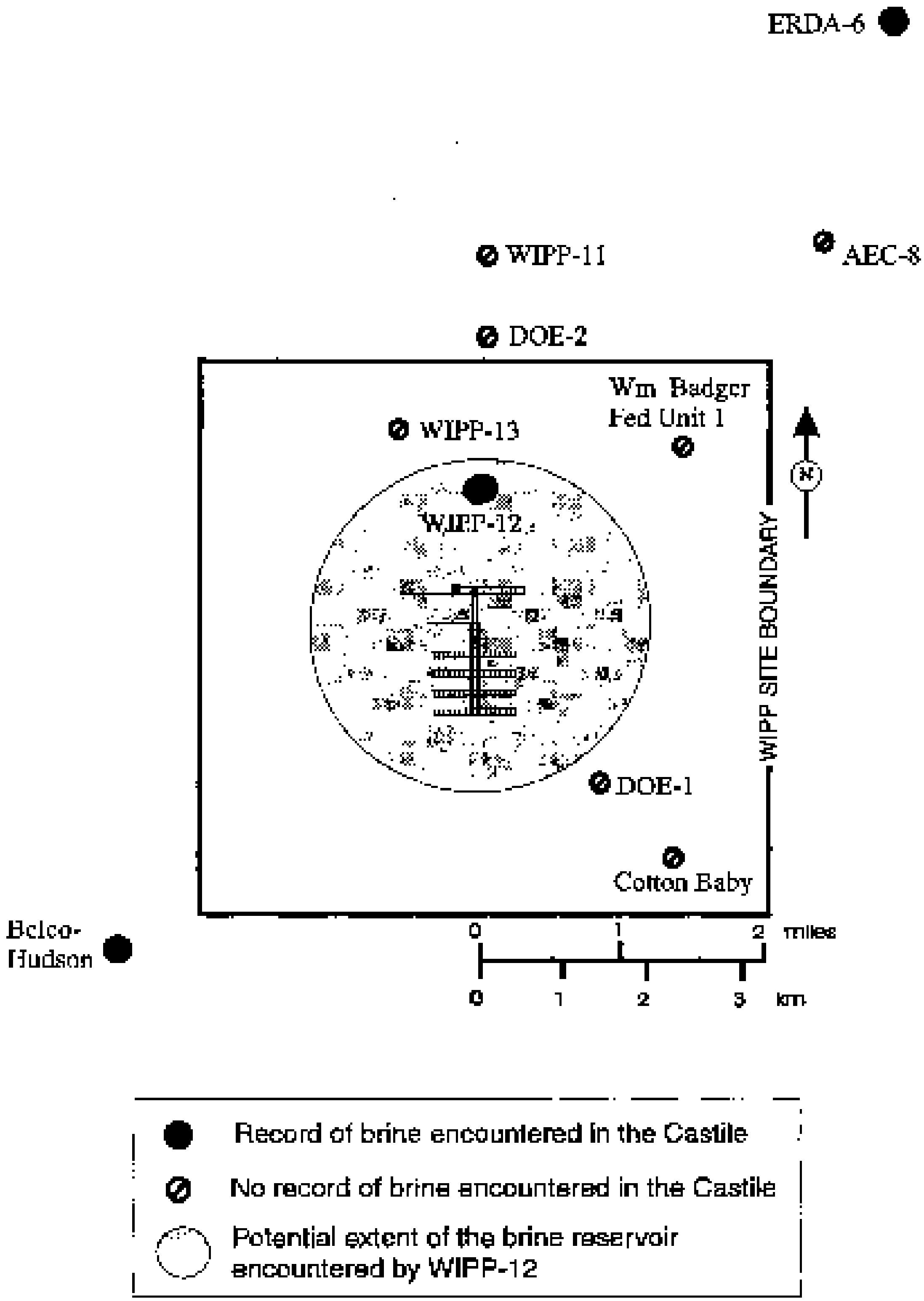


Figure 2

Figure 1 (From Swift et al., 1996)

INFORMATION ONLY



Potential extent of WIPP-12 brine reservoir using WIPP-12 pressure recovery data, rock compressibility of 1x10[illegible]Pa^{-1}, and reservoir thickness of 24 meters.

FAULTY SAMPLING RANGES

Recently, arguments have been made that if the sampled distributions of parameters used in the CCA calculations are in error, but include the likely values of those parameters, then the CCA calculations are acceptable. We disagree. Under these conditions, the CCA calculations should be repeated with the best estimate of the parameter distributions available. The use of a faulty distribution of one parameter biases the CCDF curves and confuses the assessment of uncertainty. The use of more that one faulty parameter set makes the assessment of uncertainties impossible because of the complex non-linear nature of the performance assessment models.

In this report we state our case in two ways - first by example and then abstractly. The most notable occurrence of a faulty parameter distribution is the Castile brine reservoir volume distribution used in the CCA calculations. The error has been admitted by DOE and considered by the conceptual model peer review panel.

1) The Brine Reservoir Example

This example demonstrates the pitfalls of accepting parameter errors as inconsequential in a piecemeal fashion. The conceptual model peer review panel accepted the argument that the brine reservoir parameters were acceptable because the correct values were effectively included in at least some of the sampled vectors. They also concluded that the brine reservoir interception probability was inconsequentially in error because encounters with a brine reservoir, E1 events, do not have substantially different consequences from intrusions that do not encounter brine, E2 events. They reached this conclusion through inspection of results presented for the entire set of sampled vectors. First, their basic conclusion was flawed because the repository system is too complicated to be evaluated using the data presented. Second, they had no way to evaluate the effect of the biases introduced by the flawed reservoir volume parameter distribution on the data presented.

The EEG understands that the DOE currently considers the parameter distribution for the brine reservoir volume to be from 10^5 to $1.7x10^6$ m^3 rather than the range of $3.2x10^4$ to $1.6x10^5$ m^3 as used in the CCA calculations[3]. In the first supplemental conceptual model peer review report, the panel concludes that the error in volume is of no consequence because the pore compressibility-volume product range of the calculations includes the correct range[4].

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[3]Beauhiem, R., Revisions to Castile Brine Reservoir Package Packages,memo to P. Vaughn, in WPO#31084, Sandia National Laboratories, January 16, 1997.

[4]Wilson C., D. Porter, J. Gibbons, E. Oswald, G. Sjoblom, and F. Caporuscio, Supplementary Conceptual Models Peer Review Report, DOE, Dec. 1996, Page 41.

Later, the peer review panel used the comparison of plots of brine inflow, brine saturation, and gas generation from the both E1 and E2 intrusions to conclude that the intersection of the brine reservoir insignificantly impacted the releases and hence the probability of intersecting a reservoir was unimportant to the CCA calculations. The plots included data from all vectors of replicate 1 with no indication of which data were from vectors with the acceptable pore compressibility-volume product range.

The data the peer review panel used for their decision was inadequate. This conclusion is based on our interpretation of Figures 5.1.6 and 5.1.7 of the preliminary sensitivity analysis report on the CCA Calculations[5]. Figures 5.1.6 and 5.1.7 contradict the panels conclusion. Figure 5.1.6 presents volume and EPA unit releases for the different specified second intrusion times for an initial E1 intrusion at 350 and 1,000 years. Figure 5.1.7 presents similar release data for initial E2 intrusions. For initial intrusions of 350 years, and especially at earlier second intrusion times, Figure 5.1.6 presents substantially larger volumetric and radionuclide releases. The average volumetric release is almost two orders of magnitude higher for a second intrusion at 200 years after the E1 event compared to the E2. Because of assumed solubility differences in Castile and Salado brine, the normalized EPA release is only a factor of 30 higher 200 years after an E1 at 350 years. Since EEG has stated elsewhere that the solubility differences for plutonium are much smaller than assumed for the CCA, the comparison of volumetric releases may be a better indication of the differences. However, such a comparison is biased toward low volumetric releases in the case of an initial E1 event by the use of a flawed distribution of the pore compressibility-volume product.

With a pore-compressibility-volume product equivalent to WIPP-12, the probability of brine reservoir encounter set to 1. and, plutonium solubilities consistent with experimental data, the possibility that direct brine release will violate the compliance criteria can not be ruled out based on our present understanding of the CCA modeling.

2) General Considerations

Construction of CCDF curves to demonstrate compliance with 194 Part B requires estimates of the uncertainty in parameter values. Sampling over the parameter uncertainty ranges incorporates this uncertainty in the CCDF curves. Sampling also provides some assurance that deviations from reality, of best estimates for the repository system, will not have disastrous consequences. Thus, the parameters ranges must capture the true uncertainty in the results, unless compensating conservatism is used.

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[5] J. Helton, Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant, Memo, Dec. 23, 1996.

If the parameter ranges are in error then the mean value of the CCDF curves will be biased and the distribution of the curves no longer represent the uncertainty in the understanding of the WIPP site. An error in this context means an incorrect representation of current understanding and should not be confused with an inaccurate understanding. Errors in the analysis are recognizable and correctable. The concern here is the consequence of recognizing an error but failing to correct for it. The basis for such a decision could be that the error does not matter or leads to higher CCDF curves. The decision to not correct a parameter error should only be made if the effects of the parameter are completely understood and the insensitivity or conservatism in the results can be clearly demonstrated.

Demonstrating the consequences of errors in most of the CCA parameter ranges would be difficult. The difficulty is compounded by potential interactions of errors in more than one parameter. Not only the effect on the CCA calculations must be demonstrated but the effect on potential calculations under conditions that may be caused by the other parameters must also be included. The effort could easily be much greater than the effort of a completely new set of CCA calculations and yet still fail to provide an adequate demonstration of the consequences.

The most reliable way to eliminate concerns about parameter errors is to rerun the CCA calculations with the proper values. It makes little sense to do so in a piecemeal fashion. The CCA calculations should be rerun only after a complete evaluation of the current set of calculations. Otherwise it will be nearly impossible to credibly provide reasonable assurance that the compliance criteria are met.

BRINE INFLOW FROM SALADO: 2-D VERSUS 3-D GEOMETRY IN BRAGFLO

The 2-D geometry used in the BRAGFLO appears to have caused an under-prediction of brine inflow to the repository and thus may have resulted in a significant under-prediction of the direct brine release. This assumption may also have effected the amount of releases predicted by the spallings scenario.

The justification for modeling the repository in a pseudo 3-D manner (2-D radial flaring) rather than in a full 3-D geometry has been provided through evaluation of FEP S-1[1]. The summary memo of record for the FEP S-1 screening analysis discusses the impact of the 2-D assumption on 1) brine flow through the anhydrite layers to the 2.4 km boundary, 2) flow to the top of the shaft, 3) brine flow up the borehole, and 4) the repository pressure. That memo[6] does not consider the effects of the 2-D assumption on the inflow of brine to the repository, and on the spallings or direct brine releases.

The amount of projected inflow of brine in the repository directly effects the gas pressure in the repository. Table 5.5.3 of the sensitivity analysis reported[7] lists the residual gas saturation as the parameter with the strongest influence on the projected direct brine releases. This is also shown in Figure 5.1.5 of the sensitivity analysis report (the attached Figure 1). In addition, brine inflow is important to the spallings release estimates through increased gas generation. This dependence is made clear in Table 4.4.3 of the sensitivity analysis report which lists halite porosity, a large source of brine, as the second most important parameter to spallings releases.

The screening analysis compared 2-D simulations of the repository to 3-D simulations of the repository. For computational efficiency, the calculations were performed for half the repository. Two sets of simulations were conducted for the analysis. One set of calculations used a gas generation rate below the level that would cause anhydrite bed fracturing. The second used twice the gas generation rate to ensure anhydrite bed fracturing. In both sets, less brine-inflow occurred in the 2-D case compared to the 3-D geometry. No dependency of gas generation on brine inflow to the repository was included in the calculations; gas generation was prescribed as a function of time, ending after 1,000 years in the screening calculations.

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[6]Vaughn, P., T. Hadgu, D. McArthur, and J. Schreiber, FEP Screening Analysis S1: Verification of 2D-Radial Flaring Using 3D Geometry, Memorandum to D.R. Anderson, January 26, 1996, WPO 30840, Sandia National Laboratory, Attachment 4-1 to Appendix Mass of the Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant, DOE/CAO-1996-2184, December, 1996.

[7]Helton, Jon, Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant, Memo, Sandia National Laboratories, December, 1996.

The largest impact of 2-D geometry occurs with anhydrite bed fracturing. The 3-D model predicts the flow into the repository to significantly increase if the anhydrite beds fracture, while the 2-D model predicts the flow to decrease in relation to calculations without anhydrite fracturing.

Figure 15 of the FEP S-1 analysis (Figure 2) shows the cumulative brine inflow to the repository for the high gas generation calculations. The flows calculated using the 3-D model indicate that once anhydrite bed fracturing occurs, roughly $2x10^6$ kg (1,600 m^3) of brine enters the repository in a period of 200 to 300 years and that this flow rate was continuing unabated at the time of drilling intrusion. Another $4x10^6$ kg (3,200 m^3) flowed into the repository shortly after the drilling intrusion. Figure 2 shows differences of $4x10^6$ to $6x10^6$ kg (3,200 to 6,500 m^3) for much of the 10,000 years. The brine inflow differences listed above should be doubled for the full repository. Virtually no flow enters the repository as a result of anhydrite bed fracturing in the 2-D geometry. In fact, the net flow over the 10,000 year simulation is less with anhydrite fracturing compared with the simulation without the beds fracturing. Figure 2.1.4 of the sensitivity analysis report[2] (Figure 3) indicates very little marker bed inflow with microbial gas generation of plastics and rubber, supporting the findings of the FEPs analysis. Figure 5.1.5 of the sensitivity analysis report reveals the importance to direct brine release of these low brine inflows. The highest pressures are correlated with brine saturations below the residual brine saturation of the waste. The low saturations are due partly to increasing repository pore space with increasing pressure and partly to lower brine inflow.

