9.0 PEER REVIEW

This chapter describes the regulatory basis for the conduct of peer reviews and summarizes relevant peer reviews that have been performed at the Waste Isolation Pilot Plant (WIPP). Key elements of the U.S. Department of Energy (DOE) Carlsbad Area Office (CAO) peer review program (for example, the review process, reports, and selection criteria and training for review panel members) are discussed. Three categories of peer reviews are reported in this chapter: (1) those conducted after the promulgation of Title 40 of the Code of Federal Regulations (CFR) Part 194 (U.S. Environmental Protection Agency [EPA] 1996a); (2) those conducted earlier; and (3) future or ongoing peer reviews.

In support of this application, seven peer reviews were initiated subsequent to the promulgation of 40 CFR Part 194. Per the criteria of 40 CFR § 194.27, they were conducted in a manner that is compatible with NUREG-1297 (Nuclear Regulatory Commission [NRC] 1988). The subjects of these reviews include: conceptual models; waste characterization analysis; engineered alternatives cost/benefit study (EACBS); engineered systems data qualification; waste form and disposal room data qualification; natural barriers data qualification; and passive institutional controls. These reviews are summarized in this chapter in the following sections:

- 9.3.1 – Conceptual Models Peer Review
- 9.3.2 – Waste Characterization Analysis Peer Review
- 9.3.3 – Engineered Alternatives Cost/Benefit Study Peer Review
- 9.3.4 – Engineered Systems Data Qualification Peer Review
- 9.3.5 – Natural Barriers Data Qualification Peer Review
- 9.3.6 – Waste Form and Disposal Room Data Qualification Peer Review
- 9.3.7 – Passive Institutional Controls Peer Review

The applicable peer review plans, complete peer review reports, and selected supporting documentation are provided in Appendix PEER. This chapter also presents the DOE responses to the findings and recommendations of the peer reviews. Additional documentation is available in project record packages in the CAO Record Center, which is located in Carlsbad, New Mexico.

Peer reviews that occurred prior to the promulgation of 40 CFR Part 194 were not necessarily conducted in accordance with NUREG-1297 guidelines. Therefore, candidate reviews were evaluated against specific criteria to determine whether they were appropriate for inclusion in this application. The selected historical reviews are summarized in the following sections:

- 9.4.1 – National Academy of Sciences WIPP Panel Reviews (12 reports)
- 9.4.2 – Performance Assessment Peer Review Panel
- 9.4.3 – Shaft Seal Design Independent Review
- 9.4.4 – Engineered Alternatives Task Force Report Peer Review
- 9.4.5 – Blue Ribbon Panel Peer Review
- 9.4.6 – Advisory Committee on Nuclear Facility Safety Review (two reports)
- 9.4.7 – Performance Assessment Review Team

- 9.4.8 – INTRAVAL
- 9.4.9 – WIPP Conceptual Model Uncertainty Group Review
- 9.4.10 – Environmental Evaluation Group Reviews (15 reports)
- 9.4.11 – Fracture Expert Group Review
- 9.4.12 – Fanghänel Review
- 9.4.13 – Independent Technical Review of the Bin and Alcove Test Programs
- 9.4.14 – Performance Assessment Reviews
- 9.4.15 – Technical Support Group Reviews (two reports)
- 9.4.16 – National Environmental Policy Act Reviews

The full reports from these reviews and selected supporting material are provided in Appendix PEER.

9.1 Regulatory Requirements

The certification criteria in 40 CFR Part 194 prescribes the use of peer reviews to support certain areas of the compliance evaluation. Compliance criteria in 40 CFR § 194.27 state that peer review at the WIPP be performed for several specific aspects of the program and that they be performed in a manner compatible with NUREG-1297. NUREG-1297 provides guidance on the definition of peer reviews, the areas for which a peer review is appropriate, the acceptability of peers, and the conduct and documentation of peer reviews. 40 CFR Part 194 states that *"The specific requirements in NUREG-1297 that discuss for which activities peer review should be conducted do not apply, nor do they supersede the requirements of the final rule."* (61 *Federal Register* [FR] 5228) Specific sections of 40 CFR Part 194 and NUREG-1297 provide the regulatory basis for this chapter.

The certification criteria state that any application for certification shall include documentation for the following peer reviews that are to be conducted: conceptual models used in the performance assessment; waste characterization analysis; and, engineered barrier evaluation (40 CFR § 194.27[a]). Section 194.27(b) states that these peer reviews, if conducted subsequent to the promulgation of 40 CFR Part 194, be conducted in a manner that is compatible with NUREG-1297. Section 194.27(c)(2) also states that this application include documentation of any peer review processes conducted in addition to those of 40 CFR § 194.27(a).

NUREG-1297 defines peer review as *"a documented, critical review performed by peers who are independent of the work being reviewed."* NUREG-1297 also states that a *"peer review is an in-depth critique of the assumptions, calculations, extrapolations, alternate interpretations, methodology, and acceptance criteria employed, and of conclusions drawn from the original work."*

The 40 CFR Part 194 Background Information Document (EPA 1996b) states that peer reviews can be used as part of *"a comprehensive quality assurance program"* to give *"confidence that work completed, underway, or planned was, is, or will be properly* *performed."* The Background Information Document also notes that *"additional peer review is also necessary to establish the validity of procedures, methods, or interpretations which may not be addressed by a quality assurance program . . . ASME-NQA-3-1989 . . . includes peer review among those activities affecting quality associated with the collection of scientific and technical information, when other established methods cannot be used to establish the adequacy of information."*

NUREG-1297 states that for a repository,

> *"peer reviews should be used as a management tool to achieve confidence in the validity of certain technical and programmatic judgments. The intent of a peer review is to pass judgment on the technical adequacy of the work or data submitted for review, to identify aspects of the work on which technical consensus exists, to identify aspects on which technical consensus does not exist, and to identify aspects of the reviewed work which the reviewers believe to be incorrect or which need amplification. A peer review provides assurance in cases where scientific uncertainties and ambiguities exist but in which technical and programmatic judgments and decisions still must be made."*

9.2 Peer Review Process

NUREG-1297 suggests that procedures be developed to *"implement the NUREG-1297 guidance"* and to *"provide methods for initiating a peer review."* These procedures, for any given peer review, *"should require a planning document that describes the work to be reviewed, the size and spectrum of the peer review group, and the suggested method and schedule to arrive at a peer review report."*

WIPP-specific plans and procedures ensure that peer reviews performed subsequent to promulgation of 40 CFR Part 194 were conducted in accordance with the criteria of 40 CFR Part 194 and compatible with NUREG-1297. The most pertinent of the plans and procedures are discussed briefly below.

A Peer Review Management Plan (PRMP) (DOE 1996a) was developed and approved by the CAO to describe the management processes used to control the planning, implementation, and documentation of these reviews. The PRMP defines the management approach, resources, schedule, and technical requirements for using peer reviews to confirm and/or verify the adequacy of data and/or information utilized to support the WIPP application.

CAO Team Procedure (TP) 10.5, Peer Review (DOE 1996b), implements the requirements of NUREG-1297. TP 10.5 prescribes the responsibilities, requirements, and methodologies to be incorporated in the performance of peer reviews conducted by the CAO pursuant to the criteria of 40 CFR § 194.27. The procedure provides the criteria for determining the size and composition of the review panel and for selecting individual peer review panel members, and outlines the orientation and training to be provided for the panelists. TP 10.5 also describes the actual peer review process, provides criteria for development of peer review plans and report preparation, and defines the responsibilities of individuals involved in the process.

Specific peer review plans were developed for each peer review at the WIPP. These plans documented the planning process for the peer reviews and were prepared and approved prior to performing the particular review (see Section 9.2.1).

As discussed more completely in Chapter 5.0, the Quality Assurance Program Document (QAPD) (DOE 1996c) establishes the minimum requirements for the WIPP quality assurance (QA) program. It provides guidance for development and implementation of QA programs for all aspects of the WIPP project. In particular, the QAPD provides general requirements for training, document control, and QA records management.

9.2.1 Peer Review Plan

TP 10.5 requires that the Peer Review Manager ensure that a peer review plan is prepared and approved prior to the performance of each peer review. Specific plans are approved by the CAO Assistant Manager for the Office of Regulatory Compliance.

The plan documents the planning of the peer review. It provides the scope of the peer review, a description of the work to be reviewed, the intended use of the work, the size and composition of the peer review panel, and methods for conducting peer reviews

40 CFR § 194.27(b) specifies that peer reviews performed subsequent to the promulgation of 40 CFR Part 194 be conducted in a manner compatible with NUREG-1297. NUREG-1297 states that

> *"The peer review process may vary from case to case, and should be determined by the chairperson of the peer review group, consistent with the guidance provided in this GTP* (Generic Technical Position). *In meetings and/or correspondence, the peer review group should evaluate and report on: (a) validity of assumptions; (b) alternate interpretations; (c) uncertainty of results and consequences if wrong; (d) appropriateness and limitations of methodology and procedures; (e) adequacy of application; (f) accuracy of calculations; (g) validity of conclusions; (h) adequacy of requirements and criteria. Furthermore, full and frank discussions between the peer reviewers and the performers of the work are encouraged."*

The WIPP peer review process consists of an in-depth analysis and evaluation of documented assumptions, calculations, extrapolations, alternate interpretations, methodology, and acceptance criteria employed, and of conclusions drawn in the original work. TP 10.5 specifically incorporates the above NUREG-1297 requirements into the WIPP peer review process.

9.2.2 Size and Composition of Peer Review Panels

NUREG-1297 states that

> *"The number of peers comprising a peer group should vary with the complexity of the work to be reviewed, its importance to establishing that safety or waste isolation performance goals are met, the number of technical disciplines involved, the degree to which uncertainties in the data or technical approach exist, and the extent to which differing viewpoints are strongly held within the applicable technical and scientific community concerning the issues under review. The collective technical expertise and qualifications of peer group members should span the technical issues and areas involved in the work to be reviewed, including any differing bodies of scientific thought. Technical areas more central to the work to be reviewed should receive proportionally more representation on the peer review group."*

The NUREG-1297 guidance also states that

> *"The peer review group should represent major schools of scientific thought. The potential for technical or organizational partiality should be minimized by selecting peers to provide a balanced review group."*

The size and composition of peer review panels established after the promulgation 40 CFR Part 194 were determined by a selection committee consisting of the Peer Review Manager and two members selected by the Peer Review Manager.

Peer review panel size and composition was determined by a selection committee consisting of the Peer Review Manager and two members selected by the Peer Review Manager. These individuals were picked because of their familiarity with the peer review process, the WIPP project, their impartiality, and their knowledge of potentially qualified peer reviewers.

Technical requirements for each peer review panel were established by the Peer Review Manager and provided to the selection committee, which then developed a list of potentially qualified personnel. Once a panel member was officially selected and had agreed to serve, the selection committee members documented the rationale for the selection of that peer review panel member on a "Peer Review Panel Selection, Size and Composition Justification/ Decision Form," which is maintained as a QA record.

The number of members selected for a particular panel depended on the amount and complexity of the work to be reviewed, its importance for establishing that safety or waste isolation performance goals are met, the number of technical disciplines involved, the degree to which uncertainties in the data or technical approach exist, and the extent to which differing viewpoints are strongly held within the applicable technical and scientific community concerning the issues under review. The panel members were selected based on their collective technical expertise and qualifications so that they spanned the technical issues and areas involved in the work to be reviewed, including differing bodies of scientific thought. The technical areas more central to the work to be reviewed received proportionally more representation on the peer review panel. To the extent practical, the panels represented the major schools of scientific thought pertinent to the subject being reviewed. The selection committee strived to eliminate the potential for technical or organizational partiality by selecting peer reviewers that provided a balanced panel.

The strategy for staffing the panels was to use a combination of individuals knowledgeable of the WIPP with other individuals that had little or no knowledge of the WIPP. All of the individuals had to meet the strict independence requirements. To ensure that the data review panels had knowledge of the related conceptual models, two members of the Conceptual Models Peer Review Panel were assigned to the Natural Barriers Data Qualification Peer Review Panel and two others were assigned to the Engineered Systems Data Qualification Peer Review Panel. In addition, one individual from the Waste Form and Disposal Room Data Qualification Peer Review Panel was assigned to the Waste Characterization Analysis Review Panel to ensure the latter panel was provided with timely and in-depth knowledge of chemistry data pertinent to the waste.

9.2.3 Technical Qualifications of Panel Members

NUREG-1297 states that

> *"The technical qualifications of the peer reviewers, in their review areas, should be at least equivalent to that needed for the original work under review and should be the primary consideration in the selection of peer reviewers. Each peer reviewer should have recognized and verifiable technical credentials in the technical area he or she has been selected to cover. The technical qualifications of each peer, and hence of the peer review group as a whole, should relate to the importance of the subject matter to be reviewed."*

TP 10.5 specifies that the acceptability of any peer review panel member be based on the above NUREG-1297 requirements. The Peer Review Manager is required to ensure that education and pertinent experience information is verified and documented prior to the start of the peer review process. This documentation is also maintained as QA records.

9.2.4 Independence of Panel Members

NUREG-1297 states that

> *"Members of the peer review group should be independent of the original work to be reviewed. Independence in this case means that the peer, a) was not involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed, and b) to the extent practical, has sufficient freedom from funding considerations to assure the work is impartially reviewed."*

> *"Because of DOE's pervasive effort in the waste management area, the lack or unavailability of other technical expertise in certain areas, and the possibility of reducing the technical qualifications of the reviewers in order that total independence is maintained, it may not be possible to exclude all DOE or DOE contractor personnel from participating in a peer review. In those cases where total independence cannot be met, a documented rationale as to why someone of equivalent technical qualifications and greater independence was not selected should be placed in the peer review report."*

NUREG-1297 allows both the work under review and the peer review of that work to be funded by DOE. It also provides the caveat that the

> *"independence criteria is not meant to exclude eminent scientists or engineers upon whose earlier work certain of the work under review is based so long as a general scientific consensus has been reached regarding the validity of their earlier work."*

TP 10.5 provides that the above NUREG-1297 requirements be used in selecting panel members. Each peer review panel member is required to document his or her independence. These documents are reviewed and approved by the Peer Review Manager and maintained as QA records.

9.2.5 Training of Peer Review Panel Members

TP 10.5 requires that the Peer Review Manager ensure that all peer review panel members receive adequate training prior to beginning a peer review. Training consists of reading assignments and, if deemed necessary by the Peer Review Manager or the Peer Review Panel Coordinator, briefings and classroom training. Assigned reading includes 40 CFR Parts 191 (EPA 1993) and 194, NUREG-1297, the CAO QAPD, TP 10.5, and the applicable Peer Review Plans.

TP 10.5 further requires that all panel members receive an orientation prior to the start of the peer review process. The orientation includes information on the peer review process, administrative requirements, the applicable Peer Review Plan, a summary of the technical subject matter, and an overview of TP 10.5. Panel member training and orientation are documented and this documentation is maintained as a QA record.

9.2.6 Peer Review Panel Report

NUREG-1297 states that

> *"A written report documenting the results of the peer review should be issued. It is usually prepared under the direction of the chairperson of the peer review group, and is signed by each member individually. It should clearly state the work or issue that was peer reviewed and the conclusions reached by the peer review process . . . The*

> *report should include individual statements by peer review group members reflecting dissenting views or additional comments, as appropriate. The peer review report should contain a listing of the reviewers and any acceptability information (i.e., technical qualifications and independence) for each member of the peer group, including potential technical and/or organizational partiality."*

TP 10.5 requires that a peer review report be prepared for each peer review. Each panel member is required to sign and date the report. The report describes the work or issue that was reviewed and the conclusions reached by the panel, and it provides individual statements by the members reflecting dissenting views or additional comments, as appropriate. Finally, the report lists the peer review panel members and provides technical qualifications and independence information for each member.

9.2.7 Quality Assurance Records Management

NUREG-1297 specifies that written

> *"minutes should be prepared of meetings, deliberations, and activities of the peer review process."*

TP 10.5 requires that written minutes, including graphic or calculated materials used in panel meetings, be prepared for meetings, deliberations, daily caucuses, and other activities. These written minutes are maintained as QA records. TP 10.5 also requires that a QA records management system be developed and implemented to ensure that peer review documents are identified, assembled, and transferred on a timely basis and in an orderly manner to the appropriate records center.

9.2.8 Quality Assurance Oversight

Section V of NUREG-1297 states that

> *"As a minimum, the QA organization should provide surveillance of the peer review process to ensure that the procedures conform to the guidance of this GTP and that they are followed by the peer review group."*

The QAPD establishes requirements for implementing the QA program for the WIPP peer review process. The QAPD requires that assessments be conducted to ensure that all aspects of the peer review conform to the guidance of NUREG-1297, TP 10.5, and the CAO QAPD. Audits of the peer review process have been performed in accordance with the requirements of the QAPD. Additional details regarding the WIPP QA program are provided in Chapter 5.0.

9.3 Peer Reviews Conducted After Promulgation of 40 CFR Part 194

Seven peer reviews were performed by the WIPP project to address issues deemed necessary by the CAO. These peer reviews included reviews of conceptual models, waste characterization analysis and an evaluation of the benefits and detriments of potential engineered barriers and alternatives as stated in 40 CFR § 194.27(a); data reviews of engineered systems, waste form and disposal room, and natural barriers as stated in 40 CFR § 194.22(b); and a passive institutional controls review. These peer reviews were conducted subsequent to the promulgation of 40 CFR Part 194 and were conducted in a manner consistent with the NUREG-1297 guidance, as implemented by TP 10.5 and the QAPD.

Specifically, the following peer reviews were conducted:

- an evaluation of the adequacy and reasonableness of the WIPP conceptual models;
- a review of the adequacy and completeness of the waste characterization analysis;
- an assessment of the validity of the assumptions and approach used to select or reject engineered alternatives, as delineated in the EACBS (DOE 1995b) for the WIPP;
- a data qualification review of parameters used to describe engineered systems;
- a data qualification review of parameters used to describe natural barriers;
- a data qualification review of parameters used to describe the waste form and disposal room; and,
- a determination of whether the passive institutional controls have a reasonable expectation of meeting their intended purpose.

These seven reviews are discussed, and the WIPP project response to the peer review panel's comments are provided, in the following sections. The general process used by the CAO to plan and conduct the seven peer reviews is described in Section 9.2. The complete peer review reports are provided in Appendix PEER. The reports were all consensus documents which were signed by all the members of the specific panel involved, that is, there were no dissenting views on any of the final reports for the seven subject reviews.

9.3.1 Conceptual Models Peer Review

40 CFR § 194.23(a)(3)(v) specifies that this application include documentation that the conceptual models have undergone peer review consistent with 40 CFR § 194.27. A Conceptual Model Peer Review (CMPR) Plan (see Appendix PEER) was developed and approved in accordance with the requirements of TP 10.5. The CMPR Plan describes the peer

review process used to ensure that the conceptual models used in the WIPP performance assessment reasonably represent possible future states of the disposal system.

In accordance with the provisions of TP 10.5, a peer review panel was selected and organized. The six-member panel was composed of the following individuals:

Charles R. Wilson (Chairman), Private Consultant
Florie A. Caporuscio, Informatics Corporation
John F. Gibbons II, Private Consultant
Eric B. Oswald, Private Consultant
Darrell D. Porter, Science Applications International Corporation
Glen L. Sjoblom, Private Consultant

Florie A. Caporuscio has a Ph.D. in Geology and has more than 10 years of applied pertinent experience, including having served as the Acting Section Chief, WIPP Technical Review, at EPA Headquarters' Office of Radiation and Indoor Air and as a Staff Geologist at EPA Region II. In addition to Dr. Caporuscio's highly relevant regulatory expertise, his pertinent technical qualifications include extensive expertise in site characterization, geochemistry, radionuclide transport in geological media, and related conceptual models.

John F. Gibbons II has a Ph.D. in Geomechanics and has more than 20 years of relevant experience, including having served as the Technical Director of Applied Research Associates for site characterization technology research and development activities augmented by involvement in numerous site characterizations. Dr. Gibbons' site characterization and technology research and development (R&D) experience is particularly pertinent for peer reviews involving geology, tectonics, hydrology, and related conceptual models.

Eric B. Oswald has a Ph.D. in Hydrology and Water Resources Administration and has more than 25 years of applied pertinent technical and regulatory experience. Dr. Oswald's technical qualifications include extensive surface and groundwater flow system analyses and control, contaminant transport, and related conceptual models.

Darrell D. Porter has a Ph.D. in Mineral Engineering and has more than 34 years of experience in earth sciences programs with emphasis on rock mechanics. Dr. Porter's pertinent technical qualifications include extensive involvement in site characterization, regulatory compliance, quality assurance, and technical review activities in support of deep geologic repository development.

Glen L. Sjoblom has a M.Sc. in Chemical Engineering and has more than 26 years of experience in environmental radiation protection including having served as the Director of Radiation Programs at the EPA during the development and promulgation of 40 CFR Part 191. Mr. Sjoblom's extensive environmental radiation protection experience also includes serving as Special Assistant to the Director of the Office of Inspection and Enforcement and Deputy Director of the Division of Industrial and Regulatory Medical

Nuclear Safety at the NRC. Mr. Sjoblom's pertinent technical qualifications include chemistry, waste characterization, deterministic and stochastic risk and safety analysis, and environmental protection activities in support of deep geologic repository development.

Charles R. Wilson has a Ph.D. in Civil Engineering-Groundwater and has more than 26 years of relevant experience in earth sciences programs. Dr. Wilson's pertinent technical qualifications include lead roles in the geology, hydrology, geochemistry, and geotechnical engineering disciplines on teams involved in site characterization, model development, and modeling of: landfills; water resources; groundwater flow systems; contaminant and radionuclide transport; and nuclear waste repositories in the United States and abroad.

Additional details regarding the technical qualifications and independence of the panel members are provided in the final peer review report (see Appendix PEER). Each panel member's background was carefully reviewed to ensure his strong qualifications, and to verify his independence from other WIPP work, and to confirm the absence of conflicts of interest.

The peer review was conducted from April through August 1996. After orientation and training, the panel was provided draft conceptual model descriptions and other relevant information and was briefed by WIPP project staff. Panel members also had access to the Sandia National Laboratories (SNL) Nuclear Waste Management Program Library and to reports of prior peer reviews.

The objective of the review was to determine the adequacy and reasonableness of 24 conceptual models representing features, events, and processes involved in assessing the long-term performance of WIPP. As stated in the CMPR report:

> *"A conceptual model is a statement of how important features, events, and processes such as fluid flow, chemical processes, or intrusion scenarios are to be represented in performance assessment. To be used in performance assessment, the conceptual model must be successfully translated into analytical statements and mathematical analogs. The Panel reviewed in detail the twenty four conceptual models against criteria of the EPA....The Panel also made an assessment of the information used and whether the conceptual model is adequate for implementation in an overall performance assessment model."*

Per the criteria of 40 CFR Part 194, the peer review was conducted in a manner compatible with the provisions of NUREG-1297. The eight adequacy criteria from NUREG-1297 were used as a basis for review of each model (see Section 9.2.1).

The CMPR Report was issued in July 1996 (a copy of the CMPR Report is provided in Appendix PEER). The panel initially concluded that 13 of the models were adequate for implementation and that the remaining 11 models were not adequate for use in performance assessment. The DOE provided additional information in response to the panel's concerns, and the panel subsequently determined that the responses for six of those 11 models reasonably addressed their concerns. In addition, the panel concluded that some of the responses (multiple concerns were identified for some models) relating to three additional models also reasonably addressed its concerns. Finally, the panel concluded that responses regarding three models did not reasonably address its concerns; however, one of these models was determined to have no consequence to performance assessment. The DOE's justification for using these unresolved models is discussed in the following Sections of this application.

The 24 models reviewed by the panel are listed in Table 9-1. Also provided are the panel's conclusions about the adequacy of the models and whether the panel believed that the DOE's responses reasonably addressed its concerns about those models that it determined to be inadequate.

Section 9.3.1.1 provides a brief description of the panel's discussion on the models it deemed adequate. Section 9.3.1.2 provides a brief description of the panel's discussion on the models deemed inadequate; the DOE's responses to the panel's concerns; the panel's comments on those responses; and the DOE's technical position on those concerns wherein the panel concluded that the responses did not reasonably address its concerns.

9.3.1.1 Adequate Models

The following excerpts are from the CMPR Report. They address those thirteen models that the panel determined to be adequate:

Disposal System Geometry

> *The conceptual model for the disposal system geometry provides a suitable framework for modeling the important processes and their interactions in the disposal system. . .The concept that the spatial effects of processes and interactions can be represented in two dimensions is defensible. The simplification in the system representation and computational method to simulate the two dimensions are defensible and adequate for implementation. The basic grid framework for representing the material properties of the disposal system, adjacent DRZ [disturbed rock zone], geologic formations, and intrusion scenarios is adequate and the proposed use of a finite difference method to connect the nodes and generate flow fields is also defensible and adequate for implementation.*

Salado

> *Given that the conceptual model predicts that there will be enough brine to corrode the waste and that other assumptions appear conservative, making other impacts unlikely, the model is adequate for its intended use. . .The conclusions appear to be valid. Estimates of inflow volumes from the mechanisms proposed in the model appear to be reasonable. . .The model is adequate for implementation.*

Table 9-1. Adequacy of WIPP Conceptual Models

Model	Report Findings	DOE Response Reasonable?
Disposal System Geometry	Adequate	Not Applicable
Culebra Hydrogeology	Not Adequate [1]	Yes
Repository Fluid Flow	Not Adequate	Yes
Salado	Adequate	Not Applicable
Impure Halite	Adequate	Not Applicable
Salado Interbeds	Not Adequate	Yes
DRZ	Adequate	Not Applicable
Actinide Transport in the Salado	Adequate	Not Applicable
Units Above the Salado	Not Adequate [1]	No[1]
Transport of Dissolved Actinides in the Culebra	Adequate	Not Applicable
Transport of Colloidal Actinides in the Culebra	Not Adequate	No
Exploration Boreholes	Not Adequate	Partially[2]
Cuttings and Cavings	Adequate	Not Applicable
Spallings	Not Adequate	Yes
Direct Brine Release	Not Adequate	No
Castile and Brine Reservoir	Not Adequate	Partially[3]
Multiple Intrusions	Adequate	Not Applicable
Climate Change	Adequate	Not Applicable
Creep Closure	Adequate	Not Applicable
Shafts and Shaft Seals	Adequate	Not Applicable
Gas Generation	Not Adequate	Yes
Chemical Conditions	Not Adequate	Partially[4]
Dissolved Actinide Source Term	Adequate	Not Applicable
Colloidal Actinide Source Term	Adequate	Not Applicable

[1] Although the model was found to be inadequate, it was determined to have no consequence to performance assessment.
[2] The panel concluded that responses to three of their four concerns were reasonable.
[3] The panel concluded that responses to two of their three concerns were reasonable.
[4] The panel concluded that responses to two of their three concerns were reasonable.