Table 2.5.13 of the sensitivity analysis report indicates that the potential for anhydrite bed fracturing is high. As a crude approximation, consider the undisturbed scenario of a total fracture-enhanced flow of 20,000 m^3 over a period of 2,000 years. The highest repository pressure in the FEP S-1 calculations was 13 MPa. This corresponds to a repository pore space of 85,000 m^3 (Figure 2.3.5 of the sensitivity analysis report). The increased brine flow would increase the average brine saturation by 0.23. The CCA calculations do not include simulations of both very high pressure and brine saturations above the residual brine saturation of the waste. Inspection of Figure 5.1.5 suggests a significant impact from a 0.23 saturation shift at high pressures.

The simulations without anhydrite fracturing show a decrease of $1x10^6$ to $2x10^6$ kg (800 to 1,600 m^3) in predicted brine inflow in the 2-D simulations compared to the 3-D simulations (Figure 4; Figure 10 of the FEP S-1 memo). These flows are doubled for the full repository. The differences are most likely from differences in marker beds flows to the repository.

To put these brine inflow differences in perspective, note that average brine inflow to the repository in the CCA calculations of the similar S5 scenario was almost 40,000 m^3, with an average 8,000 m^3 from the marker beds[2]. Marker bed brine flows in the S5 scenario are dominated by flows under low pressure conditions. The marker bed flows are a more significant concern in the S1 undisturbed scenario. An average of roughly 3,000 m^3 flowed into the repository from the marker beds in the S1 CCA calculations. To approximate the brine flow error in the undisturbed calculations for pressures below the anhydrite fracture threshold, we ratio the FEP S-1 differences by 3,000/8,000 - resulting in the range of 600 to 1,200 m^3 less brine inflow to the full repository. If 1,200 m^3 of brine were distributed throughout the entire repository it could increase the average saturations by 0.015 to 0.03 (0.04 to 0.08 in the S5 scenario and 0.16 to 0.32 after anhydrite fracturing in an S5 scenario). It is more likely that much of the additional brine would be consumed through increased gas generation, leading to higher repository pressures.

There are indications in the sensitivity analysis report that the computational grid effects the distribution of brine within the repository in addition to the overall magnitude of brine. One indication is the statement on page 2-26 that "Due to the computational grid in use (Fig. 1.2.1), the lower panel receives more brine inflow from the marker beds relative to its size than the upper waste panels (Fig. 2.1.2)." Another indication may be the importance of the residual gas saturation of the shaft seals to flow through the marker beds (Table 2.1.1 of the sensitivity analysis report). As stated in the report, "its selection may be due to effects related to brine and gas movement across the part of the computational grid that corresponds to the shaft in the repository and DRZ (i.e., regions 10,11 in Fig. 1.2.1)." As a result, the upper waste panels receive roughly one ninth of the brine inflow from the marker beds per panel as the lower waste panel. In a large fraction of the sampled vectors, gas generation stops in the upper panels because of limited brine availability for steel corrosion. Thus, the CCA calculations are under-predicting repository pressure as well as brine saturation.

The EEG concludes that the use of a 2-D geometry in the BRAGFLO may introduce significant non-conservatism into the CCA calculations. The FEP S-1 needs to be re-examined with appropriate consideration of the impact of increased brine saturation on calculated release estimates.

Figure 1

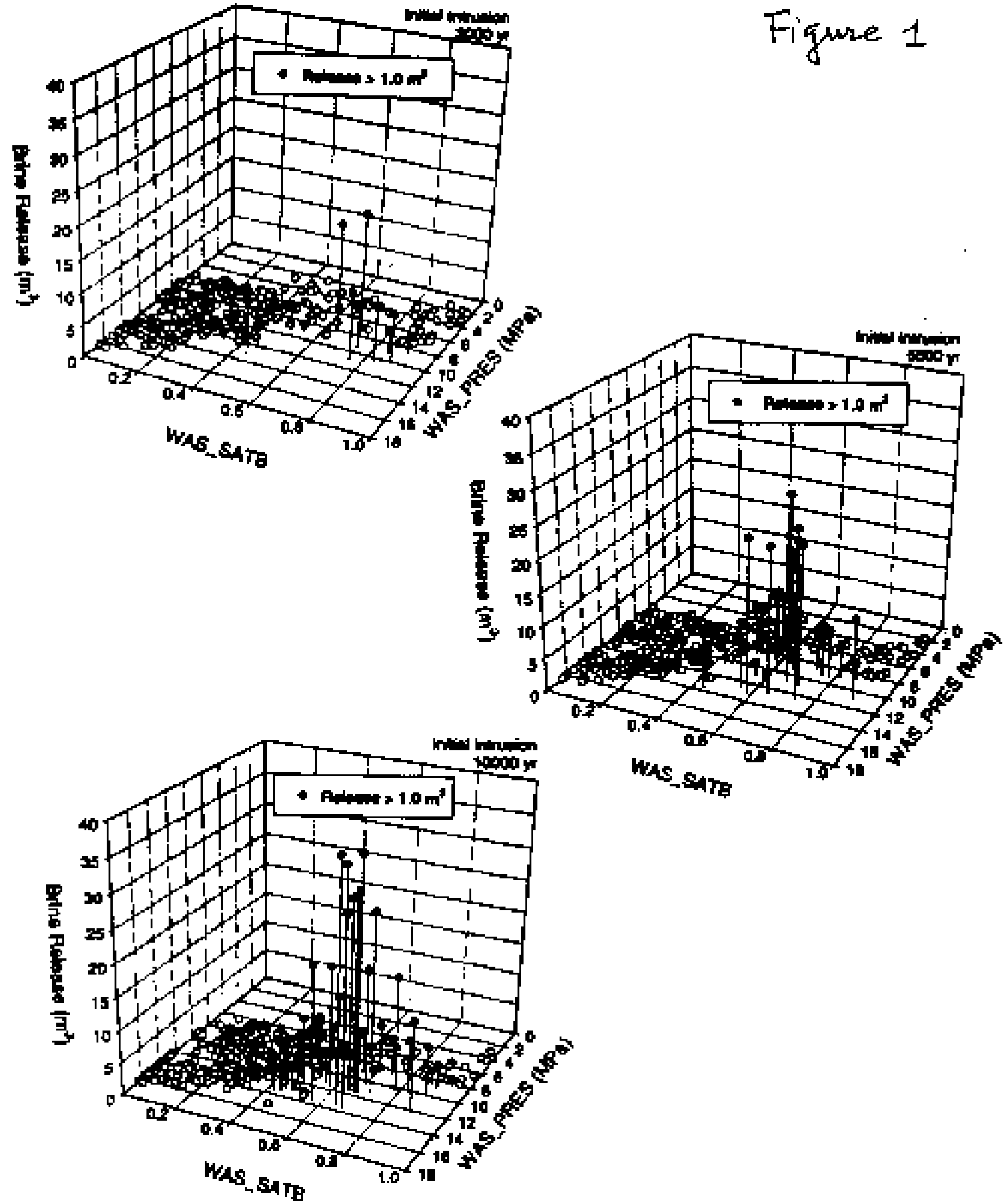

Fig. 5.1.5. Three dimensional scatterplots for volume of brine (m^3) removed due to direct brine release resulting from a single drilling intrusion into a previously unintruded repository that passes through CH-TRU waste in a lower waste panel, brine saturation and pressure (MPa).

From: Helton, Jon, Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant, Memo, Sandia National Laboratories, December, 1996.

Figure 2

From: Vaughn, P., T. Hadgu, D. McArther, and J. Schreiber, FEP Screening Analysis S1: Verification of 2D-Radial Flaring Using 3D Geometry, Memorandum to D.R. Anderson, January 26, 1996.

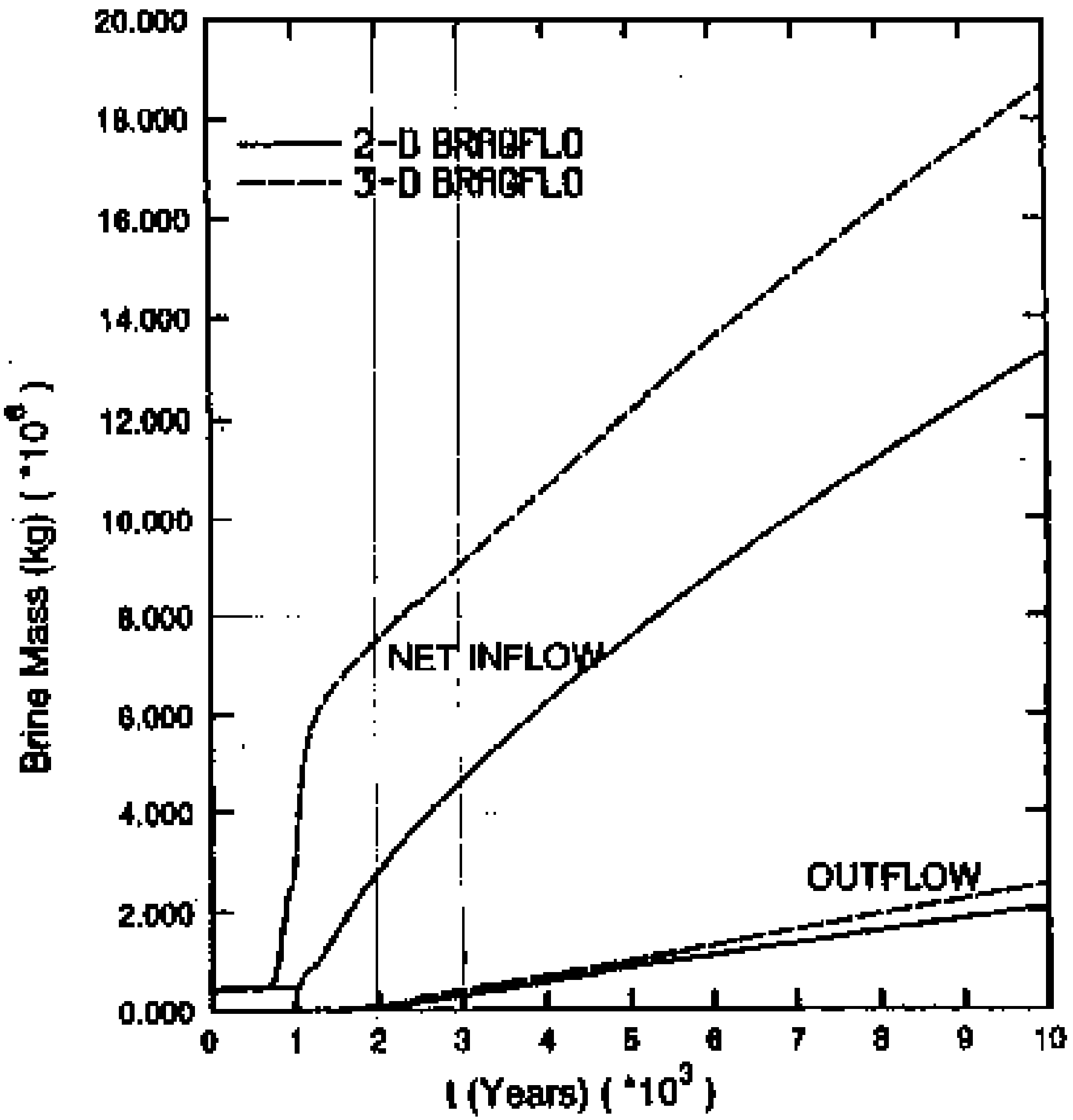

Fig. 15 Cumulative Net Brine In and Outflow at Repo.-Doubled Gas Generation rate

Figure 3

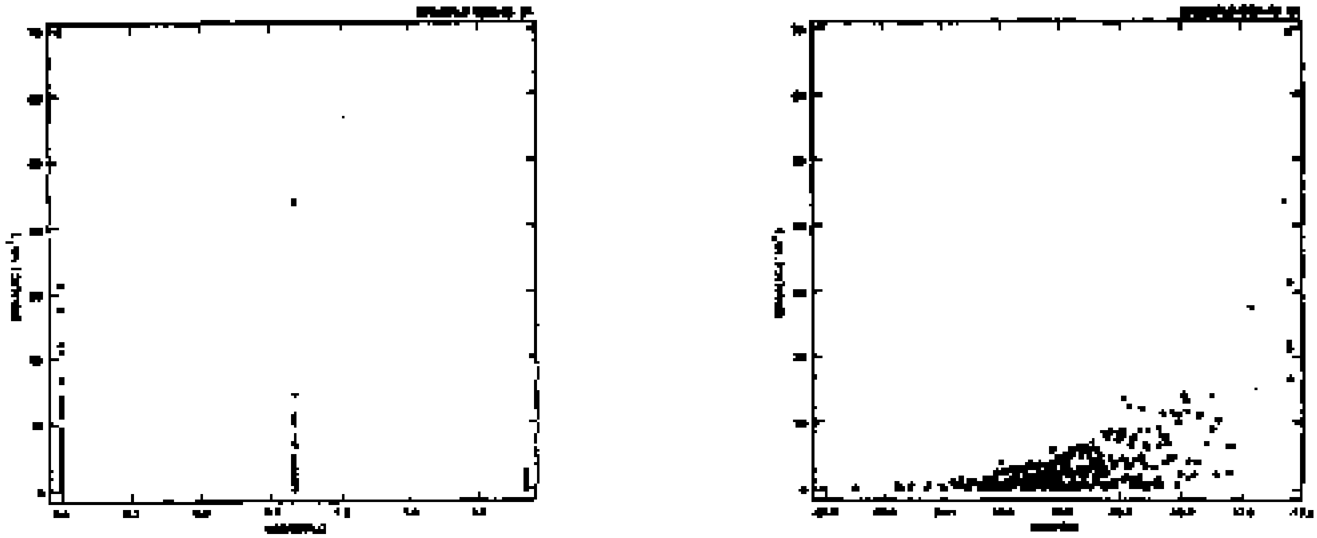

Fig. 2.1.4. Scatterplots for cumulative brine discharge (m³) from the marker beds over 10000 yr under undisturbed conditions versus microbial gas generation flag (*WMICDFLG*) and marker bed permeability (*ANHPRM*, m²).