Impure Halite

Although differences in the behavior of pure and impure halite, variable degrees of impurity, and complexities of stratigraphic distribution of zones of impurity exist, the modeling of all halite rocks in the Salado as impure halite is an acceptable model simplification. . .The model appears to be adequate for the same reasons that the overall Salado model is adequate. Brine inflow sufficient to corrode the waste and to *drive biogenic degradation is assumed. For error to be significant, brine inflow would have to be very large, which is unlikely. . .The conclusions drawn on the basis of the impure halite model are valid for PA purposes.*

Disturbed Rock Zone

All observed considerations of analysis, study, and proposed engineered applications regarding the DRZ and its impacts on effective shaft sealing appear to be valid. The understandings developed of DRZ phenomena and data reveal it is critical to engineering waste containment overall because of its potential for negative impact on shaft seals permeability and integrity and fluid flow in the rooms and their seals. It appears that all considerations of this impact and the conclusions discussed here are sound and valid. . .The panel concludes that the present DRZ model is adequate to be implemented in performance calculations.

Actinide Transport in the Salado

It seems DOE has provided a very rational way to "lump" all the various solubilities of dissolved actinides and to describe how the four main types of colloids will be "lumped" for transport. Both of these source terms have complex properties that could have been negated by the "lumping" factor. . .These two philosophies of solubility "lumping" have been clearly explained for dissolved and colloidal actinide transport. . .by the principal investigator and by this means the implementation was determined to be adequate. . .this model is wholly adequate and reasonable for implementation.

Transport of Dissolved Actinides in the Culebra

It is concluded that a dual porosity model is adequate for dissolved actinide transport analyses if ranges of model parameters are chosen properly in light of uncertainties. . .The conclusion that the actinide transport in the Culebra can be adequately modeled in a dual porosity model, with advective transport in the main flow porosity, diffusion into and physical and chemical retardation in the rock matrix porosity, is valid. . .The conceptual model appears compatible with other models it intersects with directly.

Cuttings/Cavings

This model is fundamentally appropriate. It is based on straightforward analysis, concepts, and technology that is well developed and believed to be adequate for depicting that part of the consequences of a waste room penetration by a borehole drill that is covered by this model....The CUTTINGS_S model contains well thought out and evaluated mathematics based on researched and established fluid flow technology and science. . .This model is sufficiently developed and uncomplicated that *no serious concerns were found. It appears to be capable of accurately representing the waste that might be removed during a drilling intrusion and is fully adequate for implementation in support of the WIPP performance assessment.*

Multiple Intrusions

The conceptual model for multiple intrusions is fundamentally sound and appropriately conservative, given the simplifications that are required to model a complex set of conditions in an efficient manner. . .The application of the conceptual model to the numerical model is adequate, again given the simplifications that are required to model a complex set of conditions in an efficient manner. . .The Multiple Intrusion conceptual model is adequate for implementation in performance assessment.

Climate Change

The climate change conceptual model represents a reasonable and defensible range of potential future climate extremes for incorporation into the performance assessment. The conceptual model includes a range of conditions, bounded by reasonably foreseeable future climates and their effects, that are adequate to represent impacts to groundwater flows in the Culebra Dolomite Member of the Rustler Formation. In addition to providing adequate representation of conditions for implementation, the background research and analysis supporting the formulation of the conceptual model for climate change provides adequate information for satisfying EPA guidance.

Creep Closure

The adequacy of the Creep Closure conceptual model is demonstrated by its predictiveness of room closure in existing WIPP excavations. The uncertainties inherent in the model must be assessed through the sensitivity of the porosity surface calculation. The model appears to be adequately predictive. . .The porosity surface calculation appears to address the complex issues of timing among processes and provides a means of choosing representative parameters for individual process with respect to uncertainty about process results and timing during dynamic process evolution.

Shafts and Shaft Seals

Comments concerning two issues from the preceding section are also applicable to the model's adequacy for implementation: 1) further analysis of the salt compaction data base, firmed up with additional data, is important to support parameter permeability values, and 2) an analysis has not been found to assure the shaft monolith does not create a shear zone at the shaft perimeter interface. Aside from these, the foregoing discussions outline an insightful piece of scientific and engineering work. The shafts *and seals program is well thought through and the areas of perceived concern have been addressed to various degrees of detail, each believed sufficiently adequate to support qualifying this model as adequate to proceed in supporting performance assessment.*

Dissolved Actinide Source Term

The true unknowns are to be found in the assumptions that the chemistry rapidly approaches equilibrium and that the waste has uniform characteristics and inventory. These fundamental assumptions are a basis of the conceptual model and are most probably adequate and reasonable. . .This model has turned out to be a very strong representation of how actinides would dissolve in the two major brines (Salado and Castile) of the repository and is adequate to support performance assessment.

Colloidal Actinide Source Term

Since this model is inexorably linked to the solubility concentrations of the dissolved actinide source term, one may conclude that this model is valid contingent on the validity of the other model (which was determined to be valid, with minor caveats)... The Colloidal Actinide Source Term model is a reasonable, if somewhat overly conservative representation of how actinides would sorb onto colloids in the two major brines (Salado and Castile) available for the repository. This conceptual model is adequate to support performance assessment.

9.3.1.2 Inadequate Models

As indicated above, the CMPR panel initially determined that 11 of the models they reviewed were inadequate. The CMPR panel concerns (Peer Review Panel Concerns - presented in italics below), the DOE interpretation of the panel's concerns (Statement of Issue), the DOE response to the panel's concerns (Response to Issue), and the panel reaction to the interpretation and responses (Peer Reviewer Consideration of Response) are provided below. In those instances in which the panel determined the response did not reasonably address its concerns, the DOE developed additional information regarding its position (DOE Technical Position versus Panel Issue). In some instances, a response addresses more than one concern.

The DOE responses were provided to the panel as individual memoranda. For incorporation into this application, the responses have been edited to remove the memorandum format, consolidate references, replace first-person language, insert cross-references where appropriate, and correct typographical errors. Substantive technical content of the responses has not been changed.

9.3.1.2.1 Peer Review Panel Concerns - Culebra Hydrogeology

> *No conceptual model which explains the variability of hydrologic properties and processes in the Culebra at a scale which is useful in correlating those properties in the numerical hydrologic flow model was developed.*
>
> *An extensive hydrologic testing database and an apparently adequate numerical flow model were developed as a substitute for performance assessment purposes.*
>
> *Although the Culebra conceptual model was found to be inadequate to support numerical modeling, this inadequacy was inconsequential for performance assessment because an extensive hydrologic database was developed and serves as an adequate substitute to support numerical modeling.*

Statement of Issues

The main concern is that a conceptual model that integrates geologic and geochemical data was not developed to help define the distribution of Culebra hydraulic properties for the SECOFL2D calculations. The panel notes that construction of such a conceptual model would require an extensive field and modeling program to characterize geological properties such as fracture distribution, aperture, and orientation as well as patterns of spatial variability of matrix permeability and porosity.

Response to Issues

The CMPR panel noted that although the Culebra Hydrogeology conceptual model was found to be inadequate, this inadequacy is inconsequential for performance assessment. The objective of this response is mainly to clarify a few of the issues discussed by the panel.

The DOE confirms that the main objective of the Culebra field program is to measure hydraulic and transport properties, and that the intent was always to take an empirical approach to delineating the distribution of these properties for performance assessment calculations. The DOE did, however, examine rock cores, outcrops, geophysical logs, and the shaft walls to get information about the geology of the Culebra. One use of this information was to develop a conceptual model of how geologic processes have affected the hydraulic properties of the Rustler Formation, including the Culebra. This conceptual model was not used to condition the Culebra transmissivity field for the performance assessment flow calculations (that is, in the region for which extensive hydraulic data were collected). This conceptual model was used to assign values of hydraulic conductivity in the regional three-dimensional flow model which covers a much larger area. In addition, this conceptual model was used as a basis for understanding retardation of contaminant transport in the Culebra.

The CMPR panel noted that there have been two conceptual models of regional flow, the confined model and the groundwater basin model. The DOE considers these two conceptual models to be complementary. The groundwater basin model represents the DOE's conceptual understanding of the real regional hydrologic system and is used to evaluate long-term changes in patterns of groundwater flow. The confined model is a necessary and appropriate simplification for performance assessment modeling. It provides the capability to perform detailed calculations of flow and transport in the region for which the site characterization has provided an extensive database.

The panel noted that two schools of thought about dissolution of Rustler halite have been presented in the project literature. One school argues that halite in Rustler units has been dissolved in regions beyond the modern-day extent of halite. The second school argues that the modern-day limits of halite represent essentially the original depositional boundaries. These schools represent an evolution of understanding as more information became available. The DOE's position is that the second school (that little dissolution of Rustler halite has occurred in the vicinity of the WIPP) best represents the present understanding. This position is based mainly on detailed mapping of the Rustler in the air intake shaft and the detailed depositional facies model developed by Holt and Powers (1988).

The panel notes that the project has not developed a detailed conceptual model that integrates hydrogeological features, hydrogeochemical facies, and radiogenic ages. DOE agrees with this assessment; however, consideration of these issues has made important contributions to the DOE conceptual understanding of Culebra hydrogeology. For example, the concept that groundwater flow is still adjusting to a drying of the climate at the end of the Pleistocene originated in analysis of chemical and isotopic data.

<u>Peer Reviewer Consideration of Response</u>

The DOE understood the issues and provided a reasonable response.

9.3.1.2.2 <u>Peer Review Panel Concerns - Repository Fluid Flow</u>

9.3.1.2.2.1 First Peer Review Panel Concern

> *The conceptual model and its two-dimensional numerical implementation may unrealistically restrict brine movement within the repository to the anhydrite interbeds because of the shallow depths of the borehole and shaft model cells. These restrictions could result in underestimating brine migration in the interbeds toward the accessible environment.*

<u>Statement of Issue</u>

The language "shallow depths" in the above concern is misleading. The concern is that the geometry of the finite difference grid blocks about the borehole and shaft represents the lateral or areal cross-sectional area of these units. This is an appropriate grid geometry if the flow is convergent on these units. For the undisturbed case, the flow is never convergent on the borehole. The shaft seal system is very effective in preventing fluid flow up the shaft; consequently, fluid flow is not generally convergent on the shaft area. These regions will present very small normal areas to flow in the lateral direction. For example, in an intrusion scenario, when flow is convergent on the borehole, the supporting flow from the north end of the repository and formations north of the shaft will experience a flow restriction due to the geometry about the shaft. This could restrict brine inflow to the repository region.

Response to Issue

The recommended screening decision for the FEP screening analysis S1: Verification of 2D-Radial Flaring Using 3D geometry, Sandia WIPP Central Files (SWCF)-A: 1.2.07.3: PA: QA: TSK:S1 states the following:

Comparison of outputs of calculations of the simplified two-dimensional (2-D) WIPP performance assessment grid and a corresponding three-dimensional (3-D) grid, based on the selected input data, showed that results were equivalent for the most part. Although the 3-D grid showed flow details which were not accurately represented with the 2-D grid, the computed releases to the accessible environment for both grids were nearly equivalent. This indicates that, based on the performance measures and the overall uncertainty, the current model being used for WIPP performance assessment is sufficient for estimates of calculated releases. Calculations using the 2-D grid are more computationally efficient, which is necessary for the large number of vectors.

The issue raised by the peer review panel is addressed by the FEP S1 calculation as discussed above. The FEP S1 calculation included both the shaft and a borehole in the geometry, and considered an intrusion at 1,000 years. As stated above, the computed releases to the accessible environment for the 2-D and 3-D grids were nearly equivalent. If the geometry affects flow enough to significantly change releases to the accessible environment, it would be reasonable to expect that the effect would have occurred in the FEP S1 calculation. Since no such effect was observed, it is reasonable to conclude that the effects of the geometry do not significantly impact releases to the accessible environment.

Peer Reviewer Consideration of Response

The DOE understood the issue and the response reasonably addressed the panel's concern.

9.3.1.2.2.2 Second Peer Review Panel Concern - Repository Fluid Flow

> *The conceptual model and its two-dimensional numerical implementation do not include the presence of the unplugged ERDA-9 borehole within the walls of the operations area. This borehole could provide a pathway for gas and possibly brine to the ground surface, and no description of the plugging plan for this hole was seen in the documentation provided by the Panel.*

Statement of Issue

The panel is concerned about two items: a) the potential for unplugged boreholes close to the repository acting as pathways for fluids to escape, and b) the lack of any plans to plug these boreholes.

Response to Issue

The panel's concern presumably arises because they were not aware of the project plans for borehole plugging. In fact, the project does plan to plug these boreholes using a continuous plug through the Salado. Such plugging has been evaluated by Thompson et al. (1996).

The plugging plans are addressed in Section 3.3.4 of this application, entitled Borehole Plugs. Section 3.3.4 states:

"Deep unplugged boreholes within the Land Withdrawal Area, shown in Figure 3-9 as WIPP 13, WIPP 12, U.S. Energy Research and Development Administration (ERDA) 9, and DOE 1, will be plugged according to the state of New Mexico, Oil Conservation Division, Order R-111-P. The governing regulations for plugging and/or abandonment of boreholes are summarized in Table 3-2. These solid cement plugs will go through the salt section and any water-bearing horizon to prevent liquids or gases from entering the hole above or below the salt section. The boreholes not being used for monitoring will be plugged at decommissioning. Figure 3-10 depicts a typical deep borehole plugged to the requirements of Order R-111-P."

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.2.3 Third Peer Review Panel Concern - Repository Fluid Flow

> *The sensitivity of model results to the selection of constant permeability values for the waste, panel seals, and repository DRZ has not been evaluated for the current performance assessment. Early time permeabilities may be significantly greater than the model parameter for each of these media, and could lead to underestimation of radionuclide releases.*

Statement of Issue

Consolidation of the waste, panel seals, and repository disturbed rock zone (DRZ) over time would result in lower permeabilities for these regions. How sensitive are the simulation results to the time-dependent nature of permeability within these regions?

Response to Issue

A distinct response is given for each material region.

Response for waste: The effect of dynamic permeability of the waste on system performance has been studied through calculation of preliminary conditional complementary cumulative distribution functions (CCDFs). The recommended screening decision for the FEP screening analysis DR-7: Permeability Varying With Porosity in Closure Regions, SWCF-A: 1.1.6.3:PA:QA:TSK: DR-7 states the following:

Based on the CCDFs, the inclusion of dynamic permeability with closure of the waste region, north-end, and hallways in BRAGFLO results in computed releases to the accessible environment that are essentially equivalent to the baseline case. In addition, dynamic permeability has an insignificant effect on waste room conditions relevant to releases due to blowout, cuttings, and spalling. As a result, the baseline model is conservative in its treatment of closure and dynamic permeability can be eliminated from consideration in the baseline performance assessment model.

Response for DRZ: The effect of dynamic permeability of the DRZ on system performance has been studied through calculation of preliminary conditional CCDFs. The recommended screening decision for the FEP screening analysis S-6: Dynamic Alteration of the DRZ/transition zone (TZ), SWCF-A: 1.1.6.3:PA:QA:TSK: S-6 states the following:

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

Response for panel seals: Because of the high permeability within the panel seals (10^{-15} square meters) the long-term flow should not be sensitive to variants in the seal permeability. The permeability of the panels is set to the same value as the surrounding DRZ. If the panel seal permeability is tighter, then flow between the waste regions will be diverted from the seals through the lower permeability DRZ. The resulting communication between waste regions should be similar. The flow via the panel seals is quantified by considering the compliance certification application run with the highest flow through the panel seal between the intruded panel and the rest of the repository. This was run R1_S3_V25 (replicate 1, scenario 3 (E1 intrusion at 1,000 years), run or vector 25). This run was repeated with a panel seal permeability of 10^{-17} square meters. Figure 9-1 shows a maximum cumulative brine flux across the three grid blocks representing the panel seal of approximately 180 cubic meter. The panel seal volume of 1,584 cubic meters and porosity 0.05 results in a panel seal pore volume of 79 cubic meters. The brine flux across the panel seal is approximately 3 panel seal pore volumes over the 10,000 years. This brine flux is not considered to be enough to degrade the emplaced concrete plugs. This is consistent with the logic describing the behavior of the borehole plugs. Therefore, by using 10^{-15} square meters permeability for the panel seals, more communication among panels is being allowed, which will result in overestimating the amount of waste contacted by the brine.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.2.4 Fourth Peer Review Panel Concern - Repository Fluid Flow

> *The long-term performance of the panel closure seals has not been subjected to a detailed engineering evaluation of the type performed for the shaft seal. The role of the panel seals in restricting brine flow among the waste panels and into other parts of the repository is an important element of the conceptual model and its implementation in performance assessment.*

Statement of Issue

The panel is concerned about the lack of supporting evaluations presented to them for the panel seal permeability assumption of 10^{-15} square meters.

Response to Issue

The long-term panel seal response has now been evaluated, and is documented in a 1996 memorandum by Thompson and Hansen (a complete copy of the Thompson and Hansen memorandum is provided in Appendix PEER, Section PEER.2). Basically, this memorandum argues that:

1. The panel closures include a 29 foot length of concrete. This will have an initial permeability of at least 10^{-17} square meters.

2. Flow through panel closures will be almost exclusively through the DRZ, which is assumed to have a permeability of 10^{-15} square meters, by-passing the seals due to their much lower permeability.

3. Given maximum calculated cumulative brine flow, flow through seals will be of the order of 1 - 2 pore volumes.

4. Significant degradation of the concrete of the seals will require more than 100 pore volumes, so degradation is not expected.

5. Flow along interface with salt may (at most) extend the DRZ by the order of millimeters. This will be taken up by much faster salt creep.

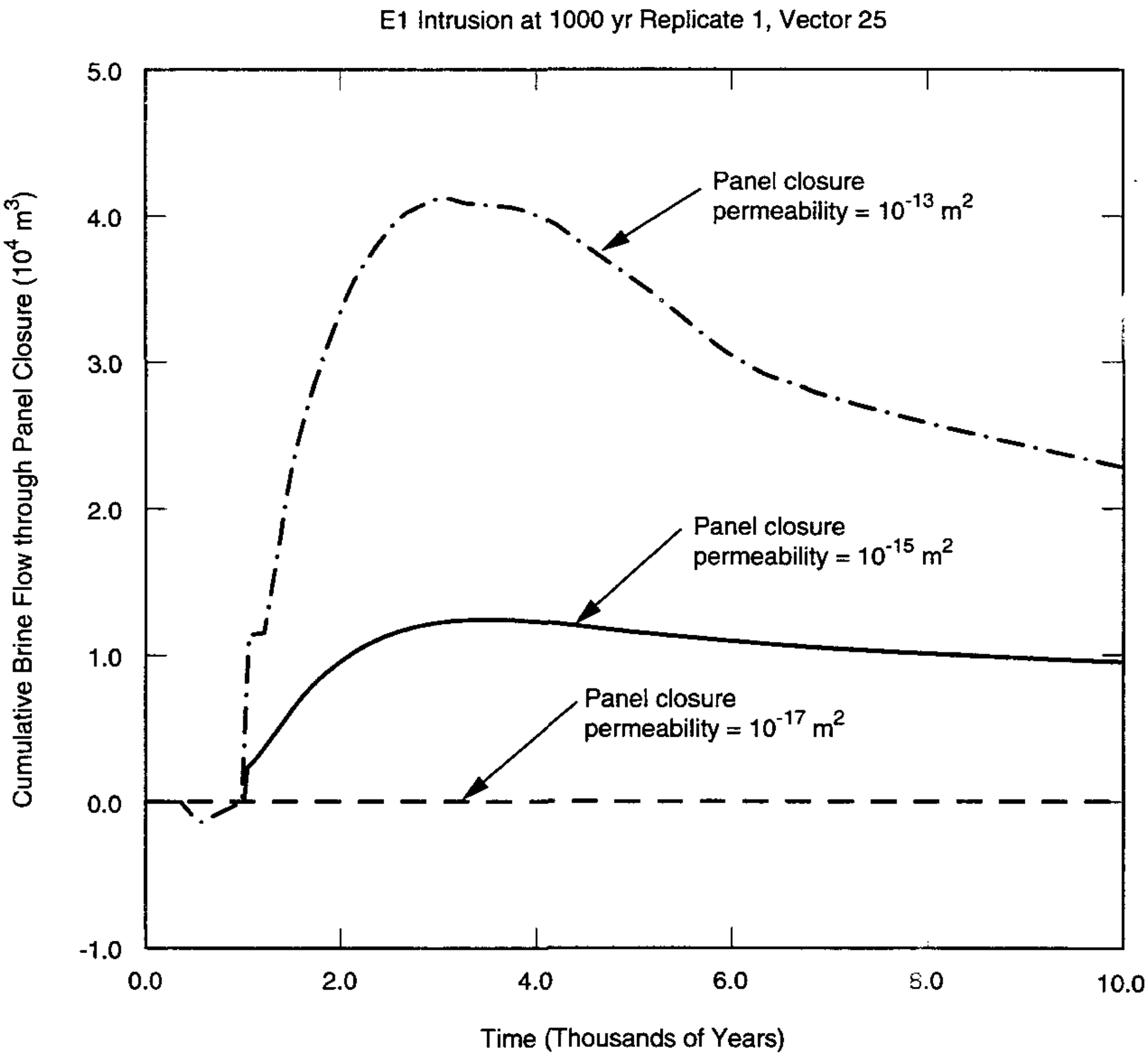

Figure 9-1. Cumulative Brine Flow through the Panel Closure between the Intruded Panel and the Rest of the Repository for Permeabilities of 10^{-15} to 10^{-17} m^2

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Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.3 Peer Review Panel Concern - Salado Interbeds

The conceptual model does not consider how the physical properties of the bounding clay seams affect model fracture propagation and permeability. Ignoring the characteristics of the clay seams may significantly overestimate the threshold pressure at which repository gases may be released.

Statement of Issue

The CMPR report (Section 3.6.2.2, Validity of Model Assumptions) listed three assumptions of the interbed model that the panel felt had not been well documented. These were: (1) the description of the mechanism of vertical crack propagation; (2) no incorporation of continuous clay seams at the base of Marker Bed (MB) 138 and MB139; and (3) the fluid storage capacity of the interbeds. The report (Section 3.6.2.3, Evaluation of Alternatives) noted two items that did not appear to have been addressed: 1) "Is storage capacity of the anhydrite layers so small that brines would be forced to travel to the land withdrawal area boundary?" and 2) "What would the consequence be if the gas threshold pressure of the clay seams were very low (for example, 0.01 MPa)?" The report states (Section 3.6.2.6, Adequacy of Application): "At no time was the logic clearly presented whereby one could track the implementation of this conceptual model into the numerical code developed for this portion of BRAGFLO. Therefore, one must state that the discussion of how the anhydrite interbed conceptual model is applied into an overall performance modeling element was not adequate." The report (Section 3.6.2.7, Accuracy of Results) further states: "The implementation of the fracture modeling was not explained in sufficient detail in any document. The method of how the code represents the physical property is unknown and one can not judge its accuracy."

These concerns were reiterated in Section 3.6.2.9, Adequacy of Implementation, of the report, in which the panel asked for clarification of six points. These points are listed and addressed below. The panel also asked that the following question be addressed: "How do the physical properties of clay seams at the contact of the interbeds affect the fracture propagation and permeability of the model?"

Response to Issue

The clay seams would probably act as preexisting planes of weakness, helping to keep fracturing horizontal and confined to the interbeds. The expression used to calculate fracture permeability is not specific to anhydrite, and can be used equally well to calculate the permeability of fractured clay seams. In terms of threshold pressure, it should be noted that the field in situ threshold pressure tests were conducted with the clay seams contained within the test zones. Therefore, the interpreted threshold pressures are representative of the combined anhydrite and clay units. The same is true for the in situ permeability tests — the clay seams were included in the test zones with the anhydrite beds during testing.

1. What is the mechanism for vertical crack propagation?

Fractures will propagate vertically if the least compressive stress is horizontal rather than vertical; that is, if the horizontal stress is less than the lithostatic load. Hydrofracture experiments conducted in MB139 and MB140 suggest that horizontal stresses may be slightly less than vertical stress in anhydrite interbeds. Thus, while subhorizontal partings and clay seams within the interbeds, which act as preexisting planes of weakness, may provide preferred fracture "guides", the potential also exists for the creation of vertical fractures providing local connections between horizontal fractures. Hydraulic fracturing experiments conducted in halite, in contrast, indicate isotropic stress conditions in the far-field with no preferred fracture orientation (Wawersik and Stone 1989).

2. What is [the] fluid storage capacity of the interbeds after dilation?

The full dilation of the interbeds for the performance assessment simulations would result in porosity changes as follows:

porosity at initial conditions = 0.011
porosity at full fracture pressure = 0.05 (MB138 and MB139)
porosity at full fracture pressure = 0.25 (MB a+b)

The potential storage is enhanced by

(0.05-0.011)/0.011 = 350 percent (MB138 and MB139)
(0.25-0.011)/0.011 = 2170 percent (MB a+b)

In order to realize these changes in storage, the pressure within the MB would have to reach full fracture pressure of 16.5 megapascals. These values are bounding in the sense that they represent end points on the mathematical functions. Simulation values would not be expected to reach these limiting values.