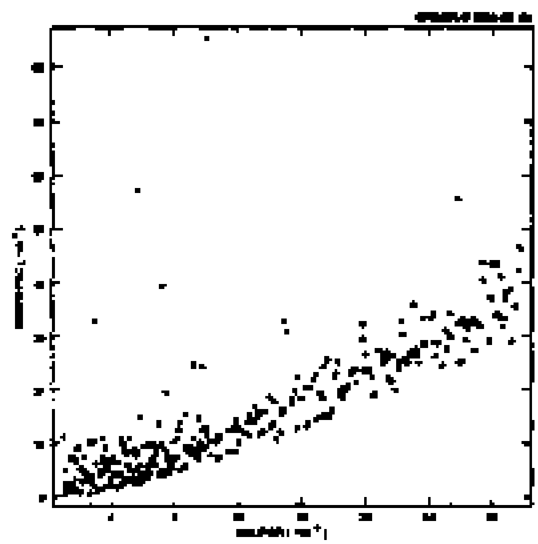

Fig. 2.1.5. Scatterplots for cumulative brine inflow (m³) to the repository over 10000 yr under undisturbed conditions versus halite porosity (*HALPOR*).

From: Helton, Jon, Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant, Memo, Sandia National Laboratories, December, 1996.

Figure 4

From: Vaughn, P., T. Hadgu, D. McArther, and J. Schreiber, FEP Screening Analysis S1: Verification of 2D-Radial Flaring Using 3D Geometry, Memorandum to D.R. Anderson, January 26, 1996.

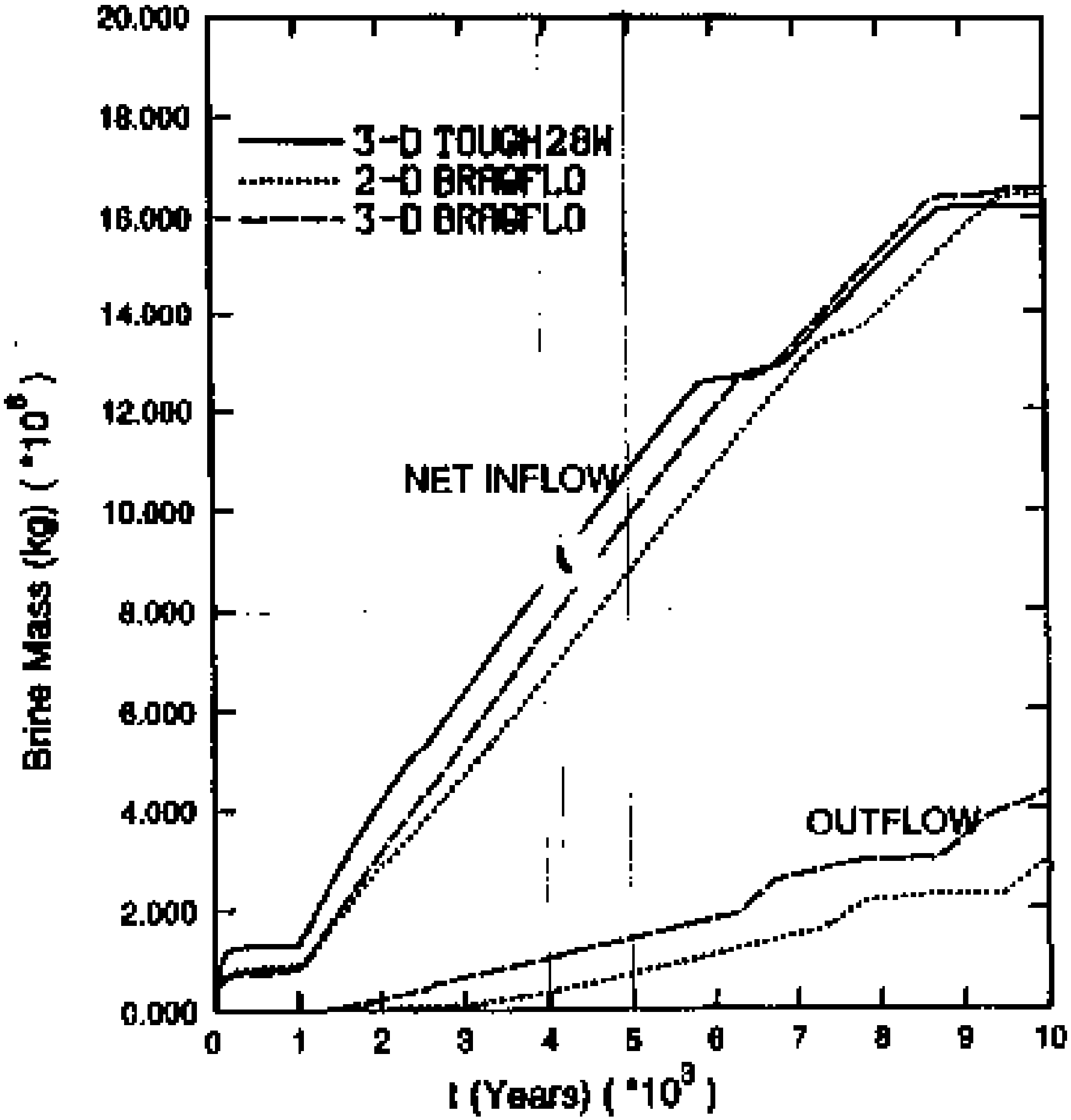

Fig. 10 Cumulative Net Brine In and Outflow at Repo. - Base Gas Generation rate

PROBABILITY OF MICROBIAL DEGRADATION

The sampled parameter for the probability of microbial gas generation determines whether cellulose and plastics and rubber will be degraded by microbial action after closure of the repository. No degradation of cellulose or plastics occurs in the calculations with a 50% probability. Only cellulose degrades in 25% of the sampled vectors. Cellulose, plastics, and rubber degrade with a probability of 25%. The preliminary sensitivity analysis report[8] lists this parameter as the largest influence on the variation of total calculated release from the WIPP repository.

The documentation[9] supporting this parameter does not contain any numerical justification for the probabilities assigned to this parameter. All of the hand calculations performed to calculate the gas generation parameters are included as attachments to the memo of Wang and Brush. Calculations for the degradation probabilities are absent from these attachments. It is the opinion of EEG that the numerical value of this parameter constitutes expert judgement. Given the importance of this parameter to the estimates of radionuclide release, this parameter should be demonstrated to be either solidly based on scientific evidence or be conservative. The justification for this parameter presented in support of the CCA does neither of these.

The numerical values of the degradation probability parameter should undergo peer review consistent with expert judgement. Otherwise, the parameter should be conservatively set to always specifying microbial degradation of cellulose, plastics, and rubber.

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[8]Helton, Jon, Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant, Memo, Sandia National Laboratories, December, 1996.

[9]Wang, Y. and L. Brush, Estimates of Gas-generation parameters for the long-term WIPP performance assessment, Memorandum to M. Tierney, WPO 31943, January 26, 1996.

BOREHOLE PLUG LIFETIME

Borehole lifetime should be a sampled parameter in the CCA calculations or else the DOE should provide demonstration that variations in borehole lifetime do not effect the release estimates.

Repository pressure is one of the key factors determining the severity of both spallings and direct brine release. The repository pressure decreases rapidly after the failure of the borehole plug from an initial human intrusion in BRAGFLO calculations of most of the sampled vectors[10]. Thus, the assumed lifetime of the borehole plugs may have a large impact on the final release estimates. The upper borehole lifetime is fixed at two hundred years in all of the BRAGFLO calculations, except for the continuous plug configuration. This conflicts with the data used to calculate the borehole lifetimes[11]. The analysis indicates that the results of investigation on corrosion and borehole lifetimes are expected to vary over an order of magnitude (Thompson, et al. page B1) and are considered to be conservative(Page B-17).

The calculation of upper plug lifetime is not entirely clear. It seems to rely on 1) an assumed corrosion rate of 1- 3 mm/year for steel casing 2) the assumption of sufficient water 3) field observations of casing failures in the Salado and 4) rapid degredation of the concrete plug after casing failure. The assumption of corrosion rate is stated to be "very aggressive" and conservative and about one thousand times faster than the corrosion rate in the repository. Short borehole plug lifetimes could be considered conservative for releases to the Culebra, but not for spallings and direct brine release to the surface. The general assumption of sufficient water is adequately justified in the analysis. However, the point is made that cement outside of the casing may inhibit access to brine(Page B-18). Field observations indicate that casing failures in the Salado are well-known (Page B-20; Bailey memo in La Venue, 1991[12]) at depths less than 1,000 feet. However, the same report(Page B-17) also includes information that casing failures in the Salado are common but not pervasive.

The borehole plug lifetimes are likely to vary by over an order of magnitude. Borehole plug lifetimes should be a sampled parameter.

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[10] Helton, Jon, Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant, Memo, Sandia National Laboratories, December 23, 1996.

[11] Thompson, T.W., W.E. Coons, J.L. Krumhansl, and F.D. Hansen. Inadvertent Intrusion Borehole Permeability, Attachment 16-3 in Appendix MASS of the Compliance Certification Application, DOE/CAO-1996-2184, October, 1996.

[12] La Venue, M. Anomalous Culebra water-level rises near the WIPP site, INTERA: Technical Letter Memorandum, January 28, 1991

INCONSISTENCY BETWEEN DIRECT BRINE RELEASE AND SPALLINGS GEOMETRY

The EEG considers the inconsistency in the conceptual models of direct brine release and spallings in the CCA calculations to be unacceptable. The transport of solids and brine to the surface as a consequence of human intrusion is a single process where both brine and solids are entrained in a high velocity gas flow. In our January 21st presentation to EPA, we argued that both brine and gas flow should be modeled as a single process.

The spallings model predicts that channels of void space will be created in a waste room as a result of room depressurization from drill penetration into the room. The channels develop because the velocity of gas is large enough to break the bond of particles from the compacted mass of waste and entrain them in the gas-flow down the channels. This process is aided by the flow of gas perpendicular to the channels. The solid mass calculated to have been released in the spallings model is assumed to evacuate an annular region around the borehole in the direct brine release model. Brine is calculated to be transported to the enlarged borehole region as described by Darcy's Law.

If open channels are created in the spallings process then pressure gradient will drive brine towards these openings. The distance to the open channels would be far less than the distance to the borehole for most of the brine in a waste room and all brine in other rooms of a repository panel. The cumulative release to the surface would, thus, be much larger than calculated by the direct brine release model.

Direct brine release and spallings should be modeled as a single process. If the process is separated into two models, these models must be consistent with each other.

WASTE PERMEABILITY VALUE FOR DIRECT BRINE RELEASE

Issue

The CCA uses a constant waste permeability value of 1.7×10^{-13} m^2 in the Direct Brine Release calculations. The method of calculating this value was questioned by a Peer Review Panel and DOE agreed that 2.4×10^{-13} m^2 was the appropriate value. The use of this higher value in CCA calculations is considered here.

The rate of radial flow to a well per unit drop in pressure or drawdown is directly related to the permeability of an aquifer. The same relation would apply to flow into a borehole that penetrated a waste storage room.

This discussion will not address other waste permeability related aspects of the Direct Brine Release, Spallings, or BRAGFLO Models such as relative permeability, residual brine saturation, and fracture flow.

Evaluation

SNL arrived at the value of 1.7×10^{-13} m^2 for consolidated waste from laboratory data on three major waste components (sludge, combustibles, and metals). The Engineered Systems Data Qualification Peer Review Panel discovered an error in the calculation of the overall permeability and, after discussions with SNL on the appropriate distribution to use on permeability values for each material, agreed with SNL that the appropriate calculated value should be 2.4×10^{-13} m^2.

The Peer Review Panel recognized that use of this higher permeability value would increase brine releases in direct proportion to the increase in permeability (41%). Yet they concluded that changing this value is not warranted because "the change does not have any effect on the final outcome," (page 9-191). The panel also opined that the data and assumptions that were used to develop the values were limited and either value was as good as the other.

Clearly there are uncertainties in the actual value of the consolidated waste permeability. There is also the question of whether the current assumption of darcy flow is appropriate or whether the rooms should be modeled as fracture flow. Neither issue is being addressed here.

Changes in the volume fractions of combustibles, metals, and sludges in the waste from the .40, .40, .20 values used in 1991 would also change this permeability calculation. The Final Waste Form volumes shown in Table 4-3 of the CCA are slightly different and result in a calculated permeability of 2.2^{-13} m^2.

Effect on CCA

The use of the higher waste permeability value ($2.4x10^{-13}$ m^2) should cause the CCDF plot of direct brine release to move 41% towards the compliance limit. The CCDF plot in the CCA (Figure 6-41) shows direct brine release to be only 0.05 EPA units at .001 probability. Increasing this by 41% would give a value of only 0.07 units and would have little effect on compliance. However, other questions are being raised about these releases: (1) Castile Brine Reservoir assumptions; (2) appropriate solubility values to use; and (3) details about the Direct Brine Release Model. These other factors could increase the calculated release by more than an order-of-magnitude. If this occurs the 41% increase could become significant.

Recommendation

If a single value for the consolidated waste permeability is to be used for direct brine release, then it should be $2.4x10^{-13}$ m^2 and not $1.7x10^{-13}$ m^2.

RANDOM EMPLACEMENT OF WASTES IN REPOSITORY

Issue

In the CCA, DOE assumes that the waste inventory will be emplaced in the repository in a purely random manner. This assumption leads to three further assumptions in the CCA:

(1) The 569 CH-TRU waste streams can be sampled randomly to determine the concentrations of radionuclides brought to the surface by cuttings and cavings;

(2) the concentration of radionuclides in the area of the waste room affected by spallings releases can be assumed to be the average of the entire WIPP inventory;

(3) the concentration of dissolved radionuclides in solution in a waste panel that has a Direct Brine Release also is calculated from the average of the entire WIPP inventory.

Evaluation

DOE correctly recognizes that the concentrations and radionuclides composition of individual waste containers vary widely and have attempted to account for this in the CCA by sampling on a volume weighted distribution on all 569 CH-TRU waste streams identified in the Baseline Inventory Report, Revision 2. This approach, if done properly, has the potential to fully capture the variability if emplacement is purely random.

EEG believes that actual waste emplacement may deviate substantially from random. This is due to three factors: (a) during the period that a waste room is being filled there is unlikely to be shipment of waste from all Generating Sites on a volume weighted basis. (b) waste being shipped from a Site in a TRUPACT II is unlikely to be representative of the entire site; and (c) wastes arriving on a TRUPACT-II trailer (e.g. 4 to 6 seven-packs of 55-gallon drums) from a site would be emplaced to gather. Its possible that as many as 1/3 of the 7-packs or Standard Waste boxes on a TRUPACT-II trailer would be stacked two-high in a waste room.

Examples of the deviations of average concentrations from individual sites from the total inventory average concentration are: (1) The Savannah River Site (SRS) average is 2.9 times the total average at 100 years; (2) Los Alamos National Laboratory (LANL) averages range from 1.3 to 1.8 times the total average from 100 years to 10,000 years; and (3) Rocky Flats (RFETS) averages range from 3.0 to 4.5 times the total average from 100 years to 10,000 years. Examples of variations within waste streams at a Site are: (1) 2,800 m^3 of residues at RFETS that are 3.3 times the Site average: (2) 60 m^3 of SRS waste that are 42 times the Site average; and (3) 850 m^3 at SRS that are 1.5 times the Site average.

Effect on CCA

In the 1991 Performance Assessment (SAND91-0893/2), Sandia National Labs (SNL) demonstrated that considering the effects of variable radionuclide concentrations in waste containers ("activity loading") resulted in normalized releases from cuttings and cavings to increase by a factor of about ten (at .001 probability) compared to using average activity in containers. SNL has used "activity loading" in PA methodology since that time and in the CCA, the sampling is on 569 waste streams for cuttings and cavings. There is no disputing the fact that sampling on activity levels will increase the calculated releases from cuttings and cavings for probabilities below about 0.5.

The radioactivity concentration and radionuclide composition of waste within a waste room or portion of a panel (i.e. the areas of influence for the spallings and Direct Brine Release calculations) would be expected to vary from the total inventory average. This variation would not be nearly as great as that expected between individual stacks of waste containers, but increases to several hundred percent of the average radioactivity concentration are clearly possible. The calculated releases from spallings at any intrusion time would be directly proportional to the radioactivity concentration.

The calculated radionuclide releases from Direct Brine Releases would depend on the concentrations of each radioactive element in solution. This concentration is dependent on the composition of individual radioisotopes in the waste. For example, in average SRS waste at 350 years the ^{238}Pu radioactivity is 75% of the total plutonium radioactivity compared to 11% of the total plutonium in the total inventory average. Thus, the radioactivity concentration of plutonium in solution would be higher for SRS waste at 350 years. Another example is concentrations of ^{233}U and ^{234}U. Appendix WCA of the CCA states the assumption that only 1% of dissolved uranium would be ^{233}U and ^{234}U, because in the total inventory these radioisotopes comprise less than 1 wt% of total uranium. However, data in the Baseline Inventory Report indicates that the 28,000 m^3 of stored CH-TRU at INEEL contains 20 wt% of ^{233}U.

These concerns of non-uniform emplacement of wastes in the repository touch on the issue of load management. The CCA concludes that load management is not necessary at WIPP (Chapter 4.3.1).

Importance to Compliance

EEG believes that deviations from the assumption of average emplacement has the potential to increase calculated releases at .001 probability from spallings and Direct Brine Release by several fold. Using a more conservative assumption of random emplacement may not result in non-compliance if all other assumptions in the CCA were held constant. However more conservative assumptions could noticeably shift the CCDF curve toward the compliance boundary and, when incorporated with other changes to the 10/96 CCA, calculations could have a significant effect on the final CCDF.

Recommendations

For the Spallings and Direct Brine Release scenarios, determining average waste concentration in one room would be closer to reality compared with using the average for the whole repository as currently used in the CCA. There are several possible approaches to determining justifiable waste room radioactivity concentrations. We recommend the following:

(1) The deviation from average concentrations of radionuclides in waste and brine could be mitigated by load management such that the concentrations in any waste room be limited to (say) 1.5 or 2 times the average at any time during the 10,000 year regulating period;

(2) A reasonable upper bound (not the theoretical maximum) for radionuclide concentration can be obtained by assuming that a room is filled entirely with average concentration waste from the generating site that results in the greatest consequences. For concentrations in the waste this would be RFETS. It is not obvious which site's waste would result in the highest brine concentration.

(3) Allow DOE to show by an appropriate statistical scheme that there is an acceptably low probability that concentrations in wastes and brine will not exceed (say) 1.5 or 2 times the average;

(4) Actually sample on this variability. Sampling might be first on the fraction of waste from each site that is brought into the room (with some deviation above and below the actual fraction of the total repository volume expected from that site). Then the variation of waste composition and concentration from each site (obtained from the 569 waste streams data) could be sampled on.

For the cuttings and cavings calculation DOE should determine an appropriate statistical scheme to evaluate the effect that emplacing wastes from individual sites in clusters will have on the current calculations involving sampling on 569 waste streams. If significant these new values should be incorporated into the CCA.

RESIDUAL BRINE SATURATION OF WASTE

The preliminary sensitivity analysis report[13] indicates (Table 5.3.3) that the calculated releases to the surface from the direct brine release model are most sensitivite to the sampled variation of the waste room residual brine saturation. For various reasons the direct brine release model may be significantly under-predicting releases. See, for example, the EEG position statements on the brine reservoir parameters, solubilities, sampled parameters and probability of microbial degredation. The sampled range of the waste room residual brine saturation is another one of those reasons.

The data and rationale for the sampled distribution of the waste-room residual-brine saturation is presented on pages PAR-27 through PAR-31[14]. The recommended distribution is uniform from 0 to 0.56. It is stated in the data section that the parameter values are based on literature values of unconsolidated materials. Ten materials are listed as the source of the data set. Eight of these data values are from unconsolidated materials with a range of 0.0783 to 0.277. Two of the source materials are consolidated sandstones with values of 0.243 and 0.560. As suggested in Appendix PAR, the sampled range should be based on unconsolidated materials. Use of the single consolidated sandstone value of 0.56 doubles the range of sampled values in a non-conservative direction.

The non-conservative distribution of 0 to 0.560 reduces the estimated releases of direct brine release. Appropriate ranges for the waste room residual brine saturation are a constructed distribution using values from the eight unconsolidated materials; a uniform distribution from 0.0783 to 0.277, or a uniform distribution from 0 to 0.277.

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[13] Helton, Jon, Preliminary Summary of Uncertainty and Sensitivity Analysis Results Obtained in Support of the 1996 Compliance Certification Application for the Waste Isolation Pilot Plant, Memo, Sandia National Laboratories, December, 1996.

[14] Appendix PAR of the Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant, DOE/CAO-1996-2184, December, 1996.

COMPENDIUM OF DIRECT BRINE RELEASE PROBLEMS

We have organized our comments on the CCA in a format so that individual sections tend to focus on single issues. To keep the individual sections brief, we have only occasionally touched on interrelationships between issues. In the case of the direct brine release model, we have found so many interrelated problems that it is worth bringing them together in a separate section. The issues raised in this section are discussed in more detail in their separate sections. The purpose here is to highlight how they have compounding effects on the direct brine release calculations.

We have identified nine separate issues that effect the direct brine release calculations. The issues are:

- Probability of microbial degradation
- Borehole plug lifetime
- Brine inflow from Salado: 2-D versus 3-D geometry in BRAGFLO
- Brine reservoir assumptions in the CCA
- Inconsistency between direct brine release and spallings geometry
- Waste permeability
- Residual brine saturation of waste
- Random emplacement of wastes in the repository
- Plutonium Solubility

Probability of microbial degradation

Direct brine release will only occur if the repository pressure is over 8MPa at the time of drilling intrusion. Above a pressure of 8 MPa, the magnitude of release is more strongly related to waste room saturation. Waste room saturation is dependent on the amount of brine entering the repository and on the repository pressure because the pore space is a function of pressure. The most important sampled parameter effecting repository pressure is microbial degradation. The microbial degradation assumptions are not defensible and may lead to a severe under prediction of the probability of greater than 8 MPa pressure and anhydrite fracturing.

Borehole plug lifetime

Borehole plug lifetimes were not sampled in the CCA analysis, so this parameter does not show up as important in the statistical sensitivity analysis. However, inspection of disturbed scenario pressure histories and the importance of borehole permeability are clear indications of the importance of plug lifetime. Borehole plug lifetimes are uncertain and the description of the development of this parameter in the CCA documentation indicates that the parameter is biased toward short plug lifetimes in an attempt to be conservative. Short plug lifetimes may lead to an under-prediction of the period of high pressures and, hence, may actually be non-conservative.

Brine inflow from Salado: 2-D versus 3-D geometry in BRAGFLO

The importance of anhydrite fracturing to direct brine release is under-represented in the CCA modeling. A full 3-D representation of the repository indicates that substantially more brine will enter the repository if the anhydrite beds open as a result of high pressures compared to brine-inflow under lower pressure conditions. The pseudo 3-D model used in the CCA analysis predicts the opposite. The highest direct brine release predictions occur with repository pressures below the initiation of anhydrite fracturing because of concurrent low brine saturation conditions. This is most likely in error.

Brine reservoir assumptions in the CCA

The DOE has admitted to the conceptual models peer review panel and in post application documents that the Castile brine reservoir parameters are incorrect. The use of these parameters in the CCA calculations severely under-predicts the importance of the Castile brine under the repository. In addition, the likelihood of intercepting Castile brine under the repository is reduced from a certainty to eight percent. Proper incorporation of the Castile brine reservoir in the CCA analysis will lead to higher brine saturations and most likely longer periods of pressures above the 8 MPa threshold.

Inconsistency between direct brine release and spallings geometry

We have identified three flaws in the actual direct brine release model. The most significant of these is the inconsistency of the void geometry of the spallings model to that assumed in the direct brine release model. The spallings model predicts the development of void channels throughout the room penetrated in a drilling intrusion. The direct brine release model assumes that all of the solid material entrained in the room depressurization has come from a annular region about the borehole. The geometric inconsistency could have a very large impact on calculated brine releases.

Waste permeability

The second flaw in the direct brine release model is a calculational error on the part of DOE. The waste room permeability value used in the direct brine release calculation is in error by 41%, based on the data used by DOE. This error leads to a 41% bias to low values in the calculated releases.

Residual brine saturation of waste

The calculated flows are also biased by using a distribution of residual brine saturations that is unrealistic. Brine moves much slower if the saturation is near or falls below the residual saturation level. Residual saturation is twice as high in the CCA calculations than can be supported. This reduces both the frequency and magnitude of the estimated releases to the surface.

Random emplacement of wastes in the repository

The CCA calculations ignore the possibility of higher consequence events due to non-uniform distribution of waste emplacement. In the direct brine release calculations the actinide content of waste in a room is assumed to be the average of all waste. In practice waste will tend to be grouped by origin and to a degree the waste steams. This would result uncertainty in the radionuclide concentrations in a room's brine content and higher releases in some instances.

Plutonium Solubility

Finally, the importance of brine release to the surface is under-represented in the calculations because of the low assumed values of plutonium solubility, especially in the case of releases subsequent to an interception of Castile brine. The difference in plutonium solubility in the Castile brine become important to calculations that include a proper representation of the Castile brine.

Of these nine problems in the direct brine release calculations, probably only the inconsistency in the direct brine release model geometry has the potential to shift the release calculations to the release criteria values. When considered together, it is clear that radionuclide transport to the surface through brine transport is potentially a much larger threat to safety than predicted in the CCA calculations and could be a much larger concern than the current predictions of release of solids to the surface.

ACTIVE INSTITUTIONAL CONTROL

The DOE conducted an elaborate elicitation exercise in 1990 to address the issue of future inadvertent human intrusion into WIPP (Hora et al., 1991). Members from each of the four “futures teams” expressed reservations about the ability of the project to fully maintain active control for even a very short period of time. Participants in the elicitation exercise were asked to address seven specific issues including the issue of active controls:

> Assuming that the radioactive waste exists and is harmful, what is the likelihood that active controls (continued management of the site) have been maintained to prevent inadvertent intrusions? (Hora et al., 1991, p. G-4).