3. Enhanced porosity and permeability are presumed to mitigate each other in terms of gas migration responses. How can this happen when permeability is a power function (not linear) of porosity?

Both permeability and porosity increase with pressure. As pressure builds up in the MBs, the permeability effect will increase the fluid mobility. The higher gas mobility will move the gas further from the repository (in the direction of negative pressure gradient). The increase in porosity will provide more storage for the gas with resulting lower gas pressures and shorter gas migration distances. The DOE does not mean to imply that the two effects are essentially equivalent and completely counteract each other. The quantitative difference between the two effects is determined by the specific fracture parameters used in the model.

4. What assumptions and limitations are made to represent the conceptual model by the mathematical code?

BRAGFLO allows for pressure-induced alterations to porosity by introducing a pressure-dependent pore compressibility. Pore compressibility is defined as the relative rate of change of porosity with respect to pressure:

$$c_f = \frac{1}{\phi}\frac{d\phi}{dp}$$

where:

c_f = pore compressibility [Pa^{-1}]
ϕ = porosity [-]
p = pressure [Pa]

For constant compressibility, porosity can be expressed as a function of pressure:

$$\phi = \phi_0 \exp\left[c_f(p-p_0)\right]$$

where:

ϕ_0 = porosity at reference pressure p_0

Below an initiation pressure, p_i, the compressibility is a constant intact value, C_i. For pressures above p_i, the compressibility increases linearly to a fully altered value, C_a, at the fully altered pressure, p_a. The porosity is then computed from the compressibility equation. For $p \le p_i$, the porosity is as given above. For $p_i < p \le p_a$:

$$\phi = \phi_0 \exp\left[C_i(p-p_0) + \frac{(C_a - C_i)(p - p_i)^2}{2(p_a - p_i)}\right]$$

and for $p > p_a$:

$$\phi = \phi_a$$

BRAGFLO is assigned values for p_i and p_a and the porosity at fully altered conditions, ϕ_a. From this information, the fully altered compressibility, C_a, is determined as:

$$C_a = C_i\left[1-2\frac{(P_a-P_o)}{P_a-P_i}\right] + \frac{2}{(P_a-P_i)} \ln\left(\frac{\phi_a}{\phi_o}\right) .$$

The fracture treatment further allows for changes in the fracture material permeability. The often-used parallel plate analogy for flow in fractured rock suggests the form:

$$\frac{k}{k_i} = \left[\frac{\phi}{\phi_i}\right]^n$$

where:

k = permeability of altered material
k_i = permeability of intact material
ϕ = porosity of altered material
ϕ_i = porosity of intact material at p_i
n = empirical parameter

The input data parameters that control the anhydrite fracturing were chosen deterministically so as to produce the appropriate pressure response as predicted by the linear elastic fracture mechanics model. Because the anhydrites have been found to have preexisting fractures that might easily be dilated, the pressure at which porosity and permeability changes are initiated is very close to the initial pressure within the anhydrite. The fracture initiation pressure (p_i) is assigned a value of 0.2 megapascals above the initial far-field brine pressure of 12.5 megapascals. The full fracture pressure (p_a) is specified to be 16.5 megapascals. A permeability of 10^{-9} square meters is given at full fracture conditions. The only parameter that is not uniform over the three modeled MBs is the full fracture porosity. The full fracture porosity in anhydrite a and b is 0.25, while in MB138 and MB139 the full fracture porosity is 0.05. From this information, the exponent, n, in the permeability formula is determined for the different MBs. Results from the performance assessment calculations using these parameters show that simulated repository pressures do not exceed the full fracture pressure of approximately 16.5 megapascals, a value slightly higher than lithostatic pressure.

5. Why is the full fracture porosity increment of 25 percent for anhydrite a and b so different from the 5 percent for MB138 and MB139?

Fracture dilation is assumed to be confined to a 10-centimeter thickness regardless of the thickness of the MB. Therefore, because 10 cm is a greater proportion of the total thickness of anhydrite a and b than of MB138 or MB139, the full fracture porosity increment is also greater. The Larson (1996) memorandum (see Appendix PEER, Section PEER.2) describes the expected fracture response for the MBs. The Lord (1996) memorandum (see Appendix PEER, Section PEER.2) describes the numerical study used to determine the fracture parameters that honor the desired fracture response.

6. What are the calculations that show that permeability increases by 10 orders of magnitude?

As suggested in Larson (1996; Appendix PEER), the full fracture permeability is used as a fitting parameter (end point on the curve) so that the appropriate response is obtained. A ten order of magnitude increase in permeability is unlikely to ever be achieved in the model.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.4 Peer Review Panel Concerns - Units Above the Salado

> *The conceptual models and the testing database are inadequate to exclude the Dewey Lakes Redbeds and the Magenta Dolomites as potential transport pathways for radionuclides in the event of an intrusion.*
>
> *The analysis of brine flow in the intrusion scenarios limits the quantity of radionuclides reaching the region above the Culebra to such small amounts that transport in the Dewey Lakes and Magenta have negligible consequences.*
>
> *The Units Above the Salado conceptual model was found to be inadequate to support the assumption that the Culebra is the only horizon above the Salado capable of significant radionuclide transport. This inadequacy was inconsequential for performance assessment because of modeling results indicating that long-term fluid flow in exploration boreholes above the Culebra was negligible because of relatively high permeability and low pressure in the Culebra.*

Statement of Issue

None Provided

Response to Issues

Hydraulic testing of the Magenta has been performed at 16 locations, 10 of which are either on the WIPP site or within 700 feet of the site boundary. At four of these locations, DOE-2, H-3, H-6, and H-19, the Culebra has been found to be fractured and have a high transmissivity, whereas the Magenta has not. The Magenta has not been found to have a transmissivity greater than 0.3 square feet per day (3.0E-7 square meters per second) anywhere on the WIPP site. In addition to the locations where the Magenta has been tested, Magenta core has been recovered from six other locations on or near the WIPP site, B-25, H-11, H-15, WIPP-12, and WIPP-34. Magenta core recovery is typically 100 percent. The Magenta has also been examined in shaft exposures at the WIPP site. The only location on the WIPP site at which open fractures have been observed in the Magenta is WIPP-13. Filled fractures are only rarely observed at other locations. Based on the combined hydraulic test results and core and shaft observations, the DOE is confident that the Magenta can be realistically modeled as a low transmissivity porous medium.

The test data support permeabilities within the Culebra significantly higher than the Magenta and Dewey Lake (2 to 3 orders of magnitude). This is due primarily to the fracture structure of the Culebra. Also, the Culebra is under pressured with respect to the Magenta and Dewey Lake. Therefore, any cross flow between the units will occur from the Magenta and Dewey Lake to the Culebra. As an example of the performance of the model on brine flow as communicated between the borehole and the upper units, the E1 (intrusion into the Castile brine reservoir) run with the highest borehole release was considered (replicate 1, scenario 2, run 23). For this run, the brine flow at the top of the Salado through the borehole was of the order 50,000 cubic meters, while the brine flow to the Culebra from all units above the Culebra was of the order 270,000 cubic meters. Further, it has been demonstrated from the NUTS that no nuclide transport occurs to any units above the Culebra.

The nonexistence of nuclide transport above the Culebra was demonstrated by the performance assessment simulations. Figure 9-2 shows the cumulative nuclide flux (in EPA units) up the borehole at a location above the Culebra and immediately below the Magenta. The figure includes all 100 NUTS runs from the first replicate of the E1 scenario. The E1 scenario is expected to have the highest borehole releases. This figure shows that the transport above the Culebra is zero uniformly over all 100 vectors

Peer Reviewer Consideration of Response

The DOE understood the issues; however, the panel concluded that the response did not reasonably address its concerns. The panel noted, however, that the inadequacy of the model is of no consequence to the performance assessment.

DOE Technical Position versus Panel Issues

As pointed out in the initial response, "Hydraulic testing of the Magenta has been performed at 16 locations, 10 of which are either on the WIPP site or within 700 feet of the site boundary. At four of these locations, DOE-2, H-3, H-6, and H-19, the Culebra has been found to be fractured and have a high transmissivity, whereas the Magenta has not. The Magenta has not been found to have a transmissivity greater than 0.3 square feet per day (3.0E-7 square meters per second) anywhere on the WIPP site."

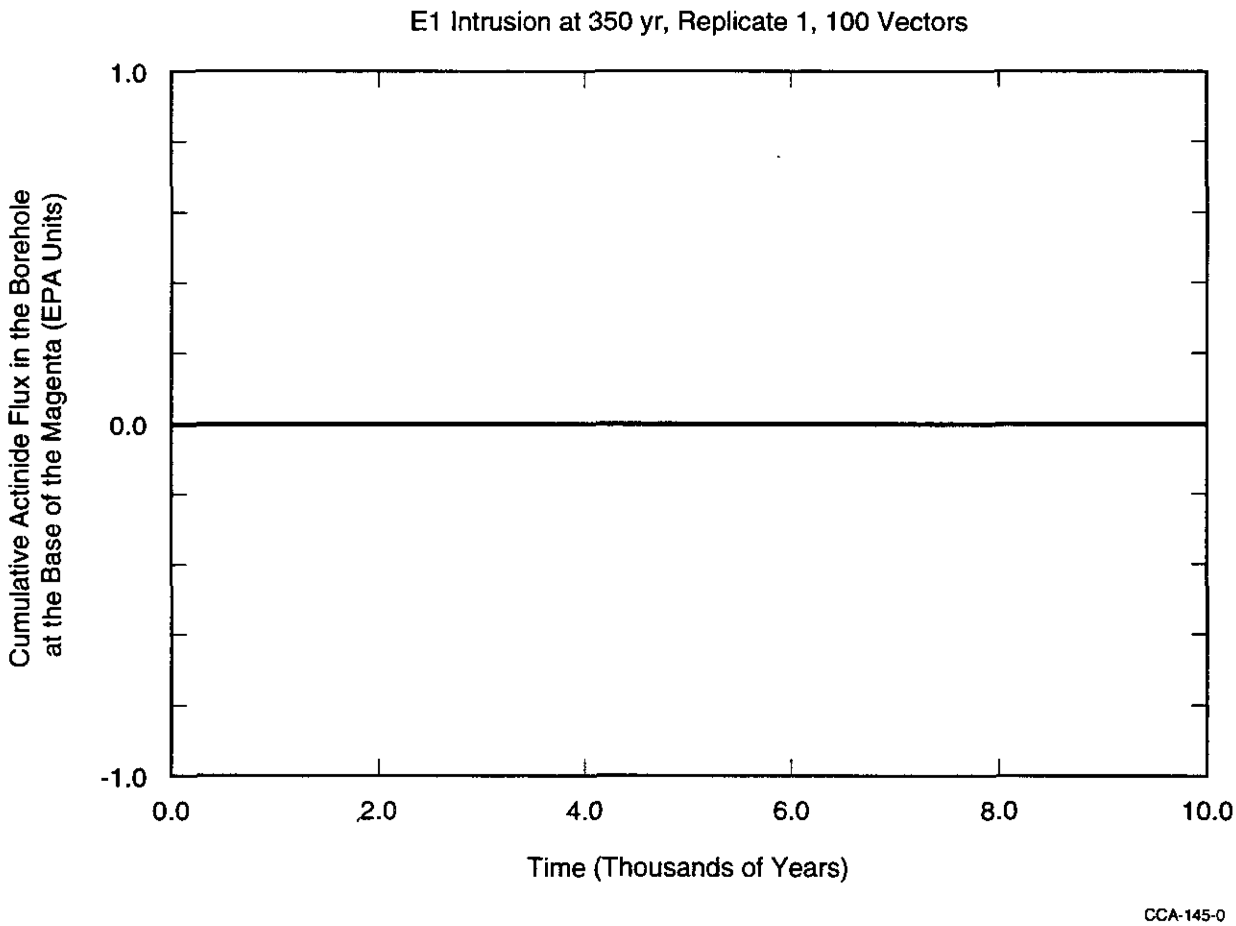

Figure 9-2. Actinide Transport to the Magenta, E1 Intrusion

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No reasonable amount of testing can "exclude the presence of fractured zones of high permeability similar to those in the Culebra." However, "based on the combined hydraulic test results and core and shaft observations, the DOE is confident that the Magenta can be realistically modeled as a low transmissivity porous medium."

In addition, as pointed out in the initial response, "The non-existence of nuclide transport above the Culebra was demonstrated by the performance assessment simulations." Therefore, as pointed out in the peer review comments, there are no performance assessment consequences to possible errors in the characterization of the Magenta or Dewey Lake.

9.3.1.2.5 <u>Peer Review Panel Concerns - Transport of Colloidal Actinides in the Culebra</u>

9.3.1.2.5.1 First Peer Review Panel Concern

> *The conceptual model does not adequately support the assumption that dissolved actinides will not interact with Culebra colloids. Ignoring this phenomenon could overestimate the travel time calculated for radionuclides to reach the accessible environment.*

<u>Statement of Issue</u>

The understanding of the panel appears to be that calculations addressing the transport of waste through the Culebra do not address the potential for waste mobilized in the repository to become sorbed onto colloids indigenous to the Culebra, and continue transport in the Culebra as a colloidal particle. Because transporting colloids may not experience as much chemical attenuation as is exerted by the Culebra minerals on dissolved materials, releases calculated in the CCDF may under-report actual releases.

<u>Response to Issue</u>

Four types of colloids have been identified and considered by the WIPP program. These colloids all fall within the traditional particle size definition of colloids. They have been distinguished based on their mode of production. The types are: (1) mineral fragments, (2) humics, (3) actinide intrinsics, and (4) microbial hosts. Formation and transport of waste by colloids generated in the Culebra was originally planned to be conducted using SECOTP2D. Experiments have shown that it is not necessary to calculate an explicit contribution to the release term from this transport mechanism. Actinides are not indigenous to the Culebra, so that type may be eliminated. Mineral fragments have been demonstrated to be unstable in WIPP brines. Mineral fragments present will agglomerate and settle out due to gravity. Humics and microbial hosts may persist in the Culebra, but column experiments containing crushed Culebra have shown that these colloids are effectively filtered out of the flow stream. As a result, colloidal transport in the Culebra will not contribute meaningfully to the CCDF and requires no explicit model.

Peer Reviewer Consideration of Response

The DOE understood the issue; however, the panel concluded that the response did not reasonably address its concern.

DOE Technical Position versus Panel Issue

Two concerns were raised in this issue:

(1) The DOE's understanding of the CMPR panel's concern was that the project has demonstrated that mineral fragment colloids are destabilized in Castile and Salado environments, but the project has not evaluated the stability behavior of mineral fragment colloids in the Culebra. Specifically, the panel would like to understand how the experiments conducted apply to the geochemical conditions of the Culebra.

(2) Transport experiments with crushed-rock columns are not acceptable because when the rock is crushed, new mineral surfaces are exposed. Powder X-ray diffraction analysis to quantify clay mineral concentration has a minimum detection limit of 2 weight percent; changes in the rock composition due to crushing the rock may not be discernible.

The DOE positions on these concerns are as follows:

(1) The kinetic stability screening experiments were conducted with several WIPP-relevant brine simulants: Culebra H-17 brine simulant consisting primarily of NaCl, with an ionic strength of about 3 molal; a Salado-like brine simulant, consisting of NaCl but containing a significant concentration of Mg, with an ionic strength of about 8 molal; and NaCl solutions, ranging in concentration up to 5 molar. The screening experiments to verify the critical coagulation concentrations of the colloidal dispersion were conducted with sequential order-of-magnitude dilutions. Typically, the colloidal dispersions were destabilized at dilutions of 10^3 or 10^4. Because the experiments involved sequential dilutions, the question of which brine was used is not important. The main point is that mineral fragment colloids are destabilized by even very small concentrations of monovalent and particularly divalent cations. All groundwaters associated with the WIPP (that is, Castile Formation, Salado Formation, and Rustler Formation groundwaters within the land withdrawal area) have several orders-of-magnitude greater concentrations of cations than that required to destabilize mineral fragment colloids.

(2) The crushed-rock column flow experiments were used to determine physical retardation of colloidal particles (humic substances, mineral fragment colloids, and microbes). In the case of mineral colloids and microbes, some chemical retardation was observed, but was disregarded in development of performance assessment parameter values. The main phenomena causing physical retardation were entrapment of colloidal particles at pore throats smaller than the particles and bridging at pore throats larger than the size of individual particles. Crushed-rock column flow experiments were used to quantify the filtration term (γ), not a retardation term

(R). The presence of clay minerals in the rock is not a critical issue in these experiments, because colloid-rock interaction was physical rather than chemical.

9.3.1.2.5.2 Second Peer Review Panel Concern - Transport of Colloidal Actinides in the Culebra

The experimental K_Ds determined for this model are not fully defensible. Such values may overestimate the retardation of actinides in the Culebra.

Statement of Issue

The understanding of the panel appears to be that the distribution coefficients (K_d) used by performance assessment for colloidal transport in the Culebra is the same as that used for dissolved materials. (In fact, only humic K_ds are assigned the same values.) The basis for the identical K_ds is the result obtained from sorption competition experiments conducted using the batch method. In competition experiments, dissolved material is exposed to a known sorbent, that is, dolomite and allowed to "equilibrate." A competing material (for example, a colloid) is then added to the equilibrated batch, and the change in dispersion composition is monitored. Highly sorptive colloids might be expected to increase the apparent concentration of actinides in the liquid by competing effectively with the substrate material, and essentially shifting the actinide distribution from the immobile dolomite to the mobile dispersion (solution plus colloids). The interaction of dissolved material with two different substrates (for example, a dolomite substrate versus a colloidal particle) is normally expected to produce different results. The anticipated complexing behavior of actinides with humics (under certain conditions) might reflect a strong chemical affinity between the two substances and in turn be reflected in preferential partitioning of actinides toward humic colloids. Without additional explanation, the reliability of the experimental results and the conservatism of associated calculations are questioned.

Response to Issue

Three sets of K_d partitioning experiments were conducted in support of the WIPP Colloid Research Program:

(1) Actinide uptake experiments were conducted to determine bioaccumulation of Th, U, Np, Pu, and Am by microbes (BNL, Los Alamos National Laboratory [LANL]);

(2) Complexation experiments were conducted with U and Am on humic substances (Florida State University); and

(3) Batch competition experiments were conducted with Th, U, Np, Pu, and Am with crushed Culebra rock in the presence and absence of humic substances (LANL).

Those experiments provided part of the basis for determining the extent of interactions between humic actinides and microbial actinides in the Culebra. Flow experiments with crushed rock and intact cores, as well as information in published literature, provided critical complementary information. The following paragraphs elaborate on concerns regarding how retardation parameters were developed for humic substances and microbes.

The purpose of the batch competition experiments with humic substances (3) was to determine whether the presence of humic substances decide K_d values. The batch K_d values measured in the presence of humic substances were, within experimental and analytical error, identical to values measured in the absence of humic substances. The most reasonable explanation is that at the pH value of the dolomite-mediated system (nominally 7.5 under WIPP-relevant pCO_2 conditions), humic substances do not effectively complex with actinides, probably because the actinide ions have undergone hydrolysis reactions and the reactive ligands on the humic substances are not sufficiently strong to compete with the hydrolysis reactions. Intact core column flow tests were used to confirm the results of the humic batch competition experiments.

It is important to note that the results of the batch competition experiments (3) suggest that the mobile humic actinide source term is probably overly conservative. As described in Appendix SOTERM the humic-actinide complexation experiments (2) were conducted under conditions leading to optimal uptake of U and Am by humics, because when those experiments were conducted, the anticipated pH of the repository spanned a wide range (Papenguth and Behl 1996, Figure 5). The addition of MgO backfill now constrains pH in the repository to about 9.3. Unfortunately, whereas it is generally accepted that actinide complexation by humics will decrease as conditions change from acidic to basic (for example, pH 9.3), no strong experimental or literature basis could be developed to predict humic actinide concentrations under the more basic pH conditions. The humic actinide source term, therefore, reflects complexation which would be expected at much more acidic conditions, and is probably quite conservative.

The CMPR report (Section 3.11) raised a concern about the lack of addition of nutrients in the microbe experiments and also actinide reduction. Note that no batch competition experiments, involving microbes, rock, and dissolved actinides, were conducted with microbes. In the microbial bioaccumulation experiments (1) that were conducted, phosphate was added as a nutrient. During each experiment, microbe population was initially low, and then increased through early to late log phase, and stationary phase (steady state population). In other words, microbes were cultured in the presence of actinides, a condition which most closely simulates what would occur at the WIPP. Proportionality constants (like K_d, but not thermodynamically based) to describe the mobile microbial actinide source term were determined at stationary phase conditions, resulting in the highest (and most conservative) value. Microbial-mediated reduction of actinides may have occurred in those experiments. However, in the experiments, the concentrations of dissolved actinides and bioaccumulated actinides were measured from filtrates and filter retentates collected at the same point in time. A decrease in actinide concentration due to reduction would be reflected in that measurement.

Peer Reviewer Consideration of Response

The DOE understood the issue; however, the panel concluded that the response did not reasonably address their concern.

DOE Technical Position versus Panel Issue

The panel was concerned with the following:

Crushed-rock column experiments were equilibrated with dissolved actinides, followed by introduction of humic substances to the column. Quantitative results would not be achieved using that technique because of kinetic inhibition of humics stripping sorbed actinides from the crushed rock. Because of the sequence of additions, time was allowed for hydrolysis of dissolved actinides to occur. The hydrolyzed actinides would have a decreased affinity for humics. Experiments with crushed dolomite are not acceptable because clay minerals would be exposed during the crushing process. Those exposed clay minerals would sorb dissolved actinides strongly, thereby reducing the potential uptake of dissolved actinides by humic substances.

The DOE position regarding that concern is as follows:

Crushed-rock column flow experiments were not conducted with actinides. In the batch sorption experiments with crushed rock, the rock was not preequilibrated with dissolved actinides. The following tests were conducted:

- complexation experiments with dissolved actinides and humic substances;

- batch sorption experiments in which humic substances and dissolved actinides were added to crushed rock equilibrated with brine;

- crushed-rock column flow tests conducted with humic substances and crushed rock, in the absence of dissolved actinides;

- intact-core column flow experiments in which Pu and Am were injected as a spike followed by elution of a large amount of humic substances and in which U and humic substances were injected simultaneously as a long step.

Regarding the panel's apparent concern on the sequences of additions, the batch sorption experiments were equilibrium experiments. Reactions such as hydrolysis, dissolved actinide sorption, and humic-actinide complexation may have different rates, but only one equilibrium can be reached in the system; the sequence of additions is inconsequential. Also, the duration of the static experiments is short relative to the time available for water-rock interactions in the Culebra transport path. Even more time would be allowed for hydrolysis reactions (which are essentially instantaneous anyway) in the actual transport situation.

Regarding the possible production of clay minerals during the crushing procedure, the microcrystalline nature of the Culebra inhibits that concentration process. Most of the surfaces in crushed rock particles are pristine because of the microcrystalline nature of the Culebra. The individual grains in the Culebra are on the order of 2 microns in size. The crushed particles are several hundred microns in diameter. Consequently, in a crushed rock particle, the total surface area is dominated by interparticle surface area, not the newly formed intraparticle surface area. In addition, the rock used was relatively poor in clay mineral concentration compared to other portions of the Culebra.

9.3.1.2.5.3 Third Peer Review Panel Concern - Transport of Colloidal Actinides in the Culebra

> *Recent experimental work to support assumptions and data for this model has not yet been published and were not available for Panel review.*

Statement of Issue

The panel would have benefited from having a referencable document during development of their positions, instead of having to rely on limited verbal discussion.

Response to Issue

Information provided to the peer review was cut off effective June 7, 1996. The referenced information referred to in the peer review was under development at the time of the review and was verbally provided to the panel. It has subsequently been documented and corroborates the verbal presentations made to the panel.

Peer Reviewer Consideration of Response

Insofar as this issue was not based on a technical issue, the panel was not requested to review the response.

9.3.1.2.6 Peer Review Panel Concern - Exploration Boreholes

9.3.1.2.6.1 First Peer Review Panel Concern

> *The potential for releases or changes in repository conditions from borehole penetrations in the operations and experimental areas of the repository does not appear to have been evaluated. Radionuclides that may have migrated into those areas through the panel closures by diffusion or other transport mechanisms could be released to the ground surface, and gas pressures could be relieved by such boreholes. Also, brine could migrate into those areas from a borehole and then into the waste panels.*

Statement of Issue

The CMPR panel concern is clearly stated. Both El- and E2-type intrusions could occur into the experimental and operations regions. E2 boreholes, which do not encounter pressurized brine in the Castile, could bring radionuclides to the surface as direct releases, if any are present in the region intersected. E2 boreholes could also provide a pathway for long-term fluid flow and radionuclide transport. El boreholes, which do encounter pressurized brine in the Castile, could result in similar consequences, and also have the potential to provide a pathway for Castile brine to reach the waste disposal region without the occurrence of a direct intrusion into the waste.

Response to Issue

The peer review panel is correct in its observation that the processes noted could occur. Justification for not modeling these processes explicitly in the performance assessment follows.

Direct releases from an intrusion into the experimental and operations regions. Direct releases from both E1 and E2 intrusions into the experimental and operations regions are not modeled explicitly because waste will not be emplaced in these regions. Releases of particulate waste (that is, cuttings, cavings, and spallings) will therefore not occur. Radionuclides could potentially be transported in brine into these regions, and contaminated brine contained in the pore space of the rock could be brought to the surface during drilling. However, the northern portions of the repository are separated from the waste disposal regions by panel closures that will greatly reduce brine flow. All waste will be separated from the northern regions by at least one set of panel closures (see Figure 3-2, Chapter 3.0), and all except the waste that will be emplaced in the north-central drift region (equivalent panel 10 in Figure 3-2) will be separated from the southern portion of the operations region by two or more sets of panel closures and from the remainder of the northern regions by three or more sets of panel closures.

BRAGFLO performance assessment calculations indicate that the panel closures will be effective in reducing brine flow. Figure 9-3 is a plot of net brine flow across the panel closure that separates the intruded panel from the rest of the waste disposal region. Results are shown for 100 realizations (replicate 1) of an El intrusion at 1,000 years. These flows represent brine leaving a panel closure separating a southern, down-dip panel from the rest of the repository. They are presumably greater than the flows that might be expected into the southern portion of the operations region following an E1 intrusion into equivalent panel 10, because some flow out of equivalent panel 10 would occur downdip rather than updip into the operations region. Flows into other portions of the northern region or for intrusions elsewhere in the waste region would be smaller.

As shown in Figure 9-3, flow across the panel closure is minor prior to intrusion. Following an El intrusion, net flow occurs away from the intruded panel. The largest flow is approximately 14,000 cubic meters, and more typical flows are approximately 3,000 cubic meters. This volume of brine will occupy some portion of the 65,000 cubic meters of total pore volume (359,000 cubic meters excavated volume at an assumed 18 percent porosity after consolidation) in the northern regions, and will be diluted by any inflow of uncontaminated brine into the region from the DRZ and MB. Releases resulting from cuttings and cavings will be limited to the actinides contained in the brine that may be present in the pore space of the solid material brought up the borehole, and will be insignificant. Direct releases resulting from brine flow up the borehole or from brine that may be contained in the pore volume of spalled material are not anticipated from the northern region because intrusions into the waste disposal region that could cause brine flow into the northern region will also depressurize the repository and remove the potential for spalling and blowout from subsequent intrusions. Blowouts may occur from the northern region if it is the first portion of the repository penetrated; however, there is no reason to anticipate that significant quantities of radionuclides will be present in the northern region under undisturbed conditions.

Long-term releases from an E2 intrusion in the experimental and operations regions. Figure 9-4 shows the net brine flow through the panel closure separating the southern, down-dip panel from the rest of the repository following an E2 intrusion at 1,000 years (100 realizations, replicate 1). Two types of behavior can be observed. In most realizations, net flow is away from the borehole, as in the E1 scenario. For these realizations, an E2 borehole in the northern region would not provide a pathway for radionuclide transport to the accessible environment. In other realizations, net flow following intrusion is toward the borehole, and with flow volumes ranging from zero to less than 3,000 cubic meters. E2 boreholes in the southern portion of the operations region, where they are separated from the nearest waste by only a single set of panel closures, do have the potential to provide a pathway for radionuclide release if they display this type of behavior. As can be seen in Figure 3-2, this southern portion of the operations region is a small area. Including E2 intrusions into this area in the performance assessment could at most increase the total number of E2 intrusions contributing to the flow of contaminated brine into the Culebra by less than 10 percent. Radionuclide transport into the Culebra would increase by even less, because only a small portion of brine flowing up an E2 borehole in the operations region would be contaminated brine that flowed northward from the waste disposal region. Given the effectiveness of retardation processes within the Culebra, small changes in the amount of radionuclides reaching the Culebra would have no effect on the CCDF. E2 intrusions into the remainder of the northern region, north of the second set of panel closures, are anticipated to have smaller volumes of contaminated brine reaching them, and will also have no effect on the CCDF.

Long-term releases from an E1 intrusion in the experimental and operations regions. Figure 9-3 demonstrates that net flow through a panel closure following an E1 intrusion into a southern down-dip panel is away from the borehole in most realizations. An E1 intrusion in the northern region would, in most realizations, result in a net flow of uncontaminated brine through the panel closures to the south, and would not provide a pathway for radionuclide transport to the accessible environment. For those realizations showing a net flow toward the borehole, effects will be similar to those of an E2 borehole displaying the same behavior.

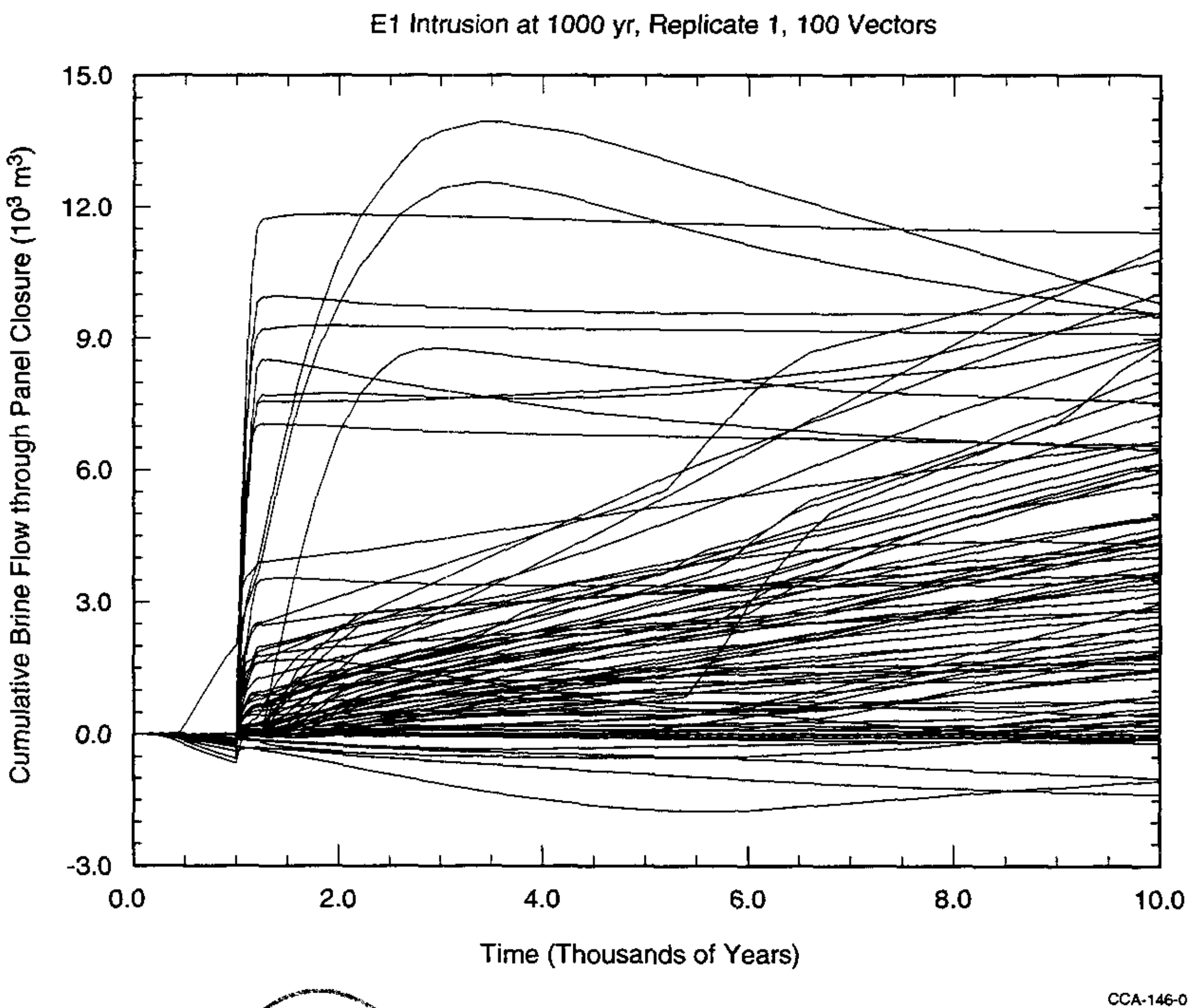

Figure 9-3. Cumulative Brine Flow through the Panel Closure between the Intruded Panel and the Rest of the Repository

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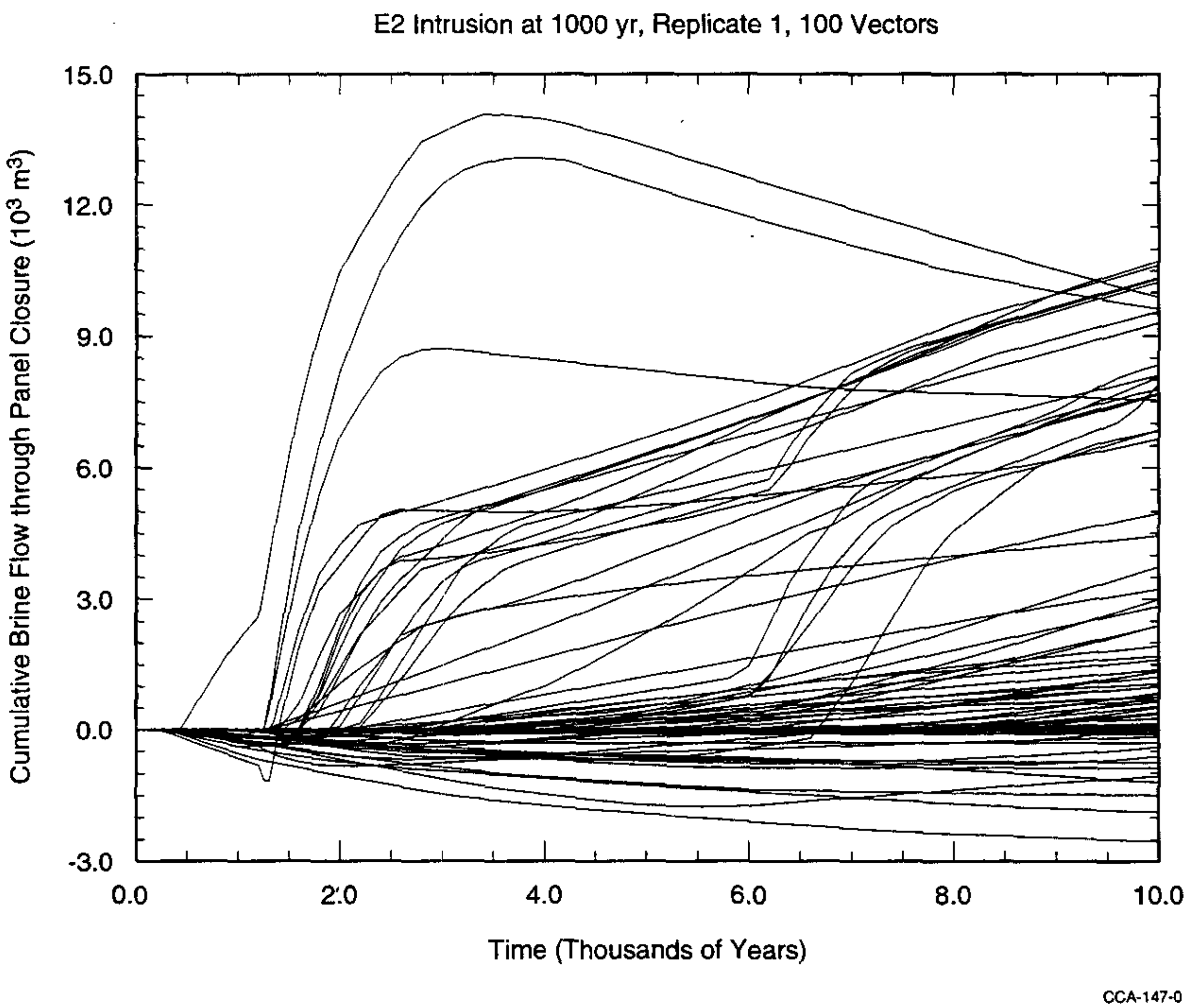

Figure 9-4. Cumulative Brine Flow through the Panel Closure between the Intruded Panel and the Rest of the Repository

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Other effects on brine and gas flow of intrusions into the experimental and operations regions. The permeability of the panel closures is not expected to be small enough to prevent gas flow and pressure equilibration throughout the repository, and intrusions into the northern regions therefore have the potential to decrease repository pressure by allowing gas flow up the borehole. This effect is not accounted for in the performance assessment calculations. Overall, consequences of including this phenomenon would be beneficial to disposal system performance, because it would reduce the likelihood of spalling and blowout releases occurring from intrusions into the waste disposal region.

If large brine flows occurred southward from the northern region following an E1 intrusion, they would raise brine saturation within the repository and could lead to increased gas generation. Large brine flows could also contribute to increased releases from subsequent intrusions into the waste disposal region. However, the permeability of the panel closures is expected to be small enough to prevent large brine flows from the northern region into the waste disposal region. Figure 9-3 shows brine flows that are representative of the volumes that might flow into the waste disposal region following an E1 intrusion in the southern portion of the operations region. Disposal system performance is not expected to be sensitive to changes of this order of magnitude in the amount of brine present in the waste disposal region. Brine flows southward from E1 intrusions into the northern portions of the operations and experimental regions will be less because of the presence of an additional set of panel closures.

<u>Peer Reviewer Consideration of Response</u>

The DOE understood the issue and provided a reasonable response.

9.3.1.2.6.2 Second Peer Review Panel Concern - Exploration Boreholes

> *The assumption that shorter (40 m) borehole plugs beneath the repository horizon will not significantly degrade during the 10,000-year regulatory time frame has not been adequately supported. For the two- and three-plug configurations, degradation of these plugs could result in creation of a low permeability pathway for fluid migration between the Bell Canyon and the repository. For the three-plug configuration, degradation could result in increased fluid migration from a Castile brine reservoir to the repository.*

<u>Statement of Issue</u>

The panel has noted that the technical report containing predictions of borehole plug performance life describes a service life range of from 500 to 50,000 years, with a best estimate of around 5,000 years, while the performance assessment calculations take the life of intermediate plugs to be 10,000 years. The panel also notes that the 5,000 year predictions of plug performance life rely on reactions that produce $Fe(OH)_2$ to control corrosion. In addition, the panel notes that other reactions (such as magnetite production) could be the operative corrosion control at greater depths, and that such changes in corrosion reaction could lead to collapse and failure of intermediate plugs in a manner similar to that predicted for shallow plugs. The result could be an effective flow path between the repository and both the Castile brine reservoir and/or the Bell Canyon aquifer.

Response to Issue

The report "Inadvertent Intrusion Borehole Permeability" (see Appendix MASS, Attachment 16-3) contains predictions of performance lives of deep (>1,000 feet) borehole plugs that range from 500 to 5,000 years. The predictions are driven by an understanding of the concrete degradation mechanisms and are sensitive to the porosity of the concrete plug. At shallow depths, plug life is controlled by casing corrosion, and the corrosion reaction is assumed to be controlled by $Fe(OH)_2$. This reaction was endorsed elsewhere by the panel when they considered corrosion in the disposal rooms. It is the most often cited corrosion reaction for iron-based alloys, and is reported from experiments on steel and is thermodynamically favored under the mildly reducing conditions expected at and above the Culebra and within a steel casing filled with oxygenated water.

Under mildly reducing or oxidizing conditions, such as may be expected at shallower depths, the corrosion mechanism operating on steel is uniform, general corrosion. Such a mechanism is expected to degrade the entire casing wall and leave a noncoherent residuum that lacks strength. As a result, corrosion to depths below a concrete plug is expected to remove physical support from the plug leading to total failure of the shallow plugs.

At greater depths, conditions are expected to be chemically more reducing and higher in alkalinity. At higher confining pressures (for example, 45 to 70 atmospheres; or approximately 1,000 to 1,500 feet deep), hydrogen gas is not mobile. Thus, at depths below the repository, corrosion of iron and equilibration with deep geochemical environments produces reducing conditions. The pH associated with natural systems is in the range 7 to 9. Under reducing, alkaline conditions, corrosion proceeds more slowly than predicted for shallower depths. More importantly, the corrosion mechanism associated with magnetite and carbonate production changes from the uniform, generalized model applied at shallower depths to one of localized, pitting corrosion. The resulting corroded casing is expected to remain largely intact but resemble a partial lattice-work of open penetrations and substantially intact pipe. As a result, the casing will continue to provide physical support to the concrete elements of the borehole plug, and failure of the plug will be associated with the concrete degradation process.

The concrete degradation process depends on the flow of brine through the plugs, and is most sensitive to the initial permeability and effective porosity of the concrete. At the expected permeabilities of the plug, and the maximum potential pressure gradients, the concrete will not degrade for between 500 and 50,000 years; this variation is a result of possible variations in the concrete properties.

The panel correctly notes that the 10,000 year performance assumed in performance assessment calculations differs from the 5,000 years (mid-range) prediction reported by Thompson et al. (1996). The performance assessment assumption was made to simplify CCDF calculations because the CCDF is not sensitive to the difference. In fact, the CCDF is sensitive only to the relationship that the lower plug lasts significantly longer than the shallow plug. This will always be the case, because of the different casing corrosion rates and mechanisms at the different depths, and because of the lower concrete permeability which can be expected at greater depth. This is expected because of the beneficial effect of the greater pressure of water on the initial permeability.

The BRAGFLO calculations begin with the assumption in both the two- and three-plug configurations that drilling into a brine reservoir initially connects the brine reservoir, the repository, and the Culebra.

In the two-plug configuration, the connection between the reservoir and the repository remains perfect for about 200 years, until the shallow plug fails and the borehole becomes filled with debris. During this time period, the repository may or may not become saturated by flow up from the reservoir, accompanied by drainage in from the Salado seeps and down from units in the Rustler. BRAGFLO shows that the major contributor to repository saturation can be the Castile reservoir, but that other sources also play a role. In some realizations, flow down the borehole dominates. The net result for most realizations is a saturation of intruded waste panels by brine of mixed compositions that is pressurized to the extent that gas generation allows.

In the three-plug configuration, the connection between the repository and the reservoir lasts several days, and then it is shut off by casing of the borehole, and eventually by placement of the intermediate plug. BRAGFLO shows that only a small portion of the repository becomes filled in this interval. For the first 200 years, or so, formation waters from the Salado are all that drain into the repository. After about 200 years, the shallow plug fails and water drains down from the Rustler sources, through the debris, saturating the repository. Gas generation in the repository generally rises due to the increased availability of moisture.

Ultimately, the intermediate plug fails; however, the permeability of the connection between the Castile brine reservoir and the repository is lower than between the Rustler and the repository. It can be inferred from BRAGFLO that the resistance of the creep consolidated debris, 10^{-12} to 10^{-15} square meters, opposes flow from the reservoir efficiently enough that flow into the repository occurs from both above and below the repository simultaneously. In addition, the brine reservoir is limited in terms of the volume of water it can provide, while the Rustler sources are assumed to be infinite. The result is that the preferred flow path for water into the repository is down the borehole into the repository. The net result is a repository saturated with mixed brines and pressurized to the extent allowed by generated gas.

The minor difference between a 5,000 and 10,000 year performance life in the intermediate plug of a three-plug configuration is minimal and does not warrant separate performance assessment calculations.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.6.3 Third Peer Review Panel Concern - Exploration Boreholes

> *The possibility that an effect on the repository could result from Castile brine encountered in an E1 borehole that is assigned a three-plug configuration does not appear to have been considered in the conceptual model. Castile brine could enter the repository during drilling before the borehole is cased and result in increased rates of corrosion, waste degradation, and gas production.*

Statement of Issues (Note: For the purpose of this response, the above exploration borehole concern has been combined with the first direct brine release concern regarding the transport of radionuclides with the discharge of brine [see Section 9.3.1.2.8.1].)

It has been hypothesized that potential interactions between the Castile reservoir, in which brine could flow into the intruded panel, or in which contaminants are removed from the waste panel during drilling, may exist, and that these pathways are not accounted for in the WIPP performance assessment. This discussion will show that these situations are accounted for within the assumptions contained in the current performance assessment conceptual models.

Response to Issues (Note: For the purpose of this response, the above exploration borehole concern has been combined with the first direct brine release concern regarding the transport of radionuclides with the discharge of brine [see Section 9.3.1.2.8.1].)

Figure 9-5 illustrates the problem. The drill bit first passes through the waste panel, at which time one of two events may occur: the wellbore experiences a "blowout", or brine flow from the panel into the wellbore (resulting in releases to the surface), or the well experiences "lost circulation", in which the drilling mud flows out of the wellbore and into the panel. The first event requires that the pressure differential be toward the wellbore (that is, $P_{panel} > P_{wf\ Panel}$). $P_{wf\ Panel}$ is the initial flowing wellbore pressure at the drill bit, which is equivalent to the pressure exerted by the column of drilling mud from the surface to the WIPP horizon. Current drillers in the area use a 1.23 specific-gravity-brine saturated mud, which will exert a pressure of approximately 8×10^6 pascals at the repository. When this pressure is exceeded in the panel, direct releases are accounted for in the Spall model for solids (within the CUTTINGS_S code), and the direct brine release model for dissolved radionuclides (Q_{BO} in Figure 9-5).

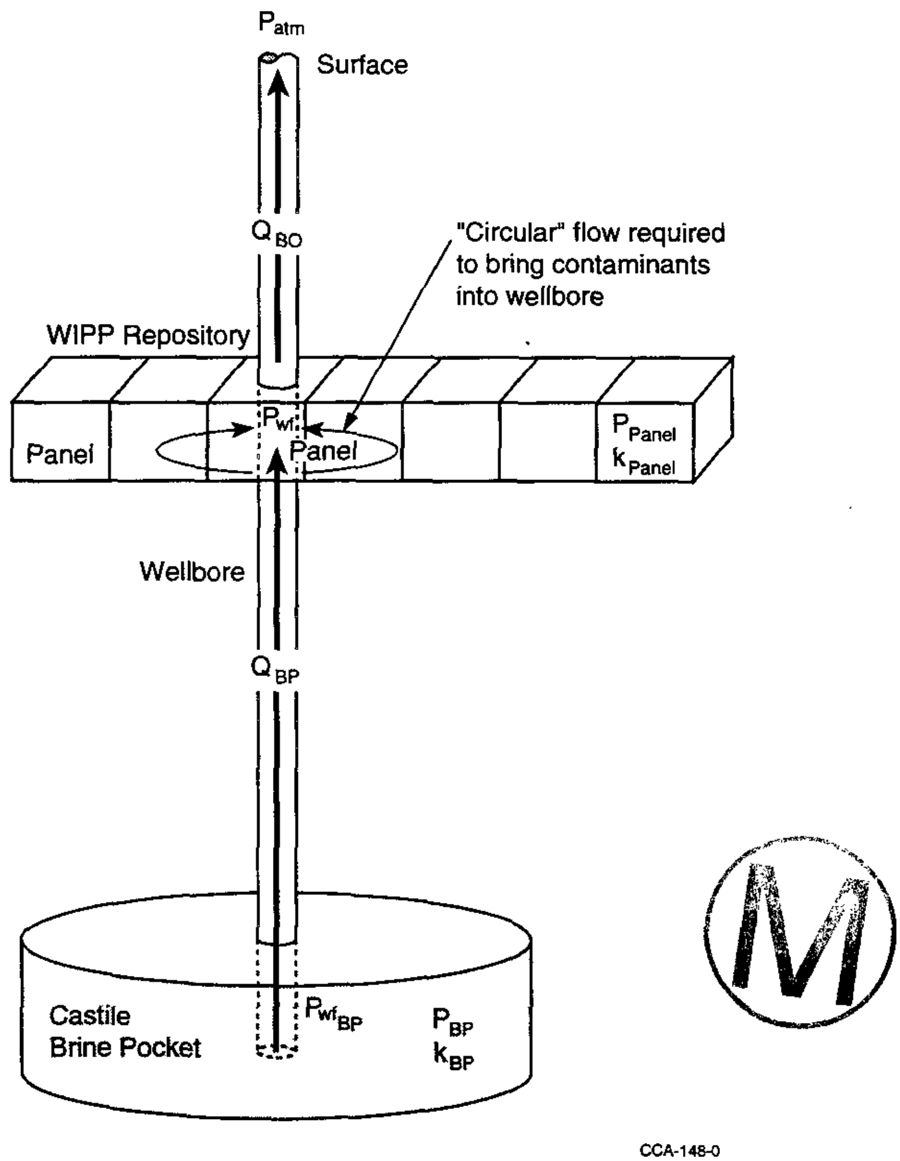

Figure 9-5. Sketch Showing Necessary Flow Path for Castile Brine To Carry Contaminants from Intruded Panel to Surface

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The second event (lost circulation) occurs if $P_{panel} < P_{wf\ Panel}$, which could result in drilling mud entering the panel during the drilling process. If the drilling mud loss into the panel is severe, current practice is to "plug" the "thief zone" (waste panel) by pumping high viscosity lost circulation material (LCM) into the thief zone until drilling mud circulation is restored. If the drilling mud loss to the panel is only a small "trickle" and the driller is able to maintain adequate circulation to the surface, he will most likely continue drilling to the next casing point, which is below the Castile.

It is important to mention the time duration of these events. Should the first event occur (the "blowout"), the direct brine release model assumes a minimum flow period of three days, which is the estimated time to continue drilling and case through the Castile. This minimum time period assumes brine "seeps" into the wellbore while drilling, and that there is little or no associated gas flow into the wellbore from the panel. The resulting increase in brine volume in the drilling mud will be treated as current drillers treat Castile brine pocket encounters, that is, to continue drilling and case the hole at the base of the Castile, at which time the cemented-in casing will stop all flow to or from the panel and brine pocket. If there is significant high-rate gas flow associated with the brine "blowout" from the panel, the direct brine release model assumes an uncontrolled flow of brine and gas which lasts for a maximum of 11 days. This is the assumed time duration to control the blowout. By "controlling" the well, current practice (and government regulations) require that the unexpected pressure be contained before drilling can continue. This can be done several ways, the most likely being to "weight up" or increase the drilling mud weight with additives and circulating until the hydrostatic pressure of the drilling mud in the wellbore exceeds the panel pressure. This will allow the driller to stop flow from the panel, at which point the blowout interval (panel) will be plugged by injecting cement, or setting casing, before drilling continues with the higher weight drilling mud. The "lost circulation" event, in which drilling mud flows into the panel, would last the length of time to case through the Castile for the "trickle" case (three days), to several hours, which is the time it would take to mix and pump the LCM plug(s) for the severe lost circulation case. In this case, the amount of drilling mud lost to the panel would be no more than several hundred cubic meters, which is the volume of the drilling mud pits (1,000 to 2,000 oil field barrels), should the driller pump the pits completely dry prior to circulating the LCM plug. This volume is significantly less (and therefore bounded) by the amount of brine available to flow from the Castile to the panel for the two-plug abandoned E1 borehole, as modeled by BRAGFLO.