Three of the four members of the Washington A Team predicted a steep decline in the probability of active controls as a function of time beginning immediately after closure (Hora et al., 1991, Figure IV-10). At 100 years after closure, they predicted the probability of active control for all four postulated future states at less than 30%. The fourth member also predicted an immediate decline, although at a slower rate, in the probability of the effectiveness of active control after closure (Hora et al., 1991, Figure IV-11). In summary, the Washington A Team predicted less than 100% active institutional control for the first 100 years beginning immediately after closure.

The Washington B Team assigned probabilities that the government would continue to maintain prudent and effective control over the WIPP. They defined the near future as 0-200 years after closure (Glickman et al., pp. F-4, F-27; Hora et al., 1991, p. IV-55). This team questioned the effectiveness of active control for the near future and assigned a probability of 80% for prudent and effective control for the near future (Hora et al., 1991, pp. IV-55-56).

Hora stated that the Boston Team allowed for 100 years administrative control (Hora, 1992, p. A-87). However, scrutiny of the Boston Team report (Gordon et al., 1991) and the report by Hora et al. (1991) suggests otherwise. It appears that the input was adjusted to fit the needs of the performance assessment calculations as explained below. This adjustment, and not the Boston Team, allowed for 100 years administrative control.

The Boston Team did not offer direct estimates of the duration of active institutional control. Rather, the Boston Team predicted socio-technical factors at 100 years, 1000 years, and 10,000 years (Gordon et al., 1991, p. C-5); points in time were incompatible with the needs of performance assessment. As noted by Hora et al. (1991, p. IV-3) "...the performance assessment calculations require rates of intrusion during the entire continuum from 100 to 10,000 years after closure." Thus, the use of midpoints on the logarithmic scale was introduced to define time periods. For example, the 100 year point was converted to a period of 0 to 300 years after closure (Hora et al., pp. IV-3 to IV-4). The first 100 years were then dropped and the results of the elicitation for ten tables were presented for time periods from 100-300 years (Hora et al., 1991, Tables IV-2 through IV-11) and not from 0-300 years. However, Table IV-14 (Hora et al., 1991) presents the calculated drilling rate probability for 0-300 years after closure. This table suggests that the Boston Team did not allow for 100 years administrative control.

Moreover, one member of the Boston Team disputed the existence of administrative control for even a short period of time. In an appendix to the Boston Team report (Gordon et al., 1990), Baram addressed the question "Can memory of WIPP be retained?" Rather than argue in the abstract, he cited examples of the factual loss of history or active control for periods shorter than 50 years. The examples included:

1) the loss of drilling history at Lyons, Kansas that was fortuitously recaptured by opponents to a proposed repository at that location,

2) the loss of information for 45 years on the dumping of barrels of radioactive waste from the Manhattan Project in the late 1940's by the Department of Defense at the Massachusetts Bay site,

3) the unavailability of information until 1986 on the release of radiation and exposure of thousands of people near Hanford beginning in 1944,

4) the use of uranium mill tailings in Colorado to construct homes and other concrete structures despite a prohibition against such activity,

5) the 1982 sewer line construction and inadvertent intrusion into a poison gas container abandoned by the Army when it closed an airfield in 1945.

"The [Southwest] team was fairly pessimistic with respect to society's ability to maintain active controls and effective markers" (Hora et al., 1991, p. IV-31). One member speculated that controls and markers may last as long as 1,000 years, two members felt that loss would likely occur within hundreds of years, and one member thought loss of markers and active control would occur in less than 100 years.

Thus, all four teams in the elicitation exercise on future societies expressed reservations about the project's ability to maintain active control for even a short period of time.

EEG recommends that the EPA should initially assume zero credit for active institutional and ask DOE to cite specific tangible factors as to how much credit can be justified. As part of building a credible argument, the CCA should also take into account the pessimism of its own expert elicitation on the limited effectiveness of active institutional control.

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3. Hora, S.C., 1992. Probabilities of Human Intrusion into the WIPP Methodology for the 1992 Preliminary Comparison, August 25, 1992. Appendix to SAND92-0700, pp. A-69 to A-99.

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PASSIVE INSTITUTIONAL CONTROL

The CCA claims that passive institutional control will be 99% effective in deterring drilling into the repository from 100 years to 700 years after closure. The components of passive institutional control include government ownership, records, and markers. Based on the DOE's experience with institutional controls in the recent past, a claim of 99% credit for passive institutional controls for 700 years does not appear justifiable.

Government Ownership and Regulation

With respect to the government ownership, the DOE maintains that "the controls that are crucial to protect the site from inadvertent exploration are BLM leasing procedures and lease records and the internal procedures of the BLM which require the DOE's review and comment for any permit application to drill within one mile of the WIPP site."[1] On October 26, 1990, the DOE and the DOI/BLM signed a Memorandum of Understanding. With respect to drilling for oil and gas, the MOU specifically required the BLM to notify the DOE of applications for permit to drill for oil and gas within one mile of the WIPP Site Boundary and that "drilling approval will be withheld until comments are received from the DOE."[2] The MOU was revoked on October 30, 1992 with the passage of the 1992 WIPP Land Withdrawal Act[3] (Section 3 (b)). How effective was the MOU for that two year period? The following example is fairly typical of the overall failure of the MOU.

The BLM approved an application to drill Well #4, Section 26, T22S, R31E, on October 15, 1991. Two days later, the BLM[4] sent a letter to the DOE requesting a review of an "Application for Permit to Drill" within one mile of the WIPP Site Boundary. The BLM received DOE's review[5] on October 25, 1991. However, not only had the application already been approved by BLM ten days earlier, but drilling had already commenced the previous day. Thus, the DOE's review was never considered in the application permitting process, the DOE review was not solicited until after the drilling had been approved, and the DOE review was not received by BLM until after drilling had started.

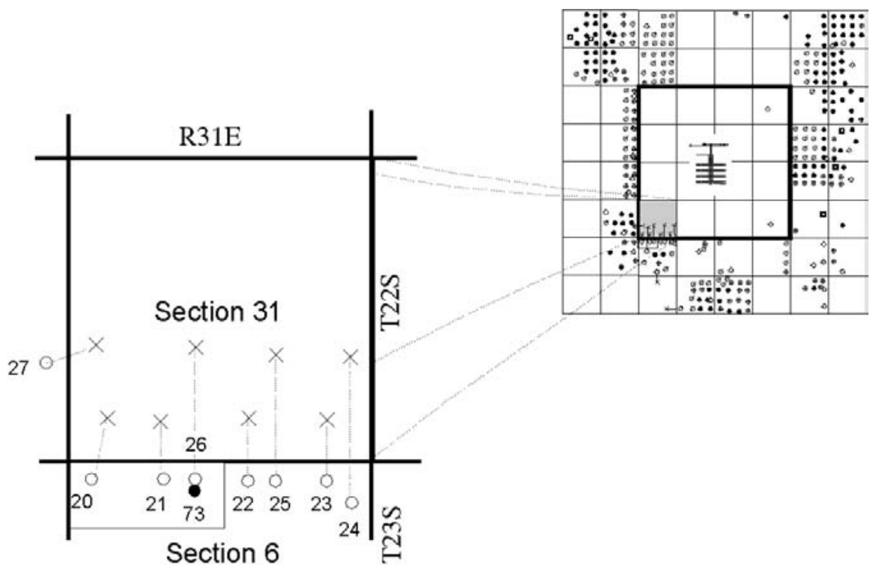
Table 1. Summary of Lapses in Institutional Control

Satisfactory procedure	3
BLM failed to request DOE review.	3
DOE failed to respond to BLM request.	9
BLM approved permits to drill before requesting DOE review.	5
BLM approved permits to drill before receiving DOE review.	5

The MOU failed in twenty-two out of twenty-five applications for an institutional failure rate of 88%. EEG notified DOE of this lapse in institutional control in 1993[6,7]. Fifty-five subsequent applications, processed through July 1994, showed a failure rate of 9%.

Records

A recent example illustrates the failure of records to communicate important information prohibiting drilling in a certain area. In 1978, the DOE purchased leases in the vicinity of the current WIPP site for the explicit purpose of preventing drilling. One area was the N½ NW¼ of Section 6 T23S, R31E (eighty acres) for which the DOE paid Bass Enterprises et al. $207,972 not to drill through the uppermost 6000 feet[8,9].



In April 1993, Bass Enterprises et al. applied to the BLM to directionally drill eight wells from Section 6 locations outside the WIPP Site to their oil and gas lease reserves 6000 feet below the WIPP Site. In August 1994, the BLM denied the drilling applications citing the WIPP Land Withdrawal Act.[10] In January 1995, Bass et al. filed a claim in federal court for a takings.[11] In June 1996, the federal court awarded Bass et al. $8.9 million plus interest.[12]

Despite the active involvement of attorneys and officials for the oil companies and four federal agencies (DOE, BLM, EPA, and the Justice Department), the 1978 judgment, forbade drilling wells in Section 6 T23S, R31E, was not discovered until after the June 1996 judgment.[13,14,15] (Refs. 14 and 15 attached). Subsequent appeal by the Justice Department states:

> Among the issues that could be addressed on remand are the implication of the discovery, made after the notice of appeal was entered in this case, that Bass did not have the right to drill from three of the locations from which it proposed to drill — and for which it sought and received compensation — because DOE had

condemned those surface locations in 1977.[13]

Hence, in less than twenty years, records failed to communicate important information concerning the restriction against drilling for oil and gas. Furthermore, a vertical gas well, James Ranch Unit 73, was drilled and completed on the eighty acres in July 1996 prior to the discovery of the lease records by the attorneys for the various federal agencies.

Markers

> "Any compliance application shall include the period of time passive institutional controls are expected ***to endure*** and be understood."[16].

On October 26, 1963 a twelve kiloton device was detonated underground at Fourmile Canyon, Nevada. The site was designated as the Shoal Site. In the late 1970's the DOE placed a substantial marker consisting of a brass plaque set in a concrete podium and anchored to a concrete base at ground zero. By 1985, the marker at the Shoal site had been completely destroyed by a massive explosion with pieces of marker scattered to the west. The brass plaque had disappeared. Shown below are the gathered remains of a DOE marker intended to identify an area contaminated by radioactive fission products. This marker lasted less than ten years. This example raises questions on the DOE's commitment to maintain a marker at WIPP.

Recommendation

EEG recommends that the EPA include full consideration of these lapses in the assessment of the DOE's claim of 99% effectiveness of passive institutional controls from 100 to 700 years after closure.

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16. U.S. Environmental Protection Agency, 1996a. 40 CFR Part 194, Criteria for the Certification and Recertification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations, Final Rule. Federal Register (9 February) vol. 61, no. 28, 5224-5245.

POTASH MINING

The CCA underestimates the areal extent of potash reserves and the potential impact of the mining of potash within the site and on adjacent federal and state properties. The use of only the existing leases adjacent to the site does not account for the currently economical potash reserves. Figure 1 shows the extent of lease grade potash ore as determined by the Department of Interior. Further, the Department of Interior notes that potash ore has been and can be economically mined at ore concentrations less than current lease grade[1].

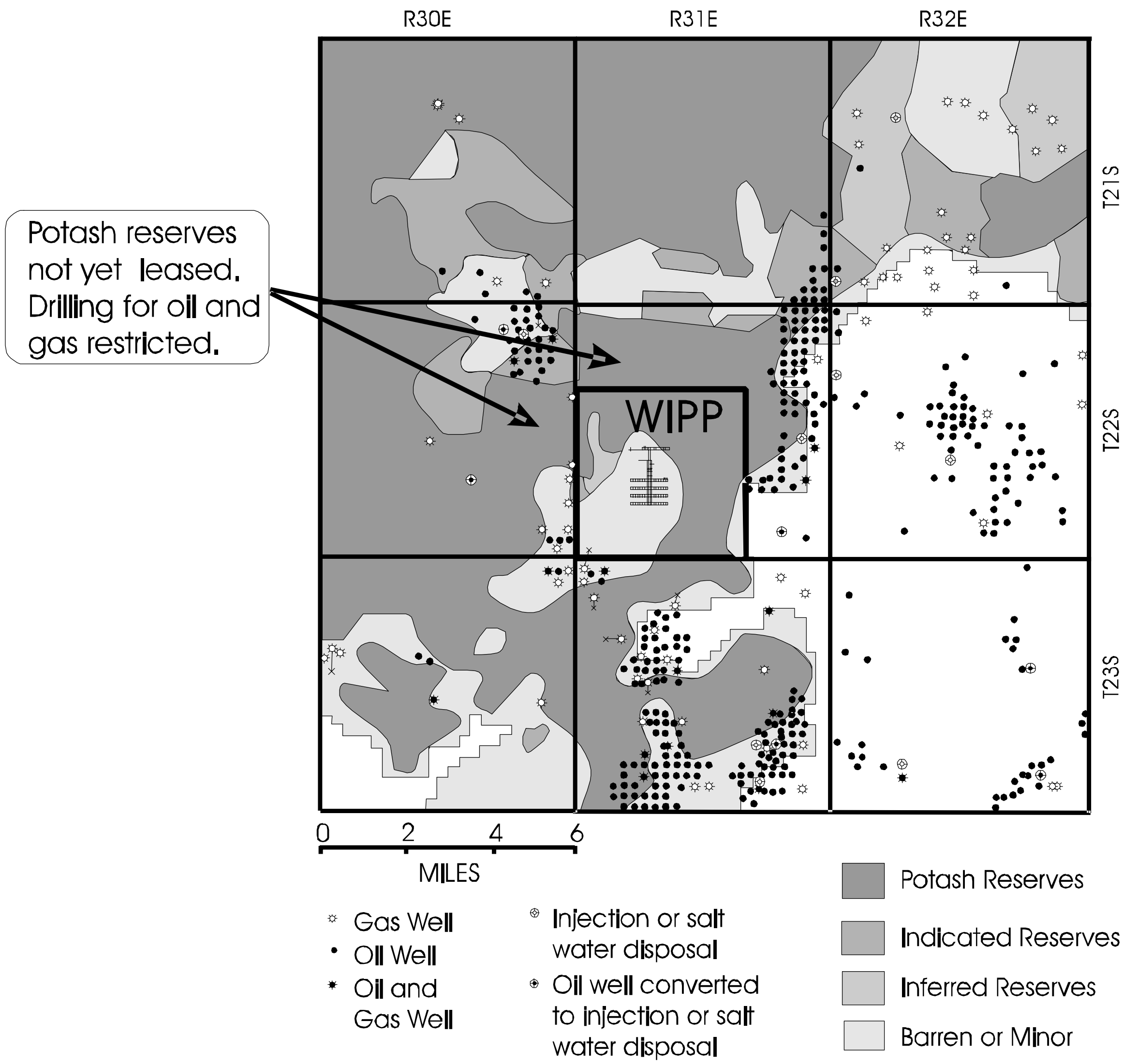

Figure 1. Lease grade potash ore[2] and oil and gas wells.[3]

For illustrative purposes, Figure 1 identifies one area of known potash reserves adjacent to the northwest boundary of the WIPP Site. Figure 2 indicates that these potash reserves have not been leased. Potash operators are allowed to hold, directly or indirectly, no more than 51,200 acres in potash permits and leases in a state (43 CFR 3530.3). An operator may not hold all the potash leases he intends to develop (Ref.4, p. 11).

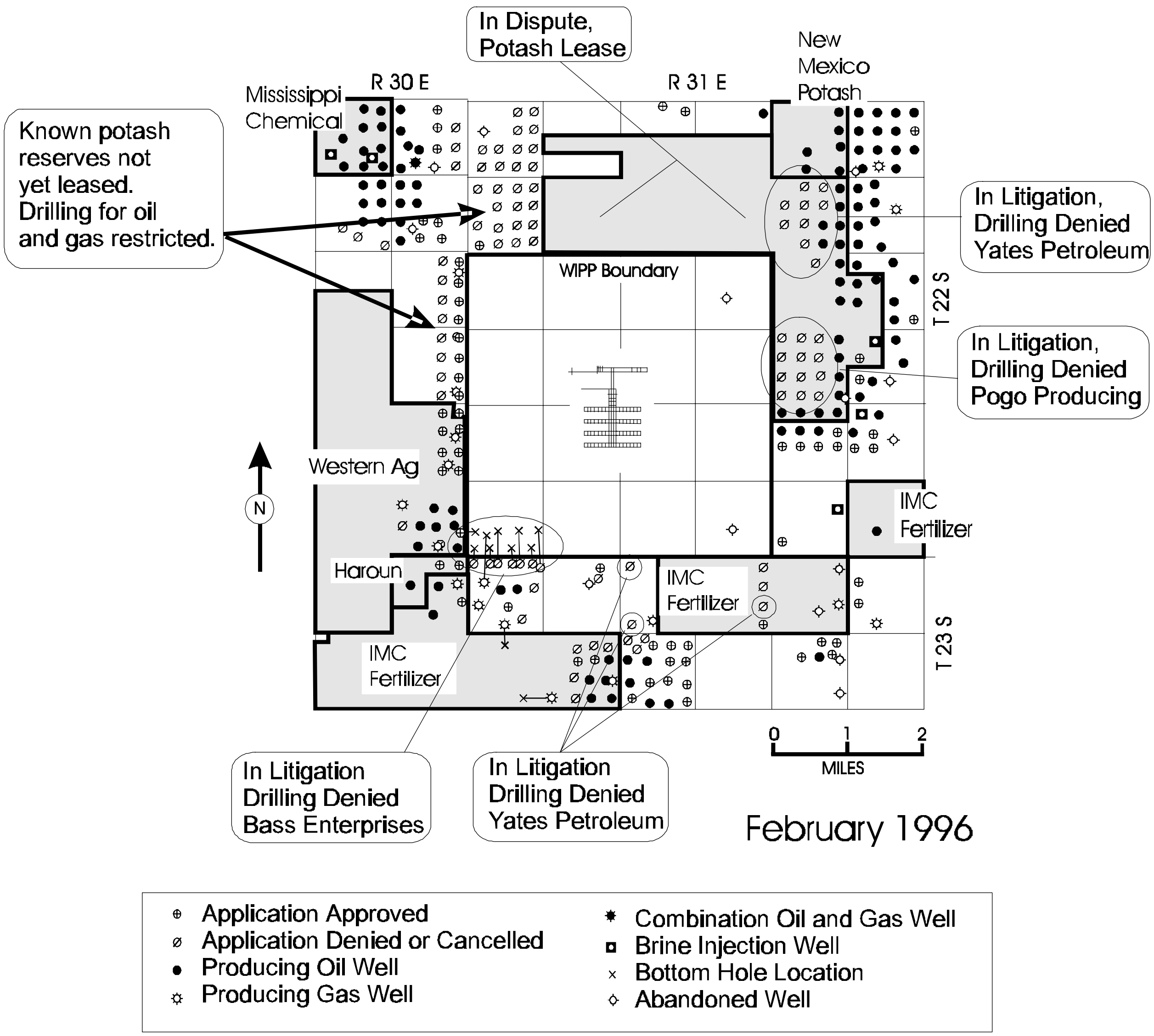

Figure 2. Drilling for oil and gas restricted by BLM due to the presence of potash reserves, leased and unleased.

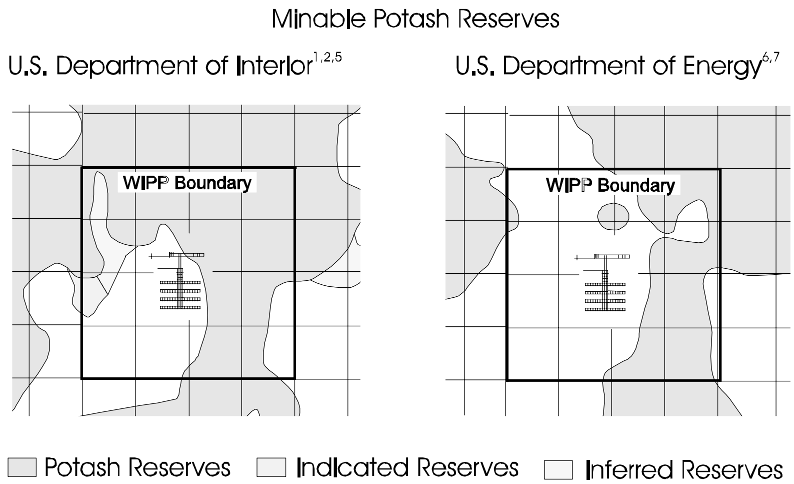

Figure 3. Minable potash.

Figure 3 shows the different estimates by DOE and DOI of the extent of minable potash within the WIPP site.

As shown in Figure 4, the CCA does not include the impact of potash mining in unleased areas which will also affect the regional hydrology. 40 CFR Part 194.32 states:

> Performance assessments shall assume that mineral deposits of those resources, similar in quality and type to those resources currently extracted from the Delaware Basin, will be completely removed from the controlled area during the century in which such mining is randomly calculated to occur.

EPA's Compliance Application Guidance for 40 CFR Part 194 (p. 46) states:

> EPA recommends that DOE use minable reserves in estimating mine linve and the extent of potential mining.

The Use of only the existing potash leases does not therefore satisfy the EPA's intent.

Limiting the CCA to "near future" resource recovery activities appears to be inconsistent with the Federal Land Policy and Management Act[7] and limiting the CCA to "exisiting leases" does not reflect anticipated mining. All federal public lands, including those adjacent to the WIPP Site, are "to be managed in a manner which recognizes the nation's need for domestic sources of minerals, food, timber, and fiber...." (Ref.8, §1702(12)). In addition, FLPMA requires the management of federal lands "be on the basis of multiple use and sustained yield unless otherwise specified by law" (Ref.8, §1701(7)). "The term multiple use means the management of the public land and the various resource values so that they are utilized in the combination that will best meet the present and ***future needs*** [emphasis added] of the American people" (Ref.8, §1702(c)). The term multiple use also means "a combination of balanced and diverse resource uses that take into account the ***long-term needs of future generations*** [emphasis added] for renewable and nonrenewable resources.... Sustained yield is defined as "the achievement and management ***in perpetuity*** [emphasis added] of a high-level annual or regular periodic output of the various

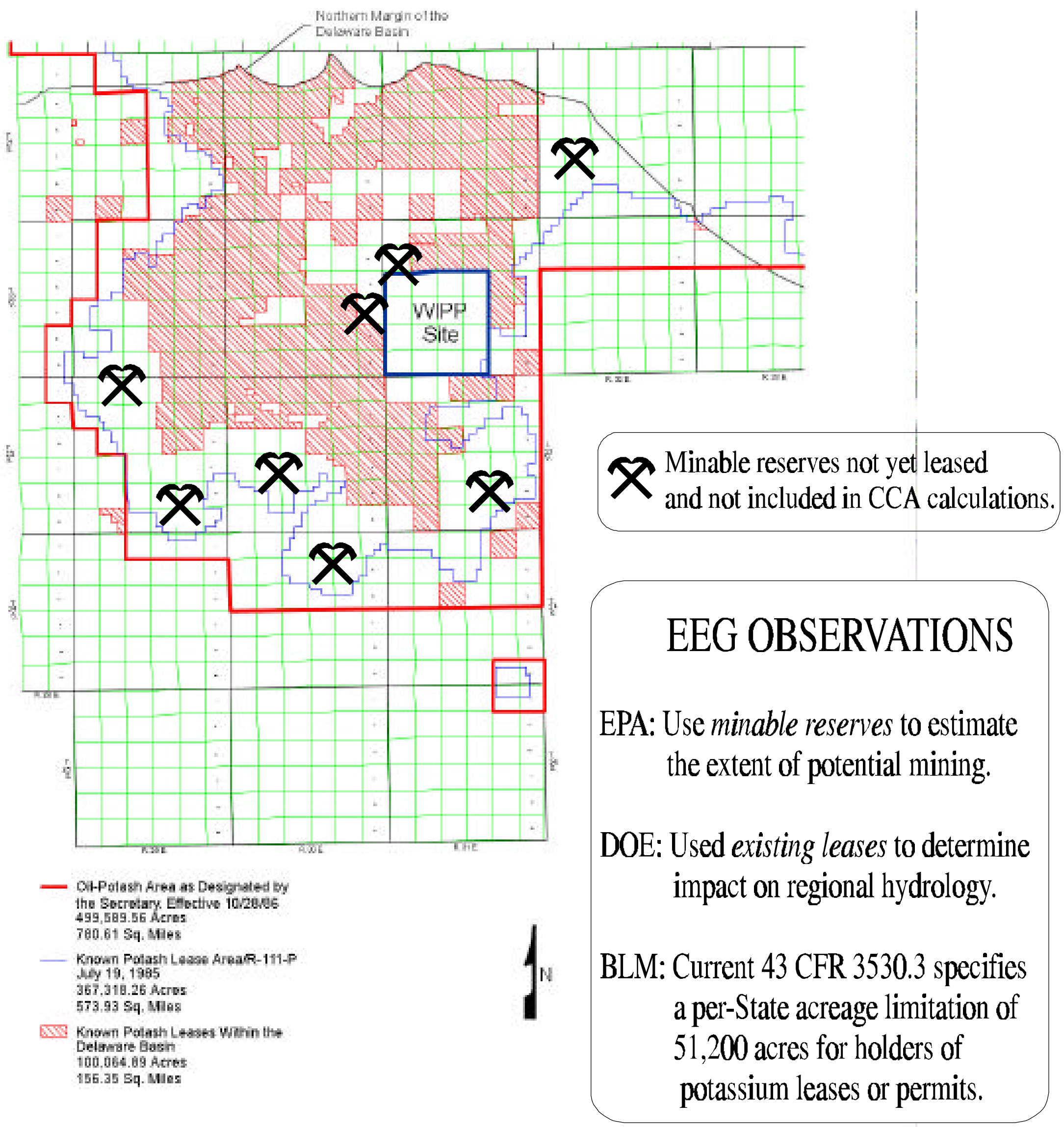

Figure 4. Potash leases within the Delaware Basin and minable potash not yet leased.

renewable resources of the public land consistent with multiple use" (Ref.8, §1702(h)). Human activities in the resource rich areas surrounding the WIPP are not limited to the ***near future*** and are not limited to ***the expected use of existing leases***.

The objectives of the state are also "to prevent waste, protect correlative rights, assure maximum conservation of the oil, gas and potash resources of New Mexico, and permit the economic recovery of oil, gas, and potash minerals..." (LeMay et al. 1988).

Recommendation

EEG recommends that the CCA consider all minable potash resources, as specified by the BLM, in the performance assessment calculations.

References

1. Cone, L.M., 1995. Oct 12 letter from U.S. DOI/BLM District Manager to G.B. Griswold.

2. U.S. Department of Interior, 1993. Preliminary Map Showing Distribution of Potash Resources, Carlsbad Mining District, Eddy and Lea Counties New Mexico By Bureau of Land Management, Roswell District.