If it is now assumed that drilling continues, and the drill bit penetrates a high pressure brine pocket in the Castile (E1 scenario), it is now possible for Castile brine to flow up the borehole and interact with the previously intruded waste panel on its way to the surface ($Q_{BP} = Q_{BO}$ in Figure 9-5). The flow into or out of the panel is still governed by the pressure differential between the panel (P_{panel}) and the borehole ($P_{wf\ panel}$). Assuming Castile brine has the same specific gravity as the drilling mud, $P_{wf\ panel}$ would be the same as it was for the initial penetration into the panel. This is because the pressures down the length of the open borehole are governed by the outlet pressure (atmospheric), which is the same for the drilling mud flows and Castile brine flows. Therefore, the high brine pocket pressure (P_{BP}) has no effect on flow into or out of the panel, other than increasing Castile brine flow up the borehole past the panel. If anything, pressures in the borehole due to Castile brine flows could only increase as a result of higher frictional forces. As previously mentioned, Castile brine pocket encounters cause little concern to present-day drillers, and flows are stopped once the hole is cased (maximum three day flow duration). The effects of this transient Castile brine flow into the waste panel on corrosion, waste degradation, and gas production will be minimal and are in any case bounded by the higher-probability 2 plug scenarios for long term release. In order for Castile brine to carry contaminated brine from the panel to the surface, it would have to flow through the plug previously set to control the aforementioned blowout or lost circulation events, into the panel, then back into the wellbore. This "circular" flow can happen only if conditions change enough during the three-day flow period to cause the pressure differentials to reverse, that is, go from $P_{panel} < P_{wf\ Panel}$ to $P_{panel} > P_{wf\ Panel}$. As long as the borehole is filled with brine, $P_{wf\ panel}$ will remain unchanged. Therefore P_{panel} would have to increase. This can only be accomplished through an increase in pressures via gas generation through corrosion and/or biodegradation. These processes take many years to generate significant gas volumes, and therefore are of no concern during the three-day time frame of active drilling through the Castile.

The possibility of Castile brine entering the waste panel and removing contaminants is accounted for in the compliance certification application calculations, through the treatment of abandoned boreholes. The two-plug scenario, which is the highest probability plugging scenario, assumes 200 years of open, relatively isolated flow between the Castile and the intruded panel. During this time significant volumes of Castile brine can enter the panel, pick up dissolved radionuclides, and simultaneously increase the panel pressure via gas generation. *Once the abandoned borehole assumes the permeability of silty sand, brine can leave the panel* and flow to the accessible environment through the surrounding geology.

In conclusion, the likelihood of Castile brine carrying contaminated brine from the intruded (E1) panel to the surface during active drilling is highly unlikely, assuming present-day drilling practices. In addition, the pressure differentials in the panel and wellbore required to achieve this type of flow could not occur in the short time frame of active drilling.

<u>Peer Reviewer Consideration of Response</u>

The DOE understood the issue; however, the panel concluded that the response did not reasonably address its concern.

<u>DOE Technical Position versus Panel Issue</u> (Note: For the purpose of this response, the above exploration borehole concern has been combined with the first direct brine release concern regarding the transport of radionuclides with the discharge of brine [see Section 9.3.1.2.8.1].)

As pointed out in the initial response, according to pipe flow dynamics, "the pressures down the length of the open borehole are governed by the outlet pressure (atmospheric), which is the same for the drilling mud flows and Castile brine flows. Therefore, the high brine pocket pressure has no effect on flow into or out of the panel, other than increasing Castile brine flow up the borehole past the panel."

It should be noted that, as pointed out in the original response, the sequence of events is that the borehole intersects the repository before it intersects the brine reservoir.

Case 1. If there is significant flow from the borehole to the repository, this would be a source of circulation loss to the driller. Therefore, the aperture from the borehole to the repository would be plugged by the driller before the borehole intersects a Castile brine reservoir. "In *this case, the amount of drilling mud lost to the panel would be no more than several hundred* cubic meters, which is the volume of the drilling mud pits (1,000 to 2,000 oil field barrels), should the driller pump the pits completely dry prior to circulating the LCM plug. This volume is significantly less (and therefore bounded) by the amount of brine available to flow from the Castile to the panel for the two-plug abandoned E1 borehole, as modeled by BRAGFLO."

Case 2. If the flow from the borehole to the repository is too small for the driller to notice, it will be less than a few gallons a minute. In this case, Castile brine may flow from the borehole into the repository after the borehole intersects the brine reservoir "and flows are stopped once the hole is cased (maximum three day flow duration)." In this case, "The effects of this transient Castile brine flow into the waste panel on corrosion, waste degradation, and gas production will be minimal and are in any case bounded by the higher-probability 2-plug scenarios for long term release."

9.3.1.2.6.4 Fourth Peer Review Panel Concern - Exploration Boreholes

> *The sensitivity of the performance assessment to the simplified approach taken to determine reference conditions for BRAGFLO output does not appear to have been evaluated for the current model configuration. If reference conditions are not provided at sufficiently frequent time intervals, the modeling results may be erroneous.*

<u>Statement of Issue</u>

The panel accepts the necessity for using reference conditions, and acknowledges that the validity of the approach had been shown in earlier performance assessments. The concern is that the validity in the current performance assessment has not been demonstrated, particularly when only two release values (at 350 and 1,000 years) have been used.

<u>Response to Issue</u>

The panel is correct that formal sensitivities of the performance assessment to the assumed conditions have not been evaluated as yet. However, the calculations use more detailed results than releases calculated at 350 and 1,000 years, as indicated in the review comments:

Cuttings

Volume of material removed is independent of intrusion time. However, concentration in each of the 570 waste streams (that is, 569 for contact-handled [CH] waste and one for remote-handled [RH] waste) is time dependent. For each waste stream, concentration is calculated at 100, 125, 175, 350, 1,000, 3,000, 5,000, 7,500, and 10,000 years. Then, linear interpolation is used to estimate waste concentration at the time of a specific drilling intrusion.

Spallings

Volume of material removed is dependent on time of intrusion and whether or not the intrusion has been preceded by a prior intrusion. Calculations were performed for (1) initial intrusion into an upper waste panel at 100, 350, 1,000, 3,000, 5,000, 7,500, and 10,000 years, (2) initial intrusion into a lower waste panel at 100, 350, 1,000, 3,000, 5,000, 7,500, and 10,000 years, (3) initial E1 intrusion at 350 years followed by a second intrusion into the same waste panel at 500, 750, 2,000, 4,000, and 10,000, (4) same as (3) but second intrusion into different waste panel, (5) initial E1 intrusion at 1,000 years followed by a second intrusion into the same waste panel at 1,200, 1,400, 3,000, 5,000, and 10,000 years, (6) same as (4) but second intrusion into different waste panel, and (7) same as (3), (4), (5), and (6) but for initial E2 intrusion. For initial intrusions, one-dimensional linear interpolation used to estimate volume of release; for second and subsequent intrusions, two-dimensional linear interpolation used to estimate volume of release concentration in repository calculated at 100, 125, 175, 350, 1,000, 3,000, 5,000, 7,500, and 10,000 years. Then, linear interpolation used to estimate waste concentration at the time of a specific drilling intrusion.

Blowout

Computational structure and associated times are the same as for spallings.

Release to Culebra

BRAGFLO calculations were performed for E1 and E2 intrusions at 350 and 1,000 years and an E2 E1 intrusion (with the E2 intrusion at 800 years and the E1 intrusion at 2,000 years). Pressure and saturation conditions in repository depend primarily on time since a drilling intrusion rather than the actual time of the intrusion. The BRAGFLO results for E1 and E2 intrusions at 350 years were used to support NUTS calculations for intrusions at 100 and 350 years. The BRAGFLO results for E1 and E2 intrusions at 1,000 years were used to support NUTS calculations for intrusions at 1,000, 3,000, 5,000, 7,000, and 9,000 years. Further, the BRAGFLO results for an E2 E1 intrusion were used to support PANEL calculations for E1 E2-type intrusions at 100, 350, 1,000, 2,000, 4,000, 6,000 and 9,000 years. Then, two-dimensional interpolation was used to estimate releases for intrusions at other times.

Transport in the Culebra

Calculations were performed for unit releases into the Culebra. The results of these calculations were then used to construct releases to the accessible environment for arbitrary time-dependent releases into the Culebra.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.7 Peer Review Panel Concern - Spallings

9.3.1.2.7.1 First Peer Review Panel Concern

> *The conceptual model for channel flow of gases toward an exploratory borehole appears to be valid but has not been adequately evaluated. Spallings is a potentially important mechanism for direct waste release to the ground surface.*

Statement of Issue

The panel considers the spall model development to be on an appropriate path, but is concerned that the channel flow scenario needs additional validation.

Response to Issue

The concept of channeling is primarily based on results of laboratory experiments conducted on graded silica sands of low moisture content (Lenke et al. 1996). At the completion of each test, plaster casts were made of the void space remaining after achieving a steady gas flow state and when no additional material was being removed. The plaster filled the large primary channels near the borehole. Castings of the void volume revealed a blowout void volume characterized by a series of partial thin shells or lenses stacked at increasing distances from the borehole. The shells provided narrow pathways or channels for the passage of gas toward the borehole. A few tests also showed radial channeling in the form of conical tubular extensions extending radially from the center.

Quantitative predictions of the solids produced by channel flow made by the model are compared to laboratory experiments to define values for "effectiveness factors." These factors are needed to calibrate the model to actual observed experimental releases.

The channel pattern is postulated to grow from a region adjacent to the borehole radially outward as the result of the eroding effects of flowing gas within weakened planes or "fractures". The weakened planes are either preexisting resulting from small local variations in initial porosity and permeability (as certainly would be the case for actual waste) or are caused by tensile and/or shear failures within the matrix resulting from local pressure gradients near the borehole.

The concept of channeling is also supported by the process used for open-hole well completions for methane production from coal seams (Mavor and Logan 1994). Open-hole cavity completion refers to the process of fracturing the coal adjacent to the wellbore through a series of controlled blowouts. The fracturing occurs in the coal due to the large gas pressure gradients that arise in the coal adjacent to the wellbore from the sudden drop in borehole gas pressure. The fracturing process increases methane gas production from the well by providing additional gas pathways or channels.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.7.2 Second Peer Review Panel Concern - Spallings

> *The conceptual model for waste erosion by flowing gases has not been adequately defined. The model describing the source(s) of waste erosion resistance and the parameter(s) characterizing that resistance have not been adequately evaluated. Errors in this conceptual model could lead to over estimating or under estimating the volume of waste released in the spallings process.*

Statement of Issue

The panel considers the spall model development to be on an appropriate path but is concerned that additional information is needed on the parameters.

Response to Issue

The concept of a fluid (liquid or gas) flowing adjacent to a stationary surface and generating a shear stress acting on that surface is well known. The pressure drop that occurs along the flow direction within pipes is based on such a phenomenon. For surface materials that have a resistance to erosion that is equal to this shear load, some of the surface material can be expected to erode and be carried along with the flowing fluid. For turbulent flow the fluid shear stress is dependent on the roughness of the surface (particle diameter), a typical dimension (for example, diameter of flow field), and the viscosity, density, and velocity of the fluid (Streeter 1958, 182). The resistance to erosion is a parameter that describes at what shear stress the surface erodes. Such a number must be related to the force required to dislodge a single particle of the surface into the fluid stream. This force can be reasonably assumed to be related to its bond to the surface (tensile strength and weight).

For spall, a model based on first principles was derived that related the forces acting on a particle projecting from the channel wall to the force required to dislodge that particle. The forces acting on the particle were based on the drag forces generated by the flowing gas which, as above, are a function of a dimension (particle diameter), and the viscosity, density, and velocity of the fluid. An empirical coefficient of drag is also necessary which is analogous to the friction factor mentioned above. The experimentally determined effectiveness factors calibrate the model to actual observed experimental releases.

Particle bonding to the surface of the flow channels is assumed to be primarily related to the macroscopic tensile strength of the degraded waste. The value of 1 pound per square inch chosen for cementation strength for the decomposed waste for the performance assessment calculations can be reasonably expected to be conservative, that is, lower than those data values found for many weak materials that are naturally occurring or that have been manufactured. Data to support this value can be found in the literature for the strengths of soils, laboratory produced mixtures of salt and clay, and mixtures of various materials with MgO (Berglund et al. 1996; Appendix PEER, Section PEER.2).

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.7.3 Third Peer Review Panel Concern - Spallings

> *The waste has not been adequately characterized and the understanding of its physical properties in its decayed state has not been adequately developed to support the Spallings model. An adequate understanding of waste erosion processes requires an adequate understanding of the properties of the waste.*

Statement of Issue

The panel's concern is mainly with the strength assumed for the decomposed waste, since this is a controlling parameter for spall releases. In this regard, the concerns are more with the "understanding of its physical properties in its decayed state" than with characterization of the waste.

Response to Issue

A value of 1 pound per square inch (6,895 pascals) was chosen to represent the tensile strength of decomposed waste for the purpose of computing spall releases resulting from a drillbit intrusion into a pressurized waste panel. Such spall releases occur only if the gas pressure exceeds the hydrostatic drilling mud pressure of approximately 8 megapascals. A chemical reaction between the waste and brine from the surroundings is necessary to generate the gas to raise the waste pore pressure to these levels. Without brine inflow, little gas will be generated and waste decomposition will be negligible. Thus, the phenomenon of spall requires both brine inflow and waste decomposition.

The future state of decomposed waste is both time dependent and unknowable. Therefore, a decomposed state is bounded by an assumption of graded granular materials. This is consistent with the granular nature of decomposed geologic materials and corresponds to an end state of the decomposition process. Such materials lack significant composite strength from the interleaving of components and is the state found to be most troublesome in oil production where sand is produced from poorly consolidated sand layers. The value of 1 pound per square inch chosen for cementation strength for the decomposed waste can be reasonably expected to be conservative, that is, lower than those data values found for many weak materials that are naturally occurring or that have been manufactured. Data to support this value can be found in the literature for the strengths of soils, laboratory-produced mixtures of salt and clay, and mixtures of various materials with MgO; the latter added as a backfill material to the waste (Berglund et al. 1996; Appendix PEER).

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.8 Peer Panel Concern - Direct Brine Release

9.3.1.2.8.1 *First Peer Review Panel Concern*

> *The basis for the assumption that radionuclides do not accompany the direct discharge of Castile brine has not been adequately supported. This assumption could lead to underestimating radionuclide releases.*

Statement of Issue

This issue is addressed in Section 9.3.1.2.6.3 (Third Peer Review Panel Concern - Exploration Boreholes).

Response to Issue

This issue is addressed in Section 9.3.1.2.6.3 (Third Peer Review Panel Concern - Exploration Boreholes).

Peer Reviewer Consideration of Response

The DOE understood the issue; however, the panel determined that the response did not reasonably address their concern.

DOE Technical Position versus Panel Issue

As pointed out in the initial response, according to pipe flow dynamics, "the pressures down the length of the open borehole are governed by the outlet pressure (atmospheric), which is the same for the drilling mud flows and Castile brine flows. Therefore, the high brine pocket pressure has no effect on flow into or out of the panel, other than increasing Castile brine flow up the borehole past the panel."

As pointed out in the original response, "In order for Castile brine to carry contaminated brine from the panel to the surface, it would have to flow...into the panel, then back into the wellbore. This circular flow can happen only if conditions change enough during the three day flow period to cause the pressure differentials to reverse, that is, go from $P_{panel} < P_{wf\ Panel}$ to $P_{panel} > P_{wf\ Panel}$. As long as the borehole is filled with brine, $P_{wf\ panel}$ will remain unchanged. Therefore P_{panel} would have to increase. This can only be accomplished through an increase in pressures via gas generation through corrosion and/or biodegradation. These processes take many years to generate significant gas volumes, and therefore are of no concern during the three-day time frame of active drilling through the Castile."

9.3.1.2.8.1 Second Review Panel Concern - Direct Brine Release

> *Radionuclide transport through entrainment of brine and waste solids in rapid, two-phase liquid/gas releases during inadvertent borehole intrusions does not appear to have been evaluated. This transport mechanism may be an important component of the conceptual model.*

Statement of Issue

The possibility of solids (spall) releases as a result of the higher erosional forces of simultaneous brine and gas flows through the waste panel is not accounted for.

Response to Issue

Entrainment of contaminated brine in rapidly flowing gas is included in the direct brine release model used in performance assessment. Basically the brine and gas flow to the wellbore is computed by BRAGFLO. These are used with a Poettman-Carpenter well-bore model to iteratively determine a bottom-hole flowing pressure, which in turn is used to determine the direct brine releases appropriate for the particular conditions (including multiphase flow). The "gas-lift" effect is accounted for in the two-phase well-bore flow model in the determination of the flowing well boundary condition.

Solid entrainment is not explicitly included in this model, however the releases due to this mechanism are expected to be no more than that already accounted for in the cuttings, cavings, and spallings model.

Peer Reviewer Consideration of Response

The DOE understood the issue; however, the panel concluded that the response did not reasonably address their concern.

DOE Technical Position versus Panel Issue

A simple modeling approach that accounts for the major influences of two-phase flow on solids releases is to increase the spall model gas density to correspond to the combined density of brine and hydrogen. The density contribution from the added brine is dependent on the liquid/gas ratio for the particular vector and is strongly correlated with the gas flow rate (Figure 9-6). For large liquid/gas ratios (large "gas" densities) the borehole flow rate is very small, while for small liquid/gas ratios (small "gas" densities) the borehole flow rate under standard conditions is large, approaching 20 cubic meters per second. Figure 9-6 shows this trend for all of the 699 downdip intrusions for which brine was released in the 1996 performance assessment as computed by BRAGFLO.

The spall model assumes that blowout gases flow up the borehole annulus and satisfy isothermal compressible flow equations in a long channel. The model also assumes that the bottom hole pressure is equal to the repository gas pressure and consequently the flow rate tends to be constant at 4.37 cubic meters per second at repository conditions. However, it is clear from Figure 9-6 that the flow rate is not constant when the effects of entrained brine are included. The competing effects of density and flow rate on spall releases can be determined by correcting the values of Figure 9-6 to repository conditions and by computing a release factor which would multiply the spall model releases. The release factor is proportional to [(borehole flow rate)("gas" density)$^{1/2}$]. Figure 9-7 shows this release factor for the 699 down-dip intrusions. The net effect of increased "gas" density and decreased borehole flow velocity decreases spall releases to less than 1/10 of the spall model.

9.3.1.2.8.2 Third Peer Review Panel Concern - Direct Brine Release

> *Releases resulting from flow into an exploration borehole intersecting a disturbed rock zone in the wall of a waste panel do not appear to have been evaluated. Large, open fractures in the walls could significantly increase the local halite permeability, allowing gas and brine to migrate through the borehole to the ground surface.*

Statement of issue

At issue is the potential for additional direct brine releases to occur due to the higher permeability of the DRZ.

Response to Issue

Inclusion of drilling intrusions into the DRZ is not expected to increase direct brine releases for the following reasons:

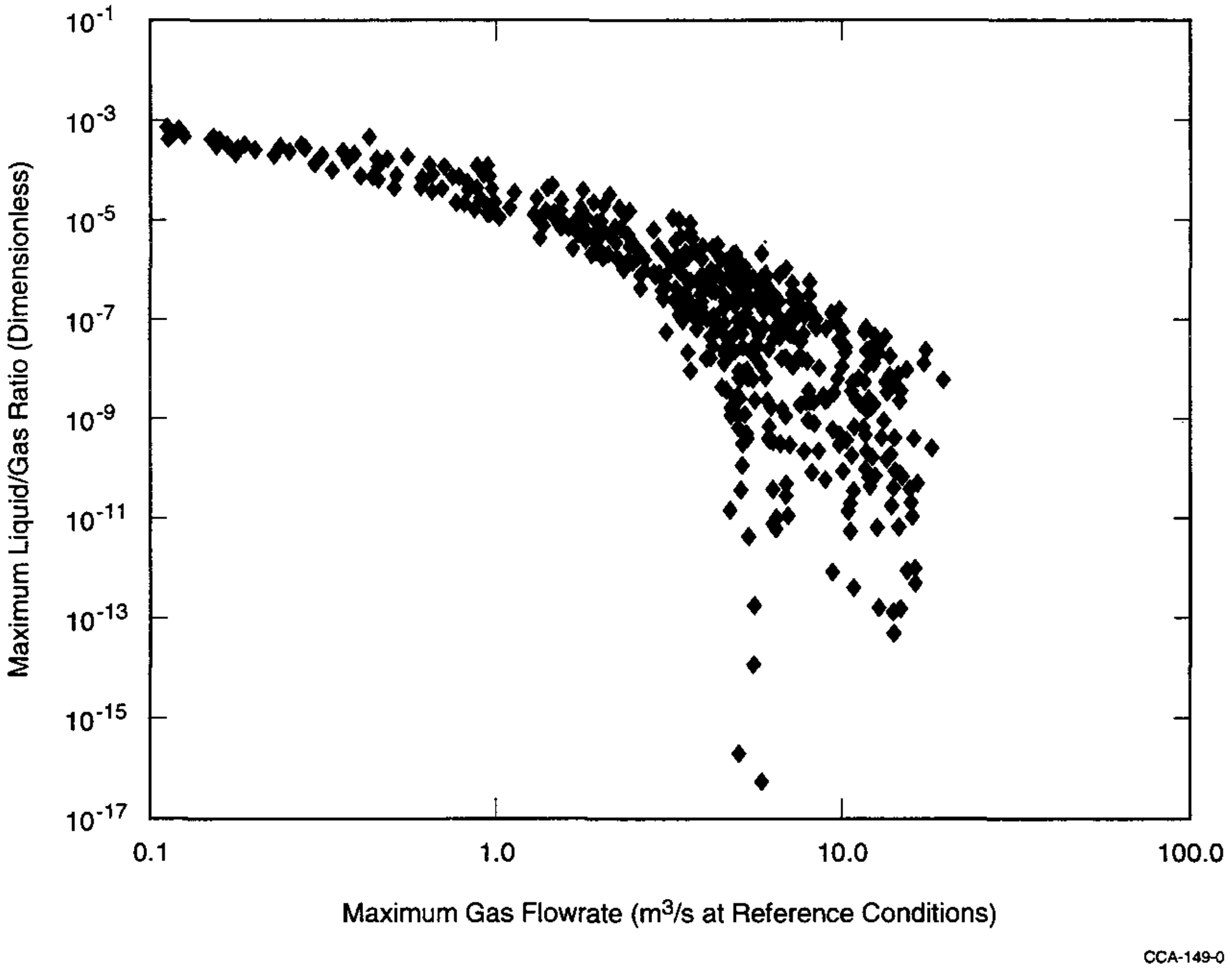

Figure 9-6. Maximum Liquid/gas Ratio versus Maximum Gas Flowrate (All Intrusions that Resulted in Direct Brine Release)

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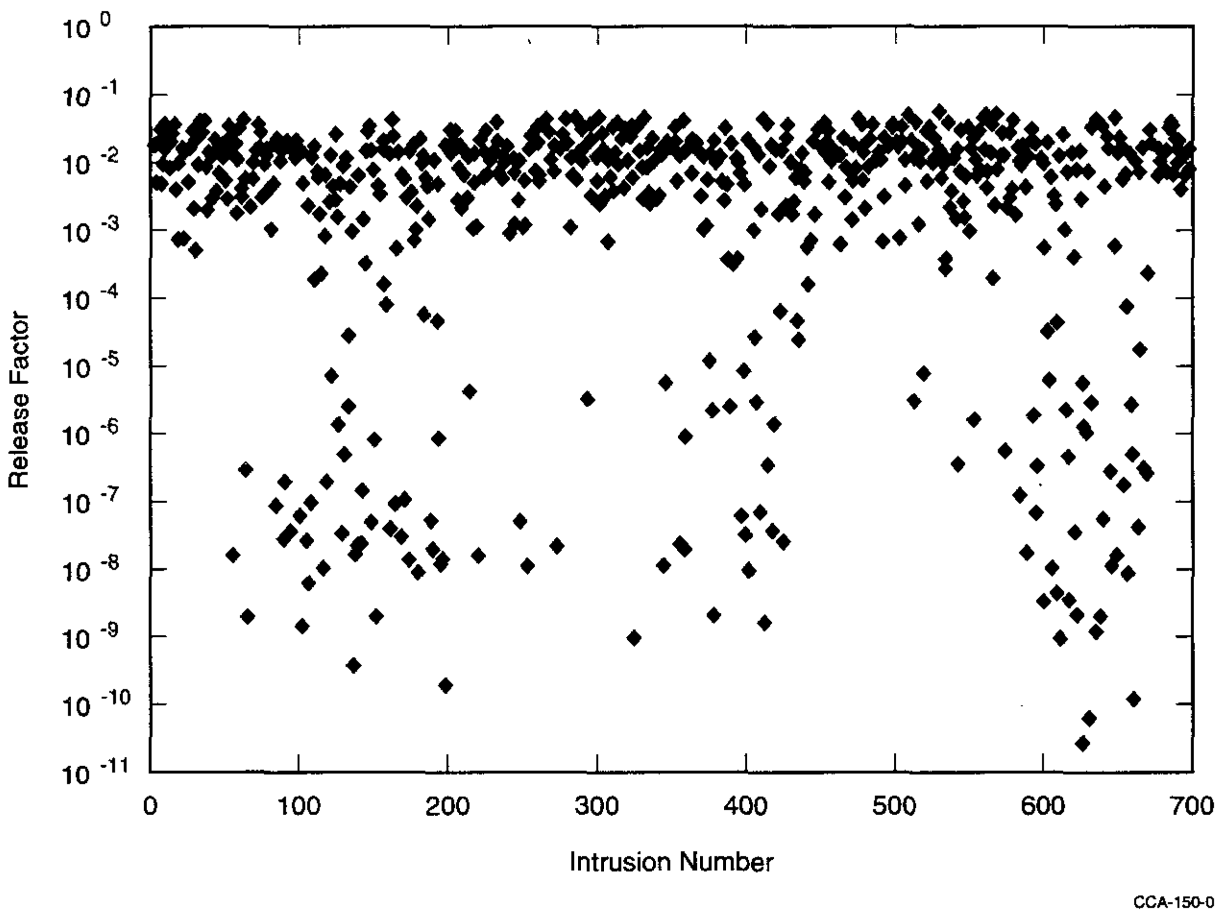

Figure 9-7. Multiplier by which Spall Releases Would Be Reduced if Effects of Two-phase Flow on Solids Were Included in Performance Assessment Modeling (All Intrusions That Resulted in Direct Brine Release)

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- The permeability of the DRZ (approximately 10^{-15} square meters) is lower than the permeability of the waste (approximately 10^{-13} square meters), which would substantially reduce the flow into the borehole compared to an intrusion directly into the waste.