3. Broadhead, R.F., F. Luo, and S.W. Speer, 1995. Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site. Carlsbad, NM: Westinghouse Electric Corporation, Waste Isolation Division. Vol. 3, Chapter XI.

4. Vaughn, G.L., 1995. December 13 Agency Answer to Appellant's Statement of Reasons by U.S. Department of Interior Bureau of Land Management General Counsel. Yates et al., appellants. IBLA 92-612.

5. Griswold, G.B., 1995a. Method of Potash Reserve Evaluation, In Evaluation of Mineral Resources at the Waste Isolation Pilot Plant (WIPP) Site. Carlsbad, NM: Westinghouse Electric Corporation. Waste Isolation Division, vol. 2, Chapter VII.

6. Griswold, G.B., 1995b. October 16 letter to J. Barker, of the New Mexico Bureau of Mines and Mineral Resources, P. Anselmo of the New Mexico Institute of Mining and Technology, W. Thayer of IMC Corporation, and S. Patchet of Westinghouse Waste Isolation Division.

7. U.S. Department of Energy, 1996. Title 40 CFR Part 191 Compliance Certification Application for the Waste Isolation Pilot Plant. DOE/CAO-1996-2184.

8. Federal Land Policy and Management Act of 1976. U.S. Code Annotated, 1989. vol. 43, secs. 1701-1784.

DOCUMENTATION OF FEPs AND PARAMETERS

In reviewing the CCA, assumptions concerning the features, events, and processes (FEPs) used in performance assessment (PA) and parameters used by the computer modeling should be checked to ensure that supporting documentation is valid. Due to limitations in manpower the EEG has not made as extensive effort to investigate the DOE's documentation of its efforts in these areas as has the EPA. However, in conjunction with various EPA efforts at SNL since the publication of the CCA, the EEG has investigated a small sample of both parameters and FEPs. This sample shows that there is cause for concern about the records available for both FEPs and parameters. In brief, three of the four parameters examined showed what seem to be significant problems for CCA documentation; and FEPs screening activities are dominated by what appears to be significant omissions and errors.

The information below may no longer be current, as SNL attempts to improve the documentation as feedback from the EPA is received. The attempt here is to show the types of problems that were in the documentation at the time the CCA was submitted.

CCA Appendix PAR Values Differ from PA Code Values

The parameter database used to construct Appendix PAR is different than the parameter database used by the computer codes at the time PA analysis for the CCA was performed. A later version of the parameter database, in which different values for some of the parameters had been added, was used for Appendix PAR, according to SNL personnel.

Table PAR-12 in the CCA shows Parameter ID # 3148, bulk compressibility (COMP_RCK CONC_PLG), to have a value of 1.2E-09 Pa^{-1}, whereas the value used in the CCA PA calculations was 2.64E-09 Pa^{-1}. Supporting documentation (Form 464s in WPO # 36591) indicates the value was 0 Pa^{-1} from March 14, 1996, to May 2, 1996, when it was changed to the 1.2E-09 Pa^{-1} value. The 264E-09 Pa^{-1} value apparently preceded the March 14, 1996 date. This implies that the parameter database used in the CCA PA may have preceded the March 14, 1996 date.

A June 17-21, 1996, CAO audit of SNL (A-96-03) discovered that many parameters had been entered into the database without following proper procedure, which included not only completion of records but also required reviews and sign-offs before entry into the database. The list of such parameters eventually grew to more than 230 (out of 1500 total parameters). If the CCA PA was using a database established prior to corrective actions for these parameters then the parameters may not have been properly qualified for use.

Documentation of Supporting Information for Parameters

Form 464s are the records that establish and justify values for parameters that are to be entered into the database used by PA analyses. The Form 464s either show justifications directly or provide information which allows tracing of the values to supporting data and analyses. For the

Castile Brine Reservoir Pressure parameter (WPO #31612), successive Form 464s may be used to illustrate the sorts of problems encountered in tracing values used for parameters.

The later of two Form 464s in the data package changes the distribution "Type" of the earlier Form 464 from "cumulative" to "triangular", which changes the method of calculating the uncertainty distribution from the median value to the mode. The use of the median value (cumulative distribution) is supported in 5 pages of information attached to the earlier Form 464, but the later Form 464 merely announces the change to the mode (triangular distribution) without justifying it. The only documentation for the change is the statement under "Interpretation" on the later Form 464:

> The mode is entered into the database in place of the median. The median was calculated and is 13.4E+06 Pa.

Apparently, the mode value was erroneously placed into the database as a median, because the mode value had been erroneously entered on the earlier Form 464 in the median block. On discovery, the solution was to use a new Form 464 to change the type of distribution so that the mode value already in the database would match the Form 464, rather than change the value in the database to the correct median value. The result appears to be that an unsupported value of 2.17E+07 Pa is in the database instead of the supported value of 1.34E+07 Pa.

The support information for the Form 464s shows additional problems. Attached to the 464s is a document entitled "Original Interpretation (1/12/96)", which includes a table of data that:

> ...defines a cumulative (empirical) distribution based on the 8 data points for pressure mentioned in the <u>source</u> <u>document</u> (SWCF-A:1.2.07.1: PDD: NON-SALDO: PKG # ?: Castile Brine Reservoir)
>
> The weights to be given to the 8 values of pressure were specified by author of source document.

The 8 pressure data point values are copied into a second table later on the page, and includes the weighting value for each.

Two other documents in the package (changes suggested by Tierney and Freeze) add two more pressure values, for a total of 10, without documenting the rationale for the addition, or referencing any document which might explain it. These might be in the "source document" cited in the quotation above, but that quote specifies "...the 8 data points...", not "...8 of the data points...".

Further, the weighting assessments are different between the Tierney and Freeze two documents, and both differ from the weighting assessments in the original interpretation. No justification is given for changing these weighting factors.

The Freeze document is apparently one page from a larger document to which there is no reference tie. On the page included, the statement is made:

> The weights are approximately based on distance from the repository. Note that WIPP-12 (inside the site boundary) is assigned a weight of 0.45...The rationale for the weights for the highest pressures (17.4 and 20.0 Mpa [sic]) is described in a later paragraph.

No later paragraph in the included parts of the document describes weighting rationale for the added pressure values, and WIPP-12 is assigned a weighting value of 0.30, not 0.45, in the table just above the quoted statement (WIPP-12 is the 12.7 MPa pressure value).

The last page in the supporting documentation consists of two source document listings, one a SAND document and the other the 1992 PA. The references list specific page numbers; the referenced pages in both documents consist of descriptions of Salado porosity parameters, and would seem to having nothing to do with Castile brine reservoir pressure.

The Form 464 points to another SNL data package (WPO # 31072), which contains a memorandum listing the data that had been sent to the Natural Barriers Peer Review Panel (the Panel was to perform a necessary review for quality assurance purposes). However, there was no documentation of the findings of the Peer Review Panel in the package, or references to the Peer Review Panel Report.

Another parameter data package (Castile Brine Reservoir Permeability; WPO # 31070) which had been sent to the same Peer Review Panel did contain a memorandum that referenced the Panel Report qualifying the parameter.

Castile Reservoir Compressibility/Volume Documentation

Another parameter (Castile Brine Reservoir Rock Compressibility; Parameter # 61) offers an interesting set of memoranda from key SNL personnel. Briefly, in late August, 1996, a SNL scientist sent a memorandum to SNL's upper management in which he stated that

> ...I believe that treatment of brine reservoirs for the CCA was indefensible and non-conservative. I believe we are systematically underestimating the amount of brine that could reach the repository....The low end of the range comes from interpretation of hydraulic tests in Salado anhydrites, not from any direct Castile anhydrite measurements. The high end of the range comes from generic information reported by Freeze and Cherry (1979) for the compressibility of jointed or fractured rock, again not from actual Castile data...

The conclusion quoted above covers both the compressibility and volume of Castile brine reservoirs, which SNL analyses consider to be interdependent.

On October 3, 1996, the same scientist wrote another memorandum in which he concluded that, because the range of values he had calculated fell within the range used in the CCA, and other SNL personnel had told him that sensitivity calculations showed that the change in range would not shift the CCDFs, the treatment of Castile brine reservoirs in the CCA was acceptable.

However, whatever the effect on the CCDFs, the range used for the parameter in the CCA are still "...indefensible and non-conservative." None of the later memoranda contest this statement.

A graph of the data points appended to the October 3, 1996 memorandum shows that the new range lay in the upper end of the range used in the CCA calculations, and the data points that lay below the new range (38% of the total) were a much longer chain, while the ones above the new range (13% of the total) were more closely associated with the new range. Monte Carlo or Latin Hypercube Sampling would seem to result in more emphasis on lower values while using the CCA range than would be the case with the new range shown in the memorandum.

This package also received its QA acceptability from the Natural Barriers Peer Review Report (DOE/WIPP-96*2004). The peer review was held months before the new range was developed, and it would seem that a similar body should pass on the validity of the use of a new range of values for the parameter.

It may be worth noting that the discussion in the Natural Barriers Peer Review Report indicates that the peer review panel viewed Castile data from the WIPP-12 borehole in considering these parameters (see Report, p. 5-18) which the SNL scientist's memorandum stated was not used in the supporting documentation for the parameter.

Documentation of the Culebra Porosity Parameter As A Constant

The CCA (in Appendix PAR) states that:

> Parameters may also be assigned a constant value in the performance assessment parameter database. These parameters are tabulated at the end of the appendix. [PAR.2.1, end of section]

The Culebra porosity parameter (Parameter ID 140, Effective Porosity) is in the Table PAR-30 (Appendix PAR, p. PAR-214) as a constant value of 1.5100E-01. The Form 464 for the parameter (WPO #32769) describes the distribution type as a constant, and states a curious circular logic in the "Interpretation" section:

> The distribution equates a point and that point is equal to the mean. Therefore, that point is a constant.

However, the documentation appended to the Form 464 shows an approximate 30% standard deviation among the 103 data points used to establish the mean. Justification for the change (from a "student's t" distribution type) is a memorandum entitled "Distributions" (Tierney, March 21, 1996) that describes the use of the various types of distributions (cumulative, delta, normal, triangular, uniform, lognormal, loguniform) but does not a description for "constant" distributions. When SNL personnel were asked for documentation of the rationale for using a constant, a memorandum relating to category 3, physical constant parameters (Pi, Avogadro's number, etc) was the only information available (the porosity parameter is a category 1, derived from experimental data). In short, no justification is provided in the data package or seems to be available for considering this parameter to be a constant.

Documentation of Features, Events, and Processes (FEPs)

Operations involving the screening and other processing of FEPs are inadequately documented. 25% of the original FEPs list was eliminated with no documentation of the process; 70% of the remaining FEPs have essentially no more documentation than what appears in the Compliance Certification Application (CCA). The documentation for the other 30% also appears to be incomplete. The rationale for excluding many of the FEPs from performance assessment (PA) is not documented in the CCA, as required by 40 CFR 194.32(e)(3).

The DOE originally developed a list of nearly 1200 FEPs, and the draft CCA (the DCCA; DOE/WIPP/CAO-2056, March 31, 1995) considered about 900 FEPs. For the CCA, approximately 240 were to be addressed, and about 90 of these are said to be "screened in", or used in the PA process. The DCCA list (≈900) is included as Appendix A to Attachment 1 of Appendix SCR to the CCA; the CCA list (≈240) are in the CCA as three tables, found in Chapter 6 (Tables 6-3, 6-4, and 6-5) and also in Appendix SCR (Tables SCR-1, SCR-2, and SCR-3).

No screening analysis plans were utilized for the reduction of the nearly 1200 FEPs to the approximately 900 included in the CCA, nor is there any documentation of the process used for each FEP. Reduction of the ≈900 was also performed without an analysis plan; this operation was later reviewed, and about 30% of the FEPs were passed on to the "SNL Side Efforts Program". The preliminary decisions on the other 70% of the FEPs seems to have been accepted without documentation of the process for including or excluding them. (The 70%-30% split of FEPs is taken from SNL documents and has not been independently verified by the EEG.)

The 30% that passed to the SNL "Side Efforts" program are required to have packages supporting the screening decision in the Sandia-WIPP Central Files (SWCF); these were to be screened based on the "FEPs Screening Analysis Plan, Version 5.2, for Phase I FEPs", dated 12-20-95 (for FEPs related to numerical and conceptual models), and "FEPs Screening Analysis Plan, Version 5-4, for Phase II FEPs" dated April 29, 1996 (for parameterized FEPs). However, at least 31 of the "Side Efforts" FEPs were only to be documented in the CCA (letter from DOE's McFadden to EEG's Neill dated August 2, 1996).

These 31 FEPs may have been part of a perhaps larger group of Phase II FEPs which were not processed in accordance with the analysis plan due to "resource constraints". The Change

Control Board was utilized to justify incorporating these FEPs into the CCA (see Wilmot, R.D., "Relationship of Side Efforts to the Compliance Certification Application" Galson Sciences Ltd 9507a-6, November 26, 1996, p. 2).

Not all of the 31 FEPs are documented in the CCA. Only "Side Efforts" FEPs were given an alphanumeric designator; the first FEP on the list (from the Neill-to-Dials letter dated July 11, 1996), "DR11, waste degradation", does not appear in the CCA nor did a rationale for its exclusion seem to be included. The Galson Sciences Ltd document cited above was written to document the location within the CCA of side efforts (p. 1); it indicates (Table 2, p. 15) that this FEP is

> ...not included in PA calculations [because]...Changes in mechanical and hydrological properties of the waste caused by corrosion need not be explicitly modeled.