- The area of the DRZ around the waste panels is probably small compared to the area of the waste panels, so including that area will not substantially increase the probability of an intrusion.

- The first intrusion has the largest release, with subsequent intrusions having little or no release. Since virtually all realizations have at least one intrusion, small increases in the probability of intrusion will not change the total direct brine releases.

- Inclusion of the DRZ (and the operations and experimental regions) would increase the area where intrusions:

    - result in little release (because of the lower permeability of the DRZ compared to the waste and the absence of waste from the operations and experimental regions) and

    - reduce pressure in the repository and thus reduce the potential for direct brine releases from subsequent intrusions.

Hence, neglecting these intrusions is reasonable.

Peer Reviewer Consideration of Response

The DOE understood the issue; however, the panel concluded that the response did not reasonably address their concern.

DOE Technical Position versus Panel Issue

The current response includes those processes that are believed to be important for releases and discusses why the particular combination of circumstances identified by the peer panel is not believed to contribute significantly to releases. In fact, it shows that the current treatment is conservative compared to a treatment including DRZ penetrations because the DRZ penetrations could vent high gas pressures without cutting, cavings, and spallings releases, and with minimal direct brine releases.

9.3.1.2.9 Peer Review Panel Concerns - Castile and Brine Reservoir

9.3.1.2.9.1 First and Second Peer Review Panel Concerns

The basis for excluding larger, potentially depressurized brine reservoirs from performance assessment has not been adequately supported. Larger reservoirs may have greater brine flow volumes and may result in greater radionuclide releases.

The basis for the concept of reservoir depletion through previous borehole penetrations has not been adequately supported. Non-depleted reservoirs may have greater brine flow volumes and may result in greater radionuclide releases.

Statement of Issues

The panel is concerned that (a) larger brine reservoirs are not included in the performance assessment calculations and (b) the depletion of reservoirs in not well supported.

Response to Issues

The Anderson et al. (1996) memorandum demonstrates that the brine flow up a borehole is not sensitive to the reservoir size and that the effects of depletion are included in the uncertainty in the size of the brine pocket.

In Figure 9-8, the results of brine flow up a borehole that penetrates a brine pocket are plotted against the sampled initial brine pocket volume from the performance assessment calculations. The borehole flow is cumulative over the 10,000-year calculational period. This figure suggests that initial brine pocket volume is not an important variable for predicting borehole flow given the other uncertainties describing brine pockets included in the performance assessment calculations.

In Figure 9-9, the results of cumulative brine flow up a borehole that penetrates a brine pocket are again displayed, this time against the sampled values of brine pocket pore compressibility. The strong correlation observed indicates this parameter dominates the uncertainty in borehole flow upon penetration of the brine pocket.

The lack of sensitivity of cumulative brine flow up a borehole that intersects a brine pocket to initial brine pocket volume suggests that other uncertainties dominate the system. Furthermore, this lack of sensitivity allows for some flexibility in the rigor applied to determining and justifying the range in brine pocket volumes considered in the performance assessment calculation.

The analysis by Stoelzel et al. (1996) (see Appendix PEER) justifies the range of the initial brine pocket brine volumes (32,000 to 160,000 cubic meters) used in the performance

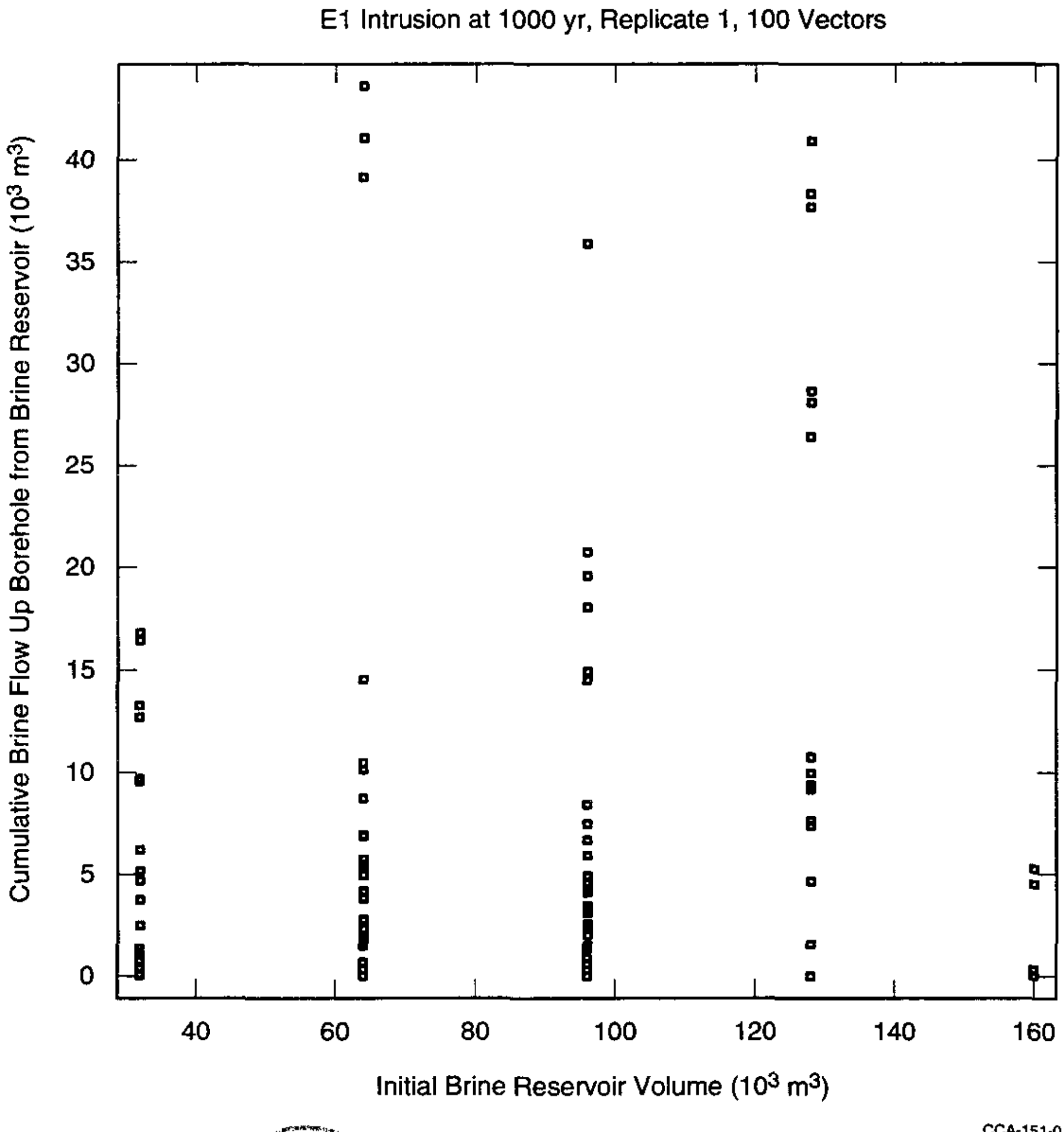

Figure 9-8. Scatterplot Showing Lack of Correlation Between Brine Flow from the Castile Brine Reservoir and the Sampled Value for Brine Reservoir Volume

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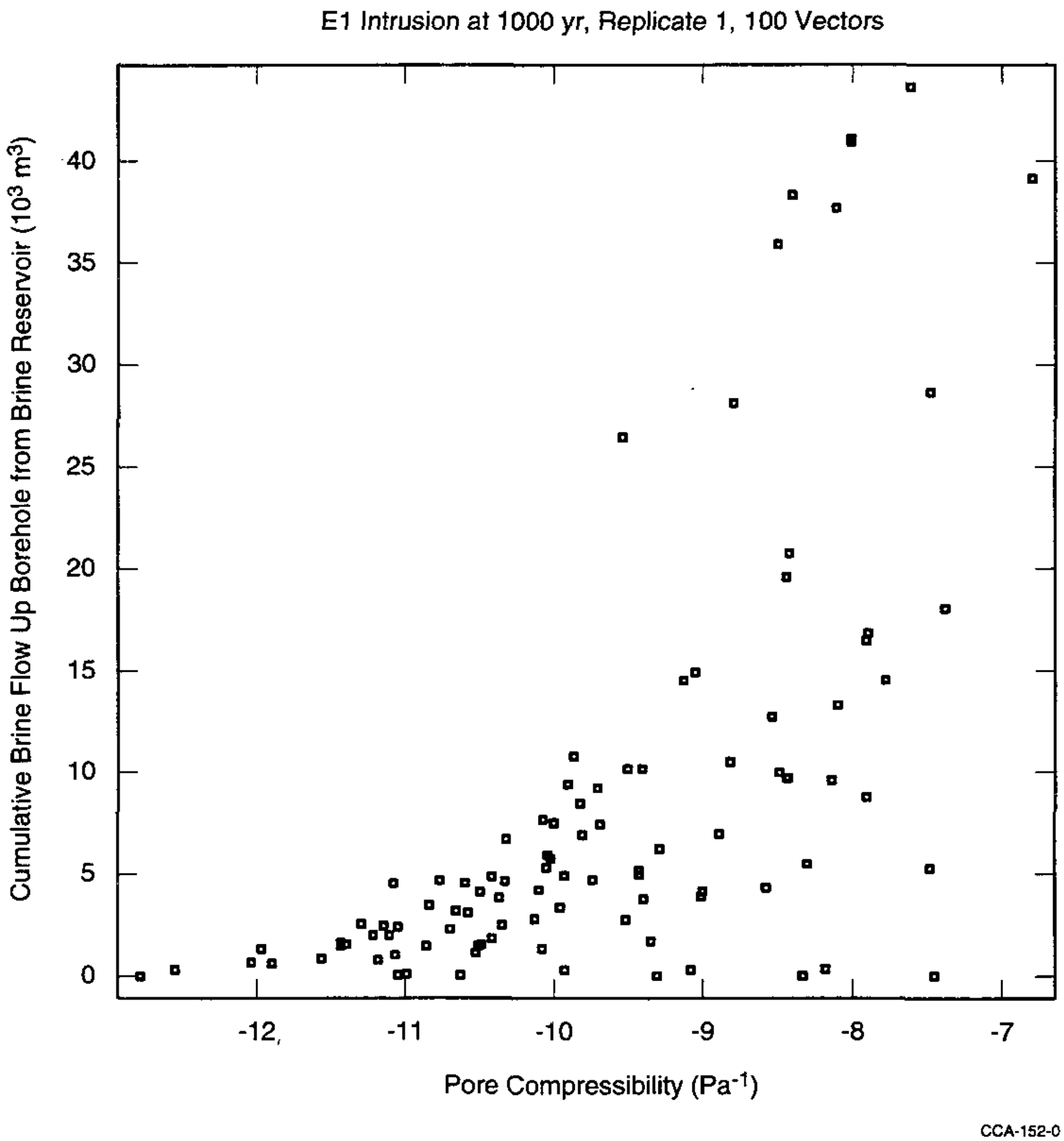

Figure 9-9. Scatterplot Showing Correlation between Brine Flow from the Castile Brine Reservoir and the Reservoir Pore Compressibility

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assessment calculation. This range is obtained from consideration of WIPP-12 data and an evaluation of depletion of the brine pocket due to penetrations that do not intersect waste.

Peer Reviewer Consideration of Response

The DOE understood the issues and provided a reasonable response.

9.3.1.2.9.2 Third Peer Review Panel Concern - Castile and Brine Reservoir

> *The expected probability of encountering pressurized brine beneath the waste panels has not been adequately supported, nor has the basis for apparently ignoring the quantitative value of site-specific geophysical data been presented. Unrealistically low probabilities of encountering brine may result in underestimating radionuclide releases.*

Statement of Issue

There are several parts to the panel concern that should be separated for a clear response:

1) the probability of encountering brine under the waste panels has not been adequately supported.

2) site-specific geophysical data are apparently being ignored without presenting the basis for ignoring it.

3) unrealistically low probabilities may result in underestimating radionuclide releases.

Response to Issue

1) In the overall context of the peer review report, this item refers to the discussion of geostatistical analyses, not the various methods of estimating probabilities based on the geophysical data (Item 2 below).

The work on estimating conditional probabilities of encountering brine in a drillhole under the waste panels was in progress during the panel deliberations, and a report was not yet prepared for the panel to review. The work in progress was presented orally to one member of the conceptual models panel before the panel completed its work. A draft report was prepared June 18, 1996 for internal review. A final report, dated July 10, 1996, has been submitted and will be reviewed by the project. The report is titled "Probability of Encountering Pressurized Brine under the WIPP" (Powers et al. 1996) and is included in Appendix MASS as Attachment 18-6.

The main points of the work can be summarized briefly. Maps of geological structure and thickness of Castile and related intervals were prepared incorporating data from many new drillholes in the vicinity of the WIPP, and the maps were interpreted as showing the relationship between brine occurrences and deformation of the Castile. The Castile under the waste panels is thought to be generally undeformed; there are no drillholes, however, in the Castile at the waste panel that would prove this to be true. An indicator function was developed for reports and non-reports of brine for 354 drillholes in a study area around WIPP, and a series of variograms were developed to show the spatial structure from these drillholes. An anisotropic model fit was used to provide parameters for ordinary kriging of the data for these drillholes. The area-weighted average estimated conditional probability was 0.08, based on computational nodes in the location of the waste panel. Nodal probabilities increase significantly north toward WIPP-12, reaching nodal values of about 0.37 in parts of the experimental area. The relationship between reported brine occurrences and thickness of certain intervals indicates that the thickness of the intervals under the waste panel area is less than the same interval in any known brine encounter. These different approaches indicate a low probability for encountering brine in a drillhole penetrating the Castile under the waste panels.

The panel discussed the validity of the geostatistical approach and the CMPR report (see Appendix PEER, 170 – 171) stated two principal objections to this approach:

a) lack of data in the vicinity of the WIPP.

b) an implicit assumption that geologic conditions at the WIPP would be similar to those in areas where brine encounters and drilling are more abundant.

Data on the Castile from drillholes near the WIPP site are limited for analyzing brine occurrences compared to some other areas. The main contributors to the geostatistical analysis at the site are WIPP-12 and DOE-1. WIPP-13, DOE-2, and commercial drillholes at greater distances contribute far less to the analysis. The strength of the analysis is that it uses the large database available to develop the spatial structure, and it honors the data at each drillhole location.

There is no assumption about underlying causes or distribution of brine occurrences. There is an assumption that the spatial information, developed from all drillholes in the study area, applies at the WIPP. Based on geological data developed independently of the geostatistical approach, Powers et al. (1996; Appendix MASS) concluded that there is a strong association of brine occurrences and Castile deformation, as indicated by thickness and structure data. As noted before, geologic data from the Castile at the site are limited. It might also be concluded that brine is not necessarily associated with structure, based on the assumption that geophysical data (Time-Domain Electromagnetic [TDEM] survey, see 2 below) indicate pressurized brine in the Castile under the waste panel location, where there is believed to be little, if any, Castile structure.

The effects on estimated conditional probabilities can be tested by assigning brine encounters or "nonencounters" in hypothetical drillhole locations around the immediate site area. The effects will differ greatly depending on the drillhole location and assignment as "an encounter" or "nonencounter".

The geostatistical approach is the most practical way to estimate the conditional probability that a future drillhole will encounter brine under the waste panel.

The geostatistical study was conducted independently of the geophysical data. The review of the geostatistical work in progress included that fact and may have contributed to the impression that the geophysical work was not being considered, at least quantitatively.

2) The geophysical data (particularly TDEM) that have been obtained represent the only significant site specific data over the waste panel. The TDEM work shows that there are very significant low resistivity anomalies that, under some of the waste panel area and adjacent to other areas, are consistent with depths of the middle to lower Castile. At this time, no other good explanation than brine has been proposed, and there has been no work that suggests the TDEM data are invalid. The method has been checked by tests near WIPP-12 that indicate low resistivity at depths approximately equivalent to the brine encounter in WIPP-12. DOE-1 did not encounter brine, and tests of TDEM near there did not indicate low resistivity within the Castile.

Most of the brine encounters that have been reported can be assigned to the lower half of the upper anhydrite (A3) or upper part of H2. Nonetheless, at least one encounter (see Table 4.2-2 in the report by Powers et al. 1996; Appendix MASS) was reported at a depth equivalent to the lower halite; another encounter was reported for a lengthy zone ranging from upper to lower anhydrite; and two encounters are from the uppermost anhydrite, but the unit may be A2. Thus, the geophysical data cannot be invalidated though the resistivity zones are interpreted to be at a depth equivalent to the basal anhydrite and lower halite of the Castile.

The interpreted depths to conductive units have been examined to estimate the area under the waste panels that might be underlain by Castile brine. Depending on the assumptions, the area ranges between about 10 percent and 55 percent. All analyses implicitly assume a uniform areal extent (similar to assuming porous medium), though the general concepts of brine reservoirs are of fractured rocks. In addition, various contouring ideas assume some small-scale structure (less than 250 meters), though a variogram of depth to conductor does not indicate any structure in ranges from 250 meters (smallest separation distance) to 500 meters separations or lag distances.

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The TDEM data are the most specific indicators of possible locations where Castile brine might underlie the area of the waste panel.

3) Releases calculated are related to the probability of intercepting a brine reservoir within the area underlain by the waste panels. It may be more difficult to determine what an

"unrealistically low probability" may be when there are different ways of examining whether a drillhole is likely to intercept brine or whether brine underlies part of the waste panel.

Peer Reviewer Consideration of Response

The DOE understood the issue; however, the panel concluded that the response did not reasonably address its concern.

DOE Technical Position versus Panel Issue

The current response provides a substantial geostatistical basis for the probability of encountering pressurized Castile brine. It extracts the maximum amount of information from the available direct data on exploration boreholes encountering Castile brine reservoirs. The indirect data (TDEM) used previously lack substantiated correlation with the probability of encountering Castile brine reservoirs but is consistent with the calculated probability from the direct data.

9.3.1.2.10 Peer Review Panel Concern - Gas Generation

9.3.1.2.10.1 First Peer Review Panel Concern

> *The conceptual model does not consider aluminum in the waste, steel in the rock bolts and netting, radiolysis of water by undissolved alpha emitters, and radiolysis of plastics and cellulosics as sources of additional hydrogen, oxygen, and other gases. Ignoring gases generated by these effects could result in underestimating the gas pressure in the repository."*

Statement of Issue

Corrosion. Anoxic corrosion of Al and Al-base metals in the transuranic (TRU) waste to be emplaced in the WIPP, and steel in the rock bolts, netting, etc., used for construction and maintenance of the repository will produce H_2 in addition to that predicted by the average-stoichiometry gas-generation model in the multi-phase flow code Brine and Gas Flow (BRAGFLO). For the calculations to support this application, the DOE considered the steel in waste containers (drums and boxes), steels and other Fe-base metals in the CH-TRU waste, and Fe-base metals associated with RH-TRU waste. However, the DOE did not consider the rock bolts and netting in the repository, nor Al and Al-base alloys in the waste. The DOE has assumed that the quantities of these metals are small relative to those included in the current and previous performance assessment calculations, and that the quantities of H_2 that would be produced by anoxic corrosion of these metals are small relative to that predicted by the current and previous performance assessment calculations. However, the DOE has not calculated the quantities of H_2 that would be produced by including them.

Radiolysis. Radiolysis of brine by solid-phase (crystalline or amorphous) actinides in the waste will produce H_2 and O_2 in addition to that predicted for dissolved actinides. Although a significant fraction of the energy associated with α-emissions from actinide-bearing solids could be absorbed by these solids, some of this energy could also be absorbed by any brine present. The DOE has calculated the maximum quantities of H_2 and O_2 that could be produced by brine radiolysis from dissolved Pu and concluded that the rate of gas production from brine radiolysis will be insignificant relative to that from anoxic corrosion and microbial activity (see Appendix SCR, Section 2.5.1.3.1). However, this analysis did not include Pu in solids.

Furthermore, the DOE has concluded, based on the results of laboratory studies summarized by Molecke (1979), that radiolysis of combustibles (cellulosics, plastics, and rubbers) will be insignificant relative to brine radiolysis (see Appendix SCR, Section SCR.2.5.1.3.2)) and, hence, insignificant relative to anoxic corrosion and microbial activity. However, the CMPR panel disagreed with this position, perhaps because compaction of the waste due to room closure may increase the radiolytic gas production rate by increasing the density of the waste and the extent to which particles interact with it.

<u>Response to Issue</u>

If added to the calculation for hydrogen production, the quantity of aluminum in the inventory would add about 4 percent to the corrodible metals in the repository. The quantity of netting and rock bolt iron represents a similarly small amount. No consequence to repository performance results from adding these additional metal quantities. The quantities themselves are small, and might increase the total moles of gas production by 10 percent to 15 percent. There is a fundamental, self-limiting relationship between gas pressure and corrosion. Prior to human intrusion, water initially drains into the repository from Salado sources, such as the DRZ and MBs. In inundated areas, metal corrodes and produces hydrogen, which exerts a backpressure on flow. In all realizations calculated by BRAGFLO, gas pressures rise high enough to prevent panel saturation. Importantly, this pressure is reached before all the metal in the panel is consumed by corrosion. In summary, prior to human intrusion, gas production is limited by the availability of water; hence addition of aluminum plus rock bolt plus netting inventory does not add significantly to the amount of corrosion gas that will be generated (Al will cause a small but indeterminate increase). The WIPP is in a location where drilling frequency is comparatively high. In 10,000 years, the repository will be intruded approximately six times. Boreholes connecting the repository to the surface are calculated to have a permeability of about 10^{-11} to 10^{-14} square meters for most of their lives. As a result, after human intrusion there may well be available water to drive corrosion, but there will also be release paths that vent elevated pressure. For most of the repository history, the principal effect of hydrogen will be to impose reducing chemical environments on waste dissolution. Accordingly, neglecting the small amounts of metal inventory or potential increases from radiolysis results in a slight conservatism. A detailed discussion of hydrogen generation is provided below.

Details of Hydrogen Generation in the WIPP Repository

Corrosion. The quantity of Al and Al-base metals in the TRU waste that will be emplaced in the WIPP is insignificant relative to that of the steel in waste containers and Fe-base metals in the CH and RH waste. According to the current version of the Baseline Inventory Report (BIR), the total, molar quantity of Al and Al-base metals is about 4 percent of the total quantity of Fe-base metals (DOE 1995a). Although the BIR does not estimate the quantity of Fe-base metals in rock bolts, netting, etc., the quantity of other Fe-base metals is probably insignificant relative to that included in the BIR.

Nevertheless, the DOE has concluded that inclusion of Al and Al-base metals and other sources of Fe-base metals would have no deleterious effect on the long-term performance of the repository. BRAGFLO calculations carried out to support this application have shown that, in the absence of human intrusion, anoxic corrosion of Fe-base metals was limited in all of the realizations (vectors) by the quantity of brine present in the repository, not the quantity of Fe-base metals. In other words, corrosion was brine-limited, not inventory-limited, over the entire range of system uncertainty. Figure 9-10 shows that, under undisturbed conditions, corrosion never consumed all of the Fe-base metals during the 10,000-year period of performance of the repository. Figure 9-11 shows the quantities of H_2 produced by anoxic corrosion in the undisturbed scenario. On a repository-wide basis, corrosion at most consumed only 60 percent of the inventory in 10,000 years. Therefore, including corrosion of Al-base metals, or increasing the quantity of Fe-base metals in the inventory would have no effect on the gas content of the repository after 10,000 years; it would only increase the quantity of uncorroded metals present after 10,000 years.

These BRAGFLO calculations also show that, in the event of human intrusion, anoxic corrosion is not necessarily brine limited, at least in the vicinity of the intrusion borehole. Therefore, corrosion can continue to consume brine and produce H_2. Figure 9-12 shows that, after intrusion of a brine reservoir at 1,000 years, corrosion consumed all of the Fe-base metals in the intruded panel in some of the realizations. However, Figure 9-13 shows that corrosion was inventory-limited only in the intruded panel. Nevertheless, including corrosion of Al-base metals, or increasing the quantity of Fe-base metals in the inventory would increase the quantity of H_2 produced in the intruded panel in those vectors in which corrosion was inventory-limited.

In the event of human intrusion, BRAGFLO predicts that the pressure of the surrounding Salado Formation will exceed that of WIPP disposal rooms, and brine inflow and corrosion will resume. However, gas will escape preferentially up the borehole because of the buoyancy of the gas and the relatively high permeability of the borehole. Therefore, additional gas production will not increase the pressure of the repository significantly under these conditions. Figure 9-14 shows the pressure in the intruded panel; Figures 9-15 and 9-16 show the volume of gas produced by corrosion and the volume of gas flowing up the borehole at the top of the DRZ above this panel. Comparison of these figures and those for the undisturbed scenario imply that as much as 25 to 50 percent more gas was produced as a result of human intrusion.

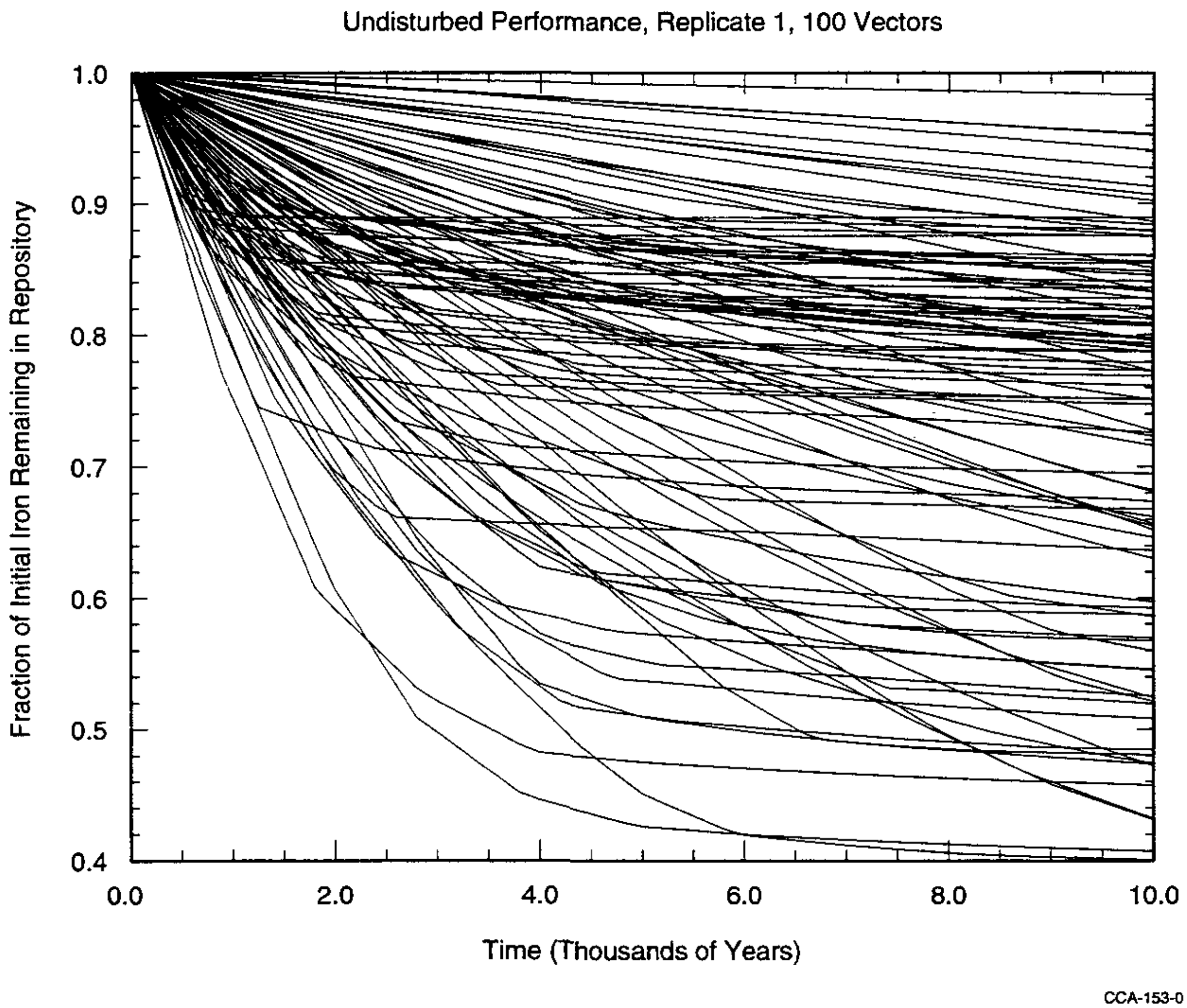

Figure 9-10. Fraction of Initial Iron Remaining in Repository, Undisturbed Performance

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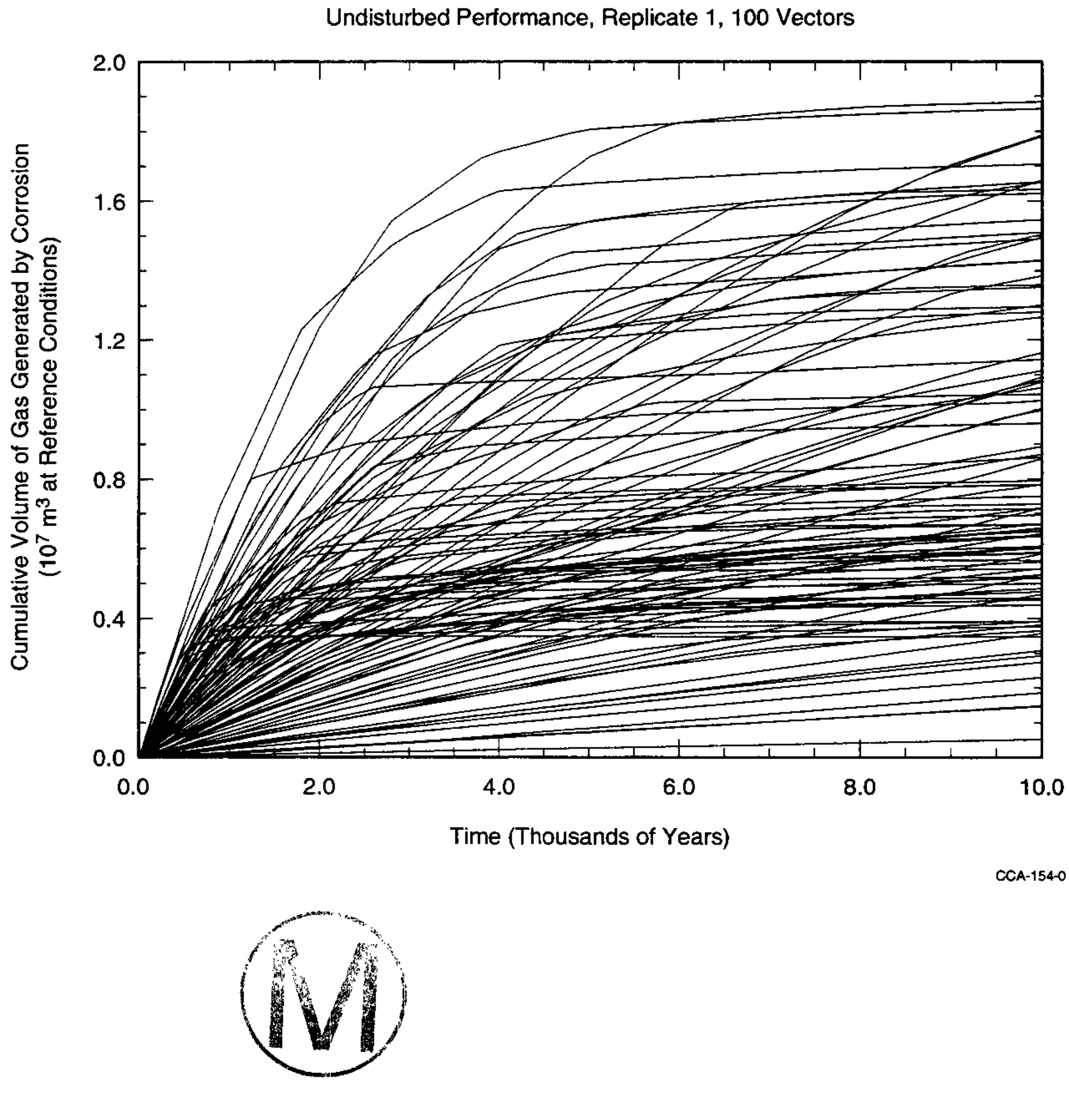

Figure 9-11. Total Gas Volume Generated by Corrosion of Iron, Undisturbed Performance

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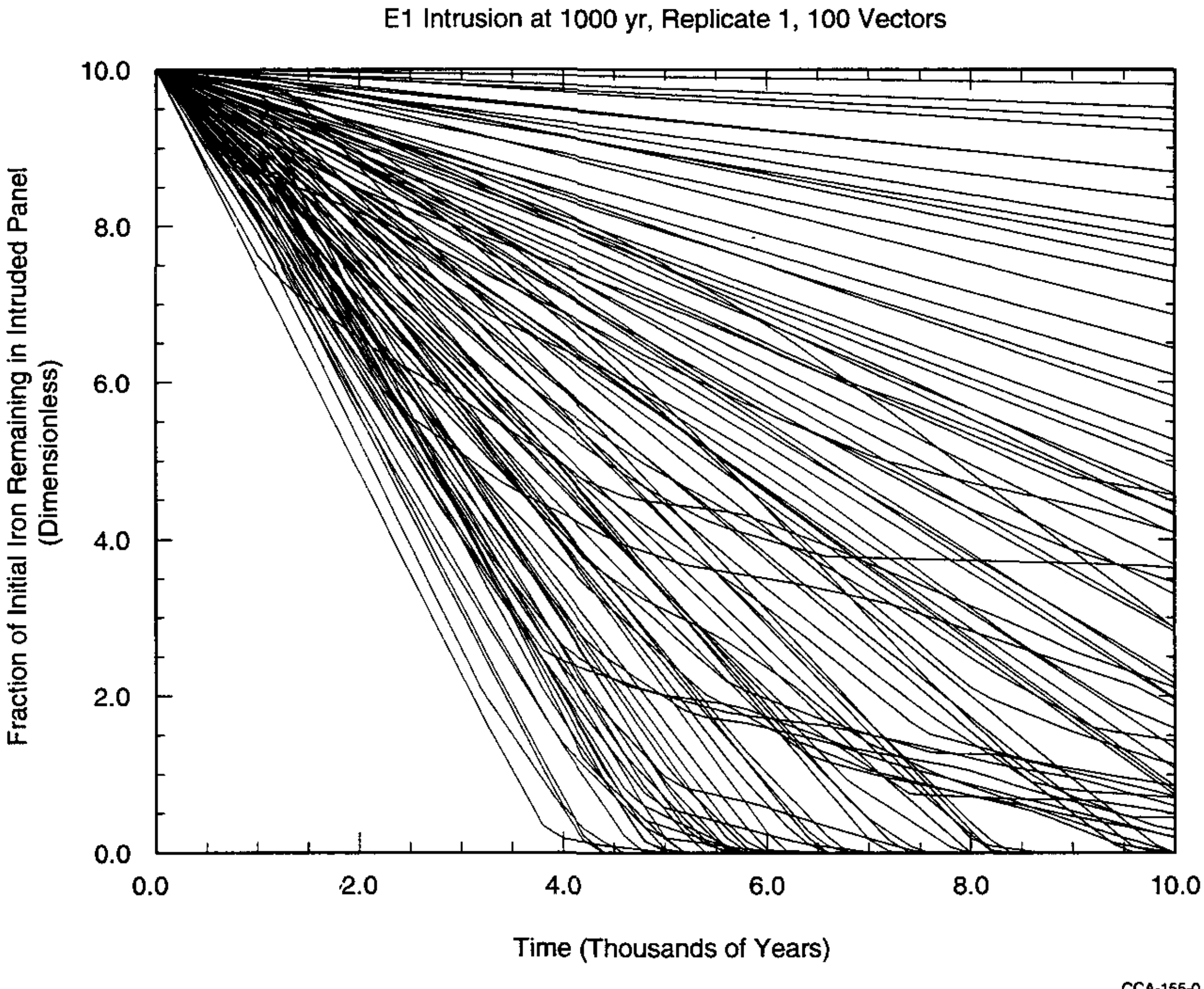

Figure 9-12. Fraction of Initial Iron Remaining in Intruded Panel, E1 Intrusion at 1000 Years

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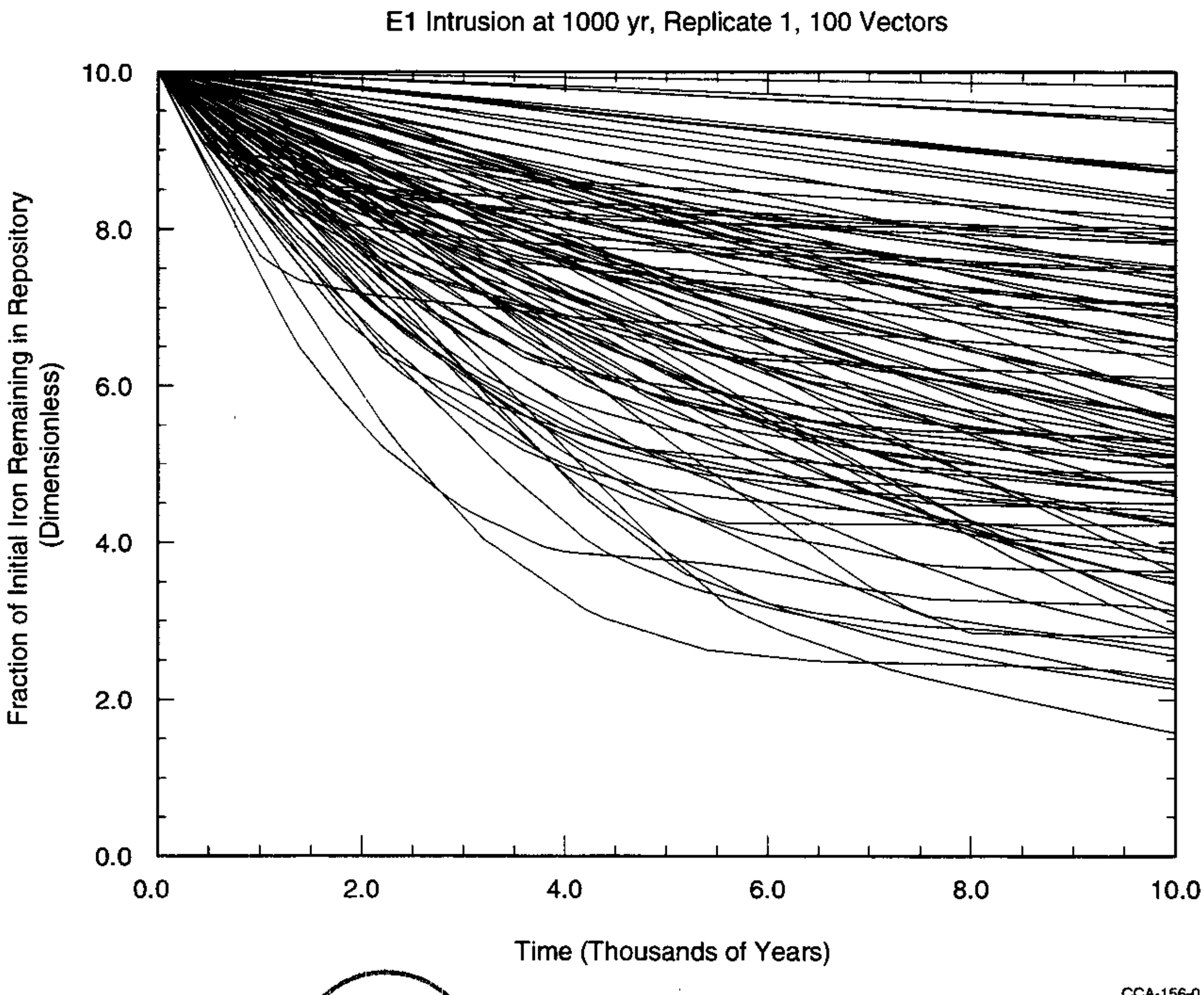

Figure 9-13. Fraction of Initial Iron Remaining in Repository, E1 Intrusion at 1000 Years

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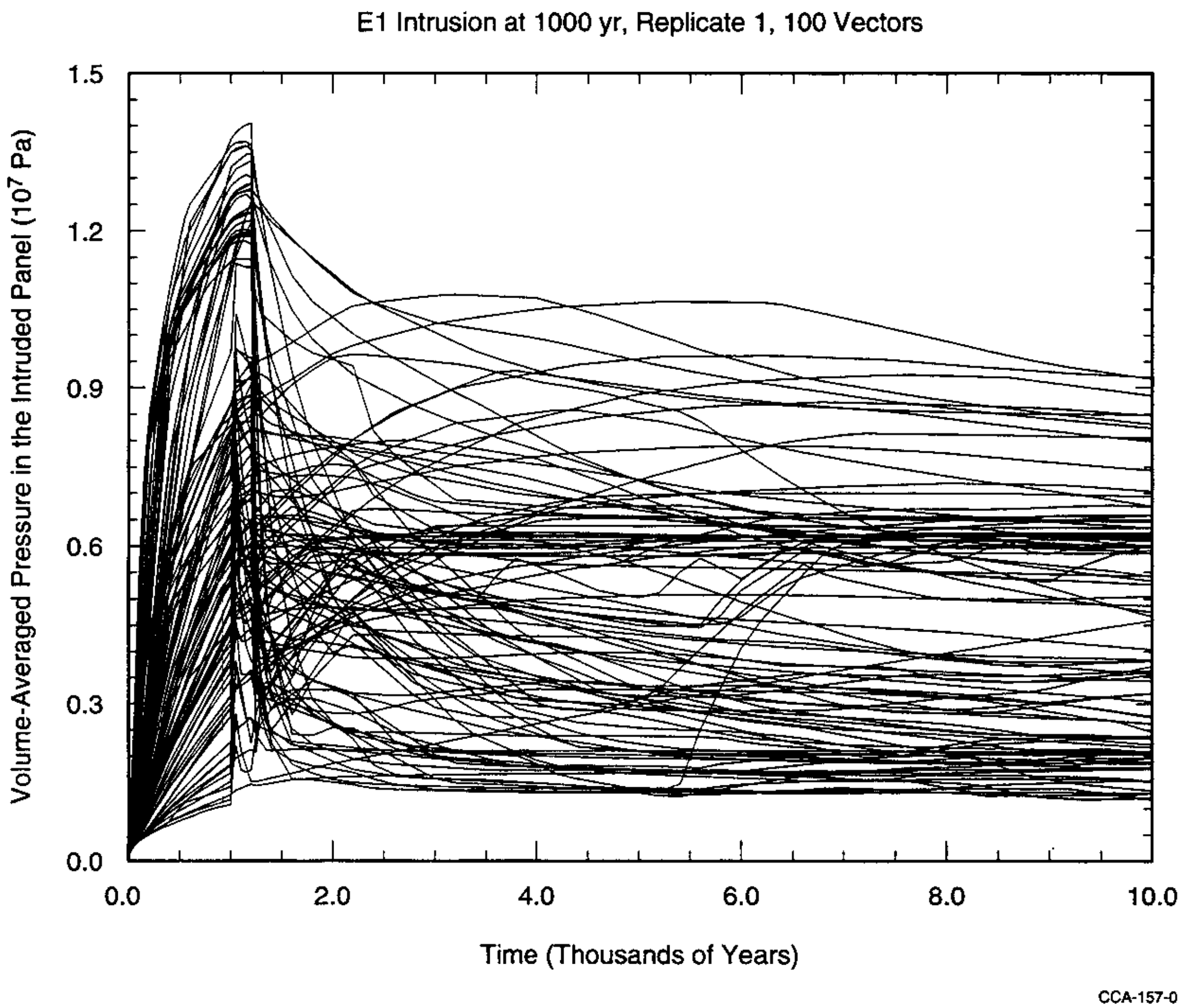

Figure 9-14. Volume Averaged Pressure in the Intruded Panel, E1 Intrusion at 1000 Years

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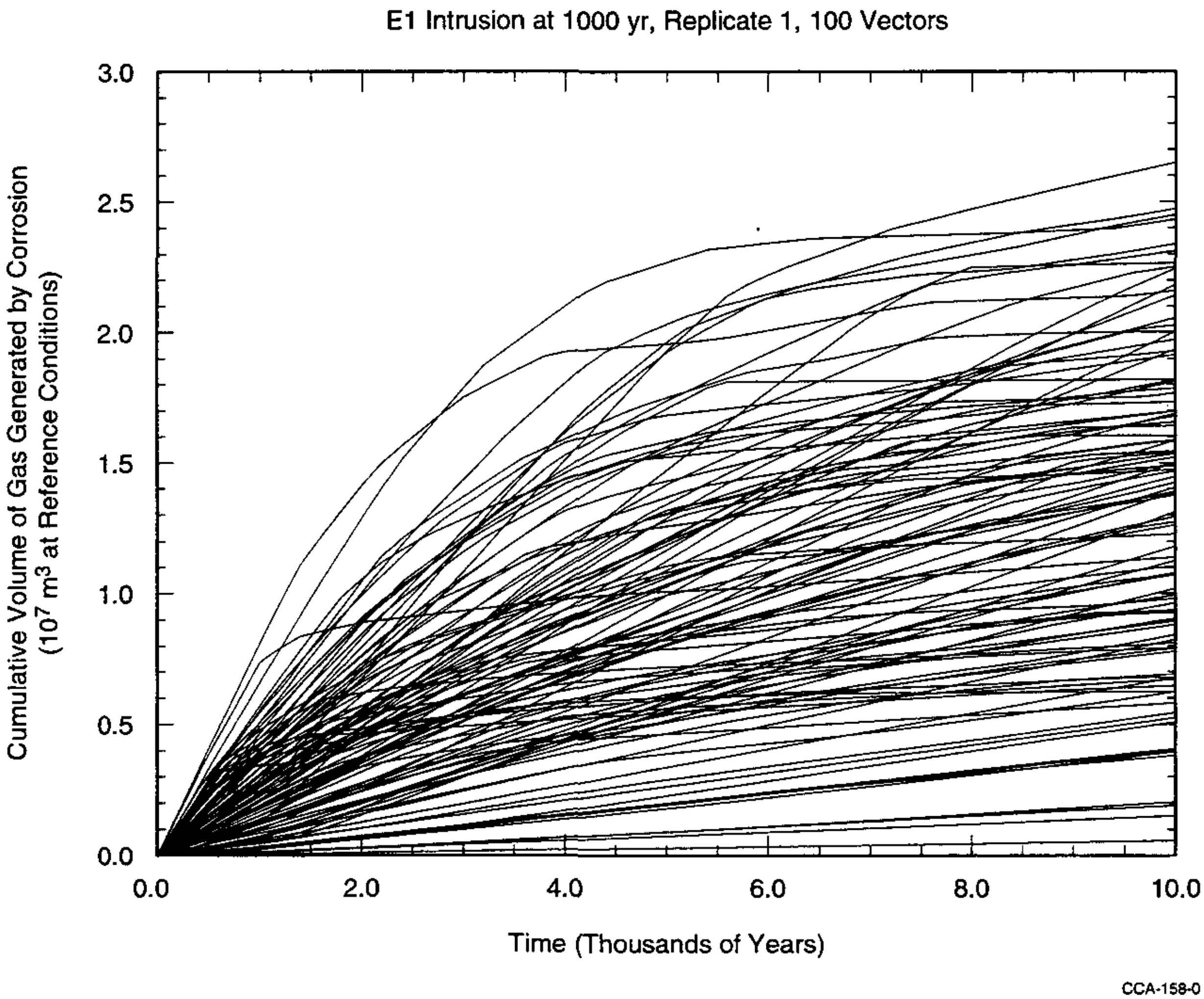

Figure 9-15. Cumulative Volume of Gas Generated by Corrosion of Iron, E1 Intrusion at 1000 Years

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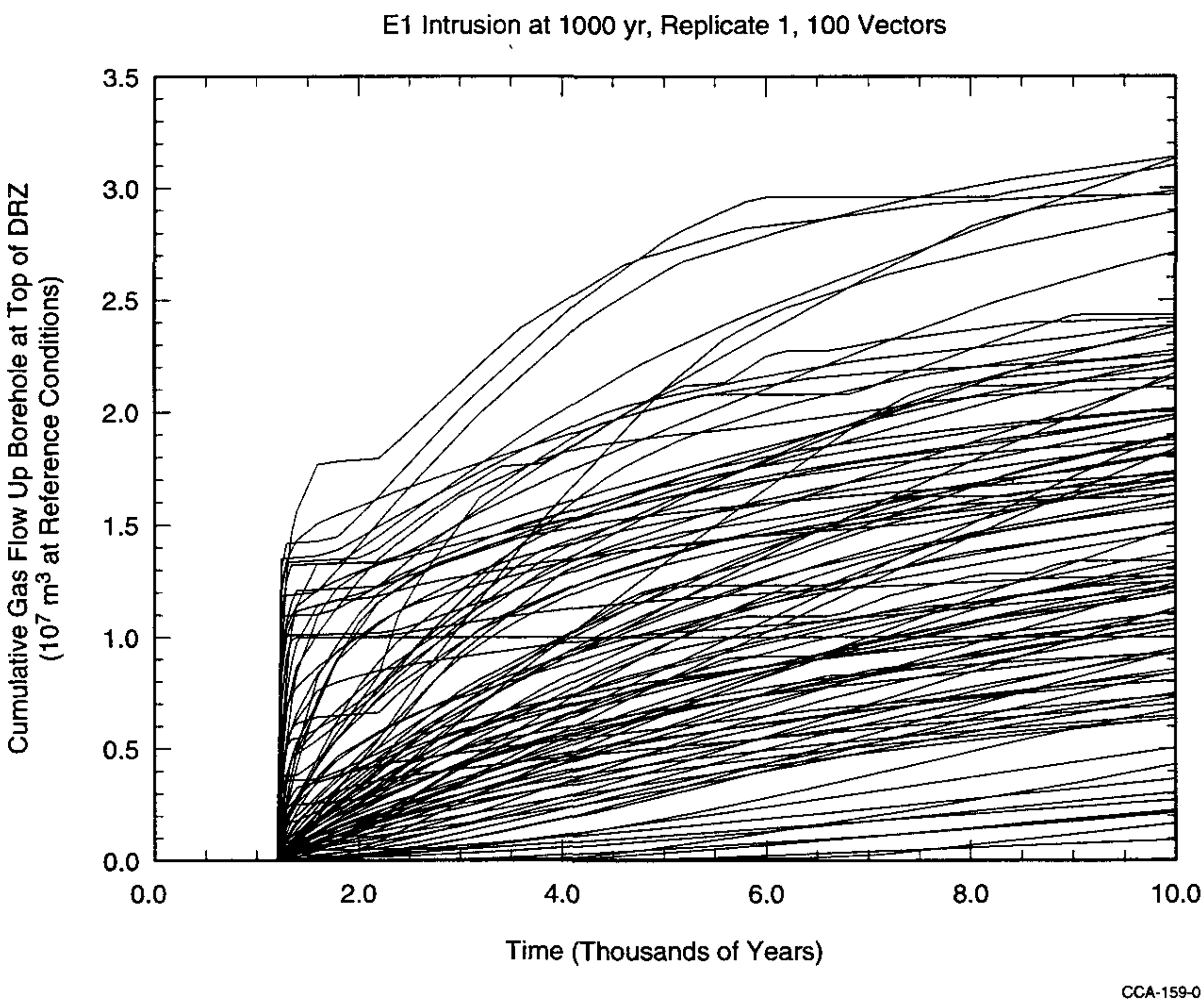

Figure 9-16. Cumulative Gas Flow Up the Borehole at the Top of the DRZ, E1 Intrusion at 1000 Years

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However, Figure 9-14 shows that this increase did not raise repository pressure significantly. In fact, the repository pressure remained well below the far-field pore pressure. This is because gas escaped up the borehole as fast as it was produced.