Table 2 also indicates that the FEP is discussed within the CCA in Sections 6.4.3.1, 6.4.3.2, and 9.3.2.2.5. These sections do not provide a rationale for excluding waste degradation--indeed, the discussions in these sections only discuss waste in terms of consolidation (p. 6-97 & 6-98), gas generation (p. 6-100) and compaction (p. 9-138). The sections from Chapter 6 could be better used to show that consideration of waste degradation was included in the PA.

Appendix A, "DCCA Fep List By Category", of Attachment 1 of Appendix SCR to the CCA does list a general category of "1.9 Waste: degradation/corrosion/dissolution" with 12 subcategories (p. 26), but no alphanumeric designators are supplied. This seems to be the closest representation of the "Side Efforts" FEP designated as "DR11, Waste Degradation", in the CCA.

This illustrates a principal concern EEG has about the FEPs documentation process: many FEPs seem to be neither adequately defined nor consistently identified. FEPs would seem to require more than a two or three word designator to adequately delineate what is encompassed and excluded from the concept, but the CCA does not contain such descriptions, nor do such accurate definitions seem to exist.

A second concern is that 40 CFR 194.32(e) requirements for documentation seem to be inadequately met. 40 CFR 194.32(e) requires that the CCA include (1) identification of all FEPs that might affect the disposal system in the regulatory time frame; (2) a list of those used in PA; and (3) documentation of the rationale for excluding those not used. There are abundant lists that show which FEPs were used in PA (Tables 6-3, 6-4, and 6-5 of Chapter 6, which are duplicated in Tables SCR-1, SCR-2, and SCR-3 in Appendix SCR; and Table 4 of Attachment 1 to Appendix SCR), but the original list of ≈1200 FEPs has not been included, and the rationale for not including at least some of the FEPs seems to be missing.

A third concern is that the Change Control Board decision to incorporate FEPs which had not been processed in accordance with analysis plans would seem to have circumvented the WIPP quality assurance programs.

This leads to a fourth concern: it appears that much of the work on FEPs has not been performed in accordance with the Nuclear Quality Assurance (NQA) standards required by 40 CFR 194.22(a). NQA-1 Basic Requirement 5 states:

> Activities affecting quality shall be prescribed by and performed in accordance with documented instructions, procedures, or drawings of a type appropriate to the circumstances. These documents shall include or reference appropriate quantitative or qualitative acceptance criteria for determining that prescribed activities have been satisfactorily accomplished.

Prescribing instructions or procedures which included acceptance criteria were apparently not developed for much of the FEPs process.

When questioned about QA assessments of the FEPs screening and documentation process, SNL cited CAO surveillance S-96-21 as having covered the 70% FEPs in its assessment of the DCCA. According to the surveillance report, this assessment was conducted by one auditor and a software QA specialist over a five-day period (February 5-9, 1996), and covered training and personnel qualification, procurement control, document reviews, records, and software. The only part of the report that could possibly be considered an assessments of FEPs is in the section concerning technical document reviews (p. 4), which covered not only the entire DCCA, but also the RCRA permit application, No Migration Variance Petition, and an Engineered Alternatives study. There is no documentation that any FEPs were reviewed during this surveillance. Thus, the reduction of FEPs from ≈1200 for the CCA's ≈240 has not been assessed by an independent organization.

FEPs in the "Side Efforts" program were said by SNL to have been assessed during CAO surveillances S-96-04 (December 1995), S-96-32 (April 1996), and CAO audit A-96-03 (June 1996). The program was still in progress during this time period, and the Change Control Board decision may not have been fashioned yet.

FEPs Screening Decision Adequacy

For the CCA, FEPs were eliminated (screened out) from consideration in PA by one of three criteria: regulatory (SO-R), for FEPs excluded by language in 40 CFR 191 or §194; low consequence (SO-C) FEPs; and low probability (SO-P) FEPs, which are defined in §194.32(d) as processes and events with less than one chance in 10,000 of occurring over 10,000 years. For SO-P, the CCA offers a less stringent interpretation (Section 6.2.2.1 lines 20-23, p. 6-39):

> In practice, for most FEPs screened out on the basis of low probability of occurrence, it has not been possible to estimate a meaningful quantitative probability. In the absence of quantitative probability estimates, a qualitative

argument has been provided.

Some FEPs screening arguments seem inadequately supported. For example, GG-13, electrochemical gradients, is screened out on the basis of probability (Galson Sciences Ltd 9507a-6, p. 25). The argument offered in Appendix SCR (p. SCR-62) is:

> Galvanic coupling could lead to the establishment of potential gradients between metals in the waste form, canisters, and other metals external to the waste form. Such electrochemical effects can potentially influence corrosion processes and therefore gas generation rates and chemical migration...Good physical and electrical contact between the metals involved is critical to the establishment of galvanic cells. Experience with experimental investigations suggests that this requirement is unlikely to be achieved under repository conditions.

None of the experimental investigations are listed in Appendix SCR. However, the Sandia-WIPP Records Center does store supporting documentation for the CCA, and for this FEP the records package is WPO # 31491, "Electrochemical Gradients Qualitative Screening Arguments for Side Effort GG-13". This document echoes Appendix SCR, stating that the FEP is SO-P because:

> Good physical and electrical contact between the metals involved is critical to the establishment of galvanic cells. Experimental investigations suggest that this requirement is unlikely to be achieved under repository conditions (Telander and Westerman, 1993).

The cited document is SAND92-7347, "Hydrogen Generation by Metal Corrosion in Simulated Waste Isolation Pilot Plant Environments: Progress Report for the Period November 1989 through December 1992". The EEG was unable to locate any descriptions of experiments or any data relating to physical or electrical contact between metals, or any references to galvanic cells or coupling in the document. The report covers experimentation on corrosion and consequent H_2 gas generation by low-carbon steel and alternative packaging materials in contact with gases (N_2, CO_2, H_2S) and brine, but offers no indication that interactions between metals was ever a consideration.

For this SO-P FEP there is not only no evidence that the 1 chance in 10,000 over the next 10,000 years criteria is met, there also appears to be no evidence for the less stringent qualitative argument offered.

In discussing this FEP, the DOE has intermingled electrochemical gradients (GG13) with another FEP, galvanic coupling (GG12), and then used an argument based on galvanic coupling to cover electrochemical gradients; this intermingling amounting to a circular argument exemplifies the EEG's concern about inadequate delineation of FEPs. Electrochemical gradients may be formed by means other than galvanic coupling (oxidizing conditions in one part of the repository, reducing in another, with brine linking them), and the possibility of such gradients should also be addressed.

Given the uncontrolled and intense compression the waste in the repository will undergo, it seems possible that the necessary physical and electrical contact between metals cited in the CCA as necessary for galvanic coupling can occur. The DOE's contention that this will not occur is unsupported by cited documents. A reliable and objectively supported argument should be advanced before rejecting the possibility--for both the GG12 and the GG13 FEPs.

FEPs Excluded on the Basis of Administrative Control

Table C-3 in Appendix C to Attachment 1 of Appendix SCR to the CCA (SCR p. 92 & 93) is titled "FEPs on the DCCA FEP list excluded from the development of the CCA FEP list as issues relating to designs different to that forming the basis of the CCA".

The FEPs in the table are the sorts of events that would seem to require a more serious consideration before excluding them from PA. Among these are the FEPs "Backfill/seal material deficiencies", "inadvertent inclusion of undesirable materials", "poor quality construction", "radioactive waste disposal error", "stray materials left", "Preclosure events", "Faulty seal emplacement", "Inadequate seal or compaction, voidage", and "Seal material deficiencies", all of which would seem to be possible events which could alter the adequacy of the repository for its intended task.

"Abandonment of unsealed repository", another on the list, would certainly seem important enough to require close consideration. Will there be funding and a willingness to continue the WIPP for a full 35 years anticipated by the design presented in the CCA?
A statement in the narrative portion of Appendix C (pp. 11-12) addresses exclusion of these FEPs:

> FEPs relating to constructional, operational and decommissioning errors (classified as RD in the DCCA) have been eliminated from the CCA FEP list. The DOE has administrative and quality control procedures to ensure that the facility will be constructed, operated, and decommissioned as specified in the CCA.

The EEG considers this statement to be inadequate justification for excluding these FEPs. Among other examples, recent administrative and quality controls concerning drilling rights and privileges in the vicinity of WIPP (see recent EEG discussions of active and passive institutional controls) illustrate that such controls are not always effective.

Attachment 1
P. 1

General Considerations: DQC's

1. For sampled distributions, CCA Chapter 5 provides a good description of why simulation values need not be covered by DQC's:

- Applicable to tasks involving quantification through sampling and analysis of specific constituents in an environmental medium (e.g., pollutants in wast streams   waste characterization and environmental monitoring).
- The performance assessment is estimated using mathematical models rather than being determined by direct measurement.

   1) Parameters are treated as being uncertain variables, rather than precisely determined quantities and are characterized by probability distributions.

   2) Parameter distributions may span several orders of magnitude due to uncertainty introduced in susequent processing. Many parameters derived from data measurements need be known only within orders of magnitude of their true value. Efforts to reduce the range do not necessarily improve model accuracy.

   3) As an example, data accuracy would be very difficult to assess for geologic site characterization activities because reference or true values do not exist.

   4) In summary, it's not practicable to apply DQC's to most scientific investigations used support a performance assessment, in which there uncertainty in the conceptual models and the resultant ranges of parameters. Instead, controls established by the QA program provide the necessary quality.

2. There are a lot of technical discussions that could be presented to describe why DQC's don't apply to specific data sets The intent here is to provide some general discussion regarding the topic.

3. 194.22(c) itself says "...to the extent practicable, information which describes how all data used to support the compliance application have been assessed for their quality characteristics, including:...[PARCC]".

4. Natural features do not lend themselves to DQC's.

January 16, 1997

Attachment 1, P. 2

CATEGORY	DATA SET	DATA SET DESCRIPTORS	PRECISION, ACCURACY, REPRESENTATIVENESS, COMPLETENESS, COMPARABILITY (PARCC)
Dominant force - relative to releases	Particle Size	• Particle sizes of waste and backfill at the time of human intrusion • What future waste might look like 10,000 years • No physical data collected • interpretative • Sampled distribution	P. No physical data collected by project. Values were selected by smallest size analog materials & largest annular space. Smallest sized values determined from textbooks standard equations. A: No physical data collected by project. Values were selected by smallest size analog materials & largest annular space. Smallest sized values determined from textbooks standard equations. R: The uniform distribution assures that all possible values are fully represented. C: Distribution captures plausible and realistic values. C. N/A. Because there is only one data set. All of the available data were used.
Less important - relative to releases	The Probability of Microbial Degradation	• Interpretative • ~~Some data collected~~ • Estimate of the likelihood of occurrence of gas generation - 50% likelihood	P: Data collected was not used to determine the distribution. Model decision formulated - 50% likelihood (yes/no), if the process will take place. The 50% value reflects a lack of knowledge of the distribution. A: Data collected was not used to determine the distribution. R: 50%, only 2 possibilities. C: Based on ~~some experimental data and~~ interpretation. C: N/A: ~~Because there is only one data set.~~ For the 50% there are only 2 possibilities.
No Impact - relative to releases	Anhydrite Permeability	• A measure of a porous medium to transmit fluid • Experimental data • Field data • Laboratory data • Sampled distributions	P: A wide range of values doesn't affect release. The laboratory and field data were combined into a single data set. A: Distribution was set up to account for a wide range of data and uncertainty in data points. R: Latin Hyper Cube sampling assures that distribution and values fully represented. C: Latin Hyper Cube sampling assures that distribution and values fully represented. C: N/A: Because all of the available data were used to create the distribution.

CATEGORY	DATA SET	DATA SET DESCRIPTORS	PRECISION, ACCURACY, REPRESENTATIVENESS, COMPLETENESS, COMPARABILITY (PARCC)
Less important - relative to releases	Gas Generation Rates	• Rate of gas generation • Experimental data • Laboratory data • Sampled distributions	P: Variability in values doesn't significantly affect release. Wide variability due to a large range of conditions in ~~field~~/lab data dominates the variability in the individual experiments. Variability scatter of the data collection values is small compared with the much broader spread assumed by the distribution to account for uncertainties in the conditions. A: Variability in values doesn't significantly affect release. Wide variability due to a large range of conditions in ~~field~~/lab data dominates the variability in the individual experiments. Variability scatter of the data collection values is small compared with the much broader spread assumed by the distribution to account for uncertainties in the conditions. R: The Test Plan is designed to explore the range of conditions expected in the repository. The sampling assures that distribution and values are fully represented. C: Latin Hyper Cube sampling assures that distribution and values fully represented. C: N/A: Because there is only one data set.
Less important - relative to releases	Panel Closure	• Bounding argument • No data collected for panel closure	Permeability is larger than what we think the true value would be. Very conservative value. The true distribution of values would all lie below the assumed values and is therefore very conservative. R: Bounds all plausible values.

No Impact - relative to releases	Releases through the Culebra: Kd's	• Experimental data
		  • Field data
		  • Laboratory data
		• All distributions
			P: Variability in values doesn't significantly affect release. Wide variability due to a large range of conditions in field/lab data dominates the variability in the individual experiments. Variability scatter of the data collection values is small compared with the much broader spread assumed by the distribution to account for uncertainties in the conditions.
			A: Distributions set-up for variability uncertainty.
			R: Representativeness of collection cannot be known for 100% certainty for natural features. Therefore accounted for by probabilistic method.
			C: Same as for Representativeness.
			C: N/A: Because all of the available data were used to create the distribution.