Furthermore, increased anoxic corrosion caused by human intrusion can affect repository performance beneficially by: (1) increasing the quantity of brine consumed, thus reducing the quantity that can flow up the borehole; (2) increasing the extent of gas interference with the flow of brine, thus decreasing the permeability of the borehole to brine.

Radiolysis. Predictions of gas production from radiolysis of brine by solid-phase actinides and radiolysis of combustibles would be subject to several uncertainties: (1) the particle-size distribution of actinide-bearing solids and, hence, the relative extent to which energy associated with α emissions from these solids will be absorbed by the solids, any brine present, and combustibles; (2) the extent to which actinide-bearing solids contact combustibles at the time of waste emplacement; and (3) the effects of room closure and long-term chemical reactions on the extent to which actinide-bearing solids contact combustibles.

Instead of attempting to predict the quantity of gas that will be produced from radiolysis of brine by solid-phase actinides and radiolysis of combustibles, the maximum quantity of gas that could be produced by these processes has been estimated and the effects of this gas on the long-term performance of the WIPP have been assessed. Although this estimate is probably much greater than the actual quantity of gas that will actually be produced by these processes, it would nevertheless have no significant effect on repository performance.

To estimate the maximum quantity of gas that could be produced from radiolysis of brine by actinide-bearing solids and radiolysis of combustibles, it was first assumed that all of the brine that will be consumed by corrosion would instead be consumed by radiolysis. The average-stoichiometry gas-generation model in BRAGFLO uses the following anoxic-corrosion reaction:

$$Fe + ((4 + 2x)/3)H_2O \Leftrightarrow xFe(OH)_2 + ((1 - x)/3)Fe_3O_4 + ((4 - x)/3)H_2. \quad (1)$$

However, Wang and Brush (1996a) specified a value of 1 for the stoichiometry factor x. Therefore, Reaction 1 reduces to:

$$Fe + 2H_2O \Leftrightarrow Fe(OH)_2 + H_2. \quad (2)$$

Brush (1995) gave the following reaction for α radiolysis of brine:

$$2H_2O \Leftrightarrow 2H_2 + O_2. \quad (3)$$

Because anoxic corrosion produces 0.5 mole of gas per mole of H_2O consumed and brine radiolysis produces 1.5 moles of gas per mole of H_2O consumed, the assumption that all of the brine that will be consumed by corrosion would instead be consumed by radiolysis increases the predicted quantity of gas by a factor of three.

It was then assumed that all of the combustibles that could be consumed by microbial activity would instead be consumed by radiolysis. The average-stoichiometry model uses the following, generalized microbial reaction:

$$CH_2O + \text{unknowns} + \text{microorganisms} \Rightarrow y\text{gas} + \text{unknowns}. \qquad (4)$$

However, to compute the stoichiometry factor "y" for the performance assessment calculations to support this application, Wang and Brush (1996a, 1996b) used the following reactions for microbial activity:

$$C_6H_{10}O_5 + 4.8H^+ + 4.8NO_3^- \Rightarrow 7.4H_2O + 6CO_2 + 2.4N_2; \qquad (5)$$

$$C_6H_{10}O_5 + 6H^+ + 3SO_4^{2-} \Rightarrow 5H_2O + 6CO_2 + 3H_2S; \qquad (6)$$

$$C_6H_{10}O_5 \Rightarrow 3CH_4 + 3CO_2. \qquad (7)$$

In these reactions, $C_6H_{10}O_5$ represents the substrate (cellulosics and, perhaps, plastics and rubbers). Although all three of these microbial reactions could occur in the repository, Reaction 7 (methanogenesis) will be much more significant than Reactions 5 (denitrification) and 6 (SO_4^{2-} reduction) because the quantities of cellulosics, plastics, and rubbers (the potential microbial substrates) in WIPP disposal rooms will be much greater than the quantities of NO^{3-} and SO_4^{2-} (the potential electron acceptors for microbial denitrification and SO_4^{2-} reduction, respectively). In the absence of radiolysis of combustibles, Reaction 7 will consume greater than 90 percent of these potential microbial substrates. This reaction produces one mole of gas per mole of organic C consumed but, because the MgO backfill will consume all of the CO_2, the net yield will be 0.5 mole of gas per mole of organic C consumed. Radiolysis of combustibles produces a variety of gases, the composition of which depends upon the composition of the material and the conditions under which it is irradiated. To estimate the quantity of gas that could be produced, the DOE has assumed that all of the combustibles in the repository will be consumed by radiolysis and that the gases produced will not include CO_2. The first assumption is highly conservative because it is highly unlikely that the entire surface area of the combustibles will be exposed to α radiation for a significant portion of the 10,000-year period of performance of the repository. Furthermore, even if this occurred, the range of α particles in combustibles such as plastics is generally a few tens of microns. This is significantly less than the thickness of these materials, typically several mils to several tens of mils in the case of plastic drum liners (Brush 1990). The second assumption is also conservative because radiolysis of combustibles produces CO_2, among other gases (see, for example, Molecke 1979). It has also been assumed that radiolysis will produce one mole of gas per mole of organic C consumed, an assumption which may or may not be conservative. Because microbial activity (in the presence of MgO) produces 0.5 mole of gas per mole of organic C consumed and radiolysis of combustibles produces 1.0 mole of gas per mole of organic C consumed, the assumption that all of the combustibles would be consumed by radiolysis increases the predicted quantity of gas by a factor of two.

The assumptions that all of the brine that will be consumed by corrosion would instead be consumed by radiolysis and that all of the combustibles that could be consumed by microbial activity would instead be consumed by radiolysis would at most increase the quantity of gas produced in a given realization by a factor of two to three. The actual factor by which the quantity of gas produced would increase depends on the relative amounts of gas produced by corrosion and microbial activity. If radiolysis consumed some, but not all, of the brine and some, but not all, of the combustibles, the increase could be significantly less than a factor of two to three.

In any case, the DOE has concluded that increasing the quantity of gas by a factor of two or three would not affect the long-term performance of the repository deleteriously. BRAGFLO calculations conducted for the this application have shown that, in the absence of human intrusion, the repository pressure increased to values equal to or slightly greater than lithostatic pressure in several realizations even without radiolysis (see Figure 9-17). The pressure did not exceed 16.5 megapascals in these calculations because BRAGFLO includes a model to simulate fracturing in the anhydritic interbeds above and below the repository (Anhydrites A and B, MB138, and MB139). If the repository pressure exceeds 12.7 megapascals, the fracture model generates additional voids in and increases the permeability of these interbeds, thus limiting the pressure to 16.5 megapascals. Increasing the quantity of gas produced by a factor of two to three would increase the number of vectors in which lithostatic pressure is attained, but not the maximum pressure.

Figure 9-18 shows the cumulative mass of contaminated brine (brine that has been in the waste-disposal area) as a function of time. After 10,000 years, the largest quantity of contaminated brine in all the interbeds is only about 2,000 kilograms (1.6 cubic meters), even with a repository pressure of 16.5 megapascals. The reason that so little brine flowed out of the repository under undisturbed conditions is that brine was consumed rapidly by corrosion, not low pressure. Any additional brine that flowed in was in most cases rapidly consumed. This maintained the brine content of the repository at levels low enough to prevent additional brine outflow despite the pressure gradient. In view of these results, it is highly unlikely that increasing the quantity of gas produced by a factor of two to three would increase brine outflow enough to be of regulatory concern.

In the event of human intrusion, increased gas production will not increase direct release of brine nor spallings to the surface, nor the long-term release of dissolved radionuclides. Figures 9-19 and 9-20 show that direct releases to the surface during drilling occurred only in those realizations in which the repository pressure was greater than 8 megapascals. However, at pressures above 8 megapascals, there was no correlation between the pressure and the size of the release. Furthermore, Figures 9-21 and 9-22 show that, for the E1 and E2 human-intrusion scenarios, there was no correlation between the quantity of gas produced and the pressure. This is because gas escaped up the borehole as fast as it was produced (see above).

Therefore, increasing the quantity of gas produced by a factor of two to three would not increase direct releases. Similarly, increasing the quantity of gas would not increase long-term dissolved releases because of gas escape up the borehole. In fact, in the event of multiple intrusions, venting decreased the pressure to values at or close to hydrostatic pressure as the brine content of the repository increased (see Figure 9-23).

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.1.2.10.2 Second Peer Review Panel Concern - Gas Generation

> *An adequate basis has not been presented for the assumption of complete and rapid carbon dioxide removal by magnesium oxide in the waste panels. The chemical conditions in the repository would significantly change if the magnesium oxide did not function as planned, and could result in higher radionuclide releases than the model would estimate.*

Statement of Issues (Note: For the purpose of this response, the above gas generation concern has been combined with the chemical conditions concerns regarding the assessment of phase equilibria and the reaction of the MgO backfill with the CO_2 generated by microbial action [see Section 9.3.1.2.11.2.1].)

The panel understands that in theory MgO (periclase) and $Mg(OH)_2$ (brucite) react with CO_2 to create carbonate phases such as $MgCO_3$ (magnesite). The carbonate equilibria impose a pH control on the brines resident in the waste panels. The panel questions whether or not the buffering phases will form fast enough that no excess CO_2 will remain. In addition, the panel recognizes that equilibrium thermodynamic codes have performed calculations of the phases and compositions that will be stable in the WIPP repository. The panel questions whether or not the codes were sufficiently complete to account for all possible Mg-containing carbonate phases that might occur either through absolute stability or metastable stability. The panel's concern is that the actual phase assemblage may impose geochemical conditions that differ from those calculated, and that the actual conditions might result in different solubilities and mobilities for mobilized waste components.

Response to Issues (Note: For the purpose of this response, the above gas generation concern has been combined with the chemical conditions concerns regarding the assessment of phase equilibria and the reaction of the MgO backfill with the CO_2 generated by microbial action [see Section 9.3.1.2.11.2.1].)

The ability of MgO to perform as expected is dependent on the following requirements:

1) The MgO will interact with any brine which may enter the repository and participate in transport.

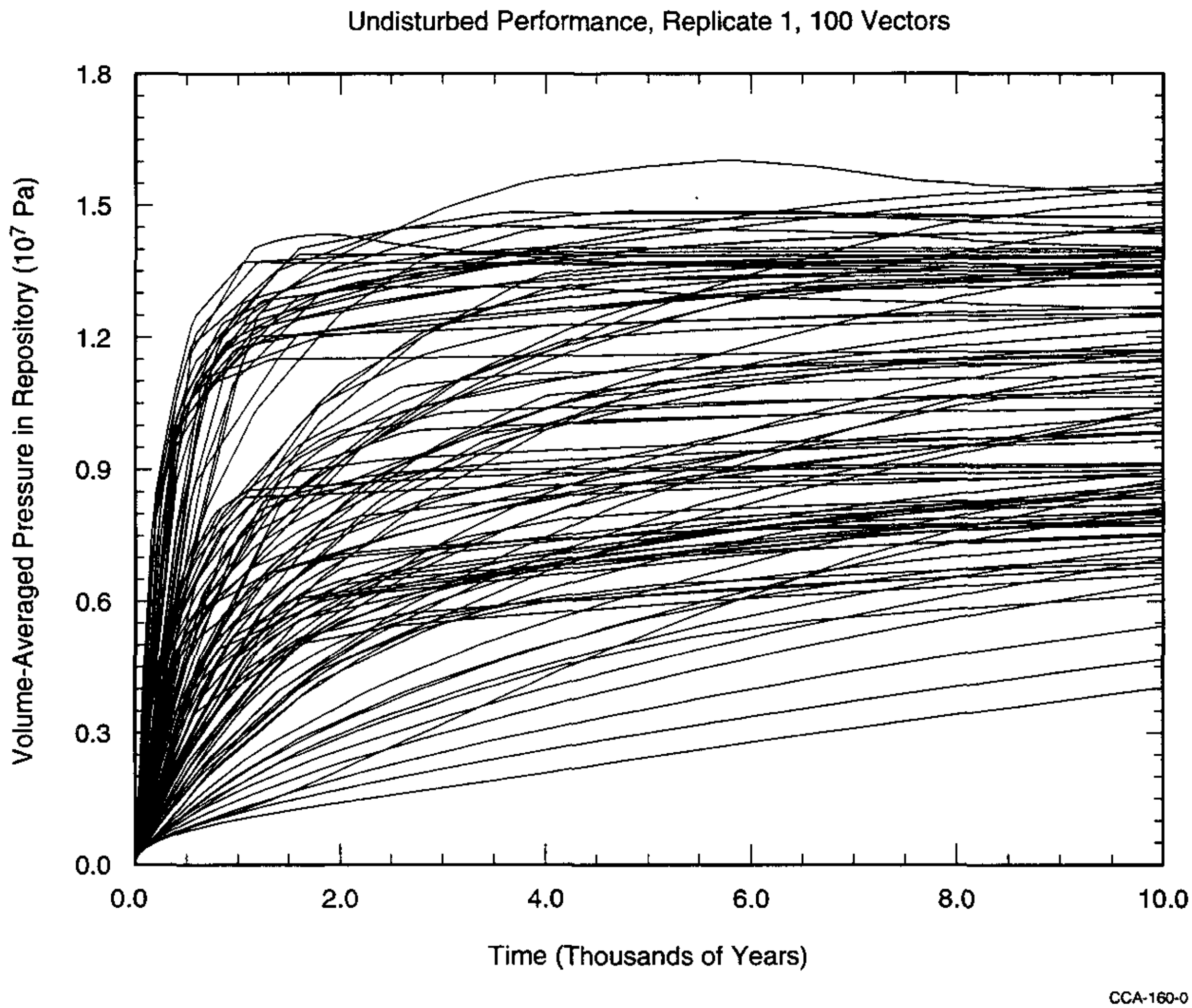

Figure 9-17. Volume-Averaged Pressure in the Repository, Undisturbed Performance

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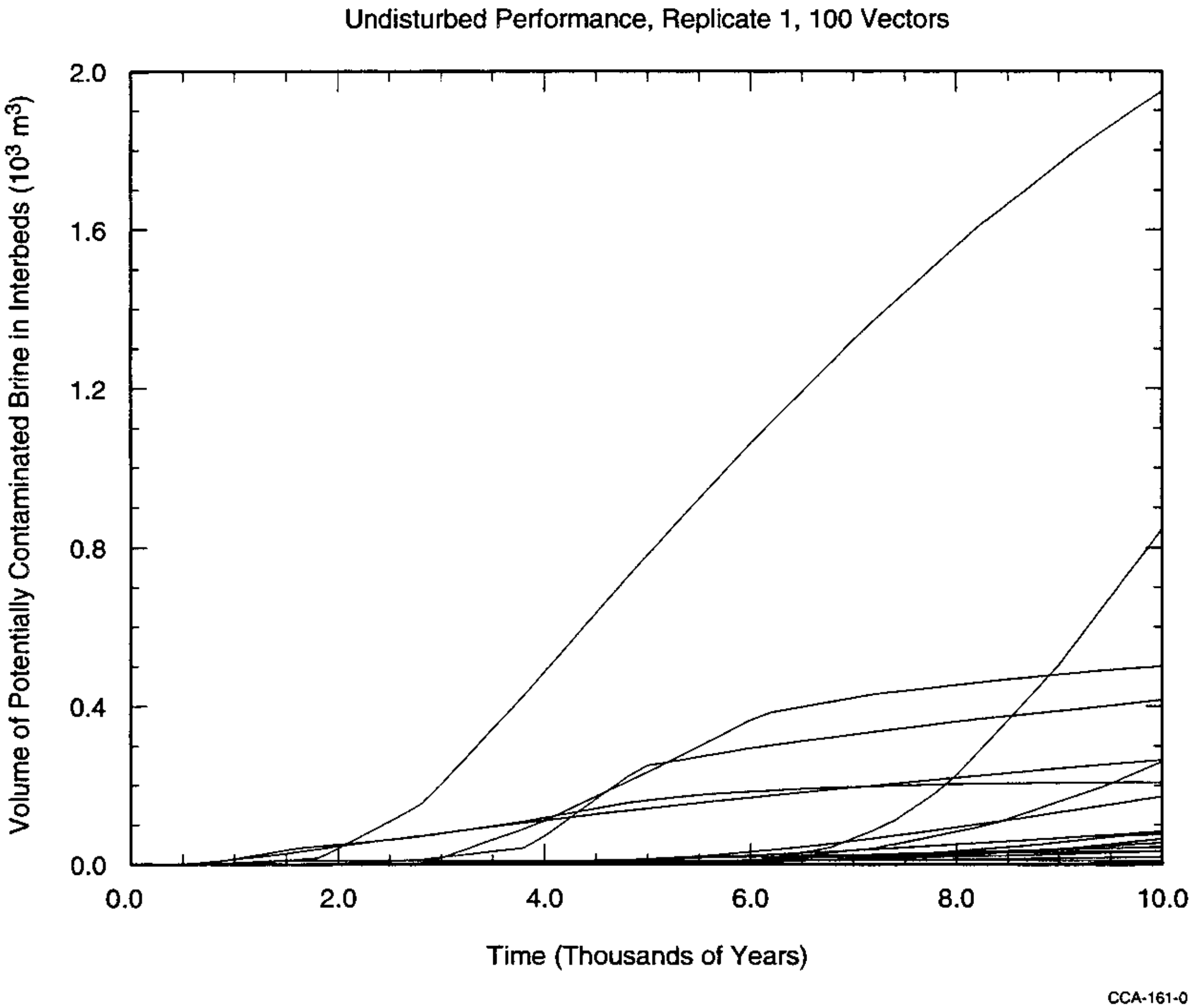

Figure 9-18. Volume of Brine in Anhydrite Interbeds That Has Previously Been in Contact with Waste, Undisturbed Performance

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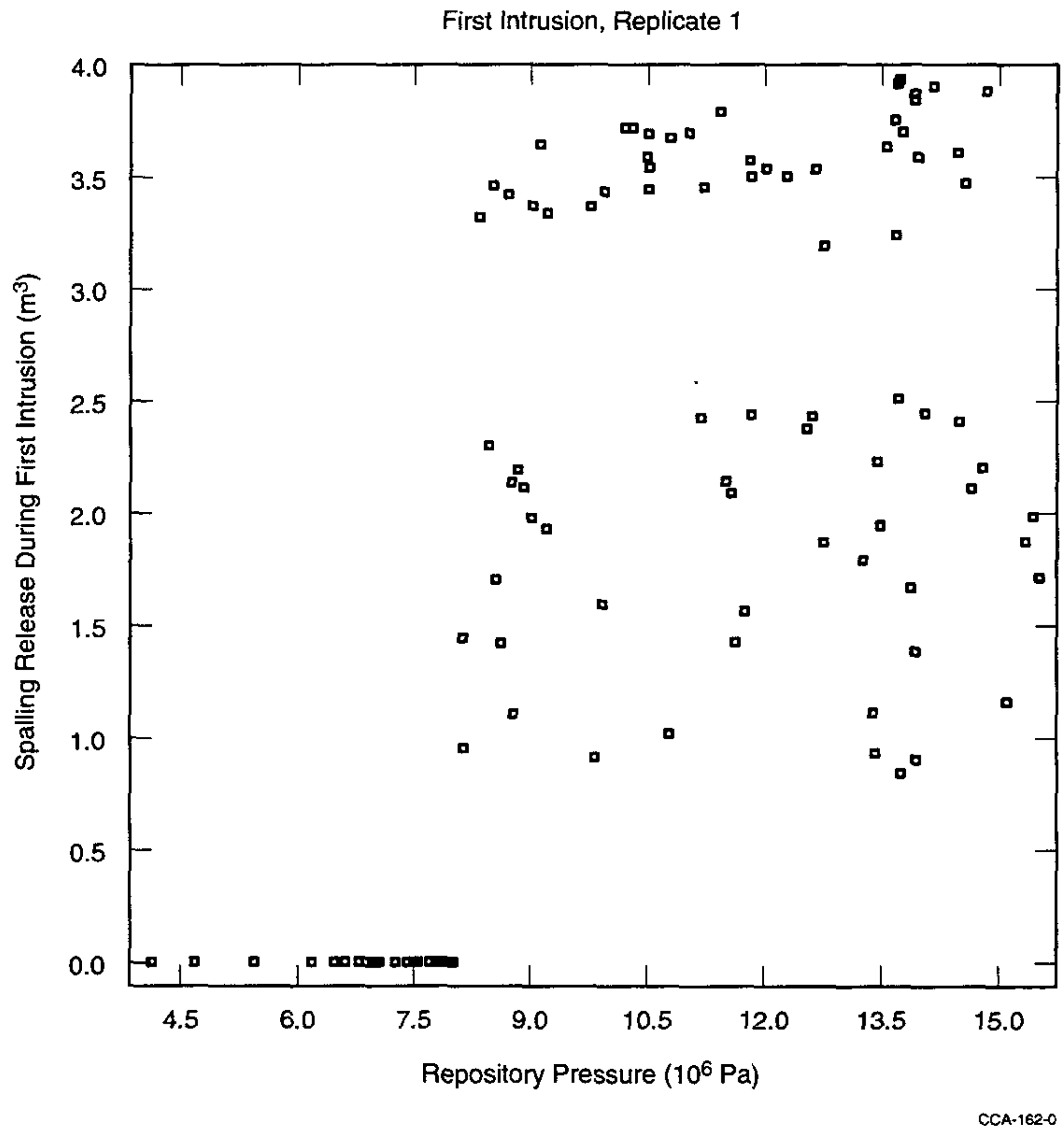

Figure 9-19. Scatterplot Showing Relationship of Spalling Releases to Repository Pressure, First Intrusion into the Repository

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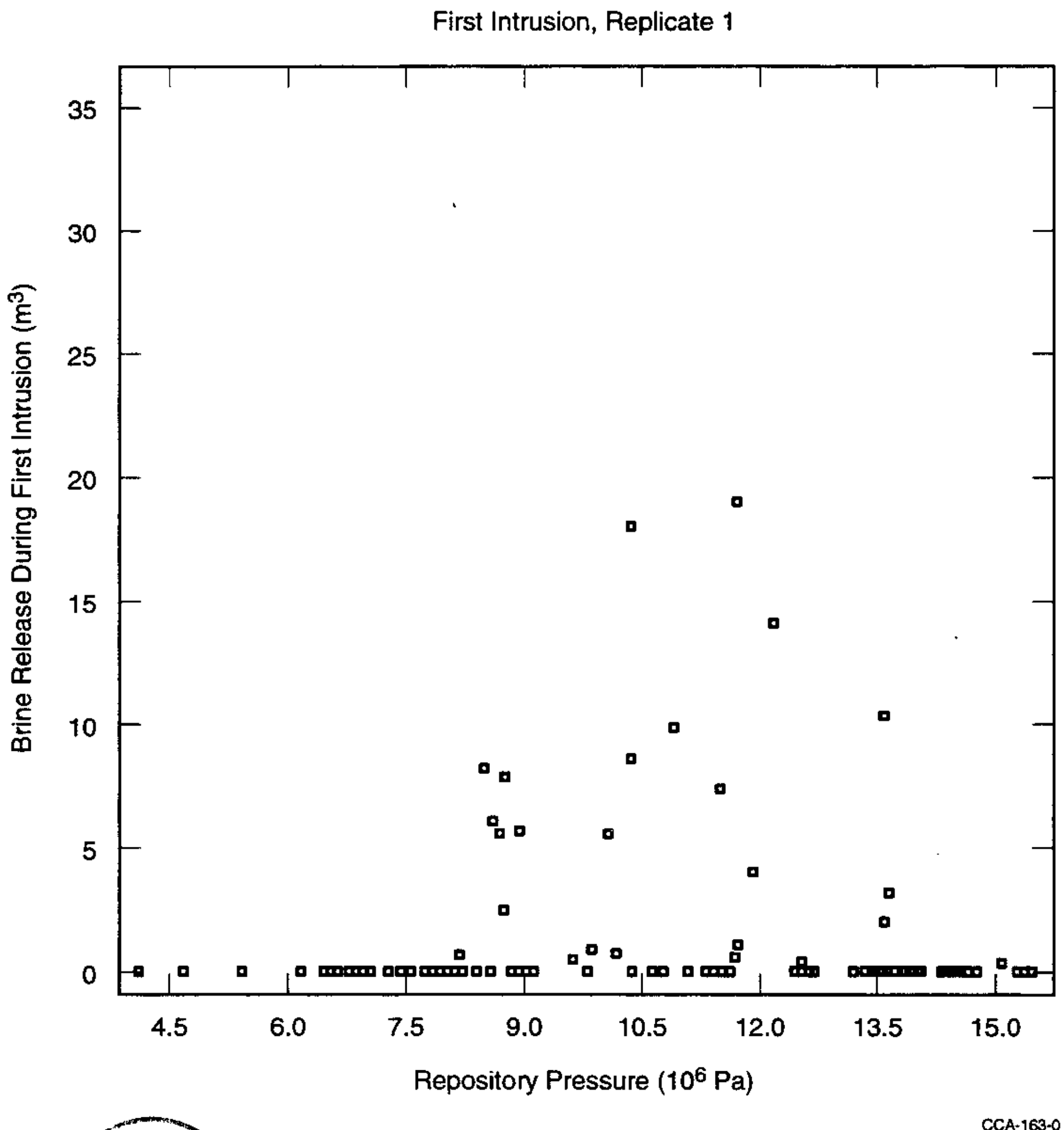

Figure 9-20. Scatterplot Showing Relationship of Direct Brine Releases to Repository Pressure, First Intrusion into the Repository

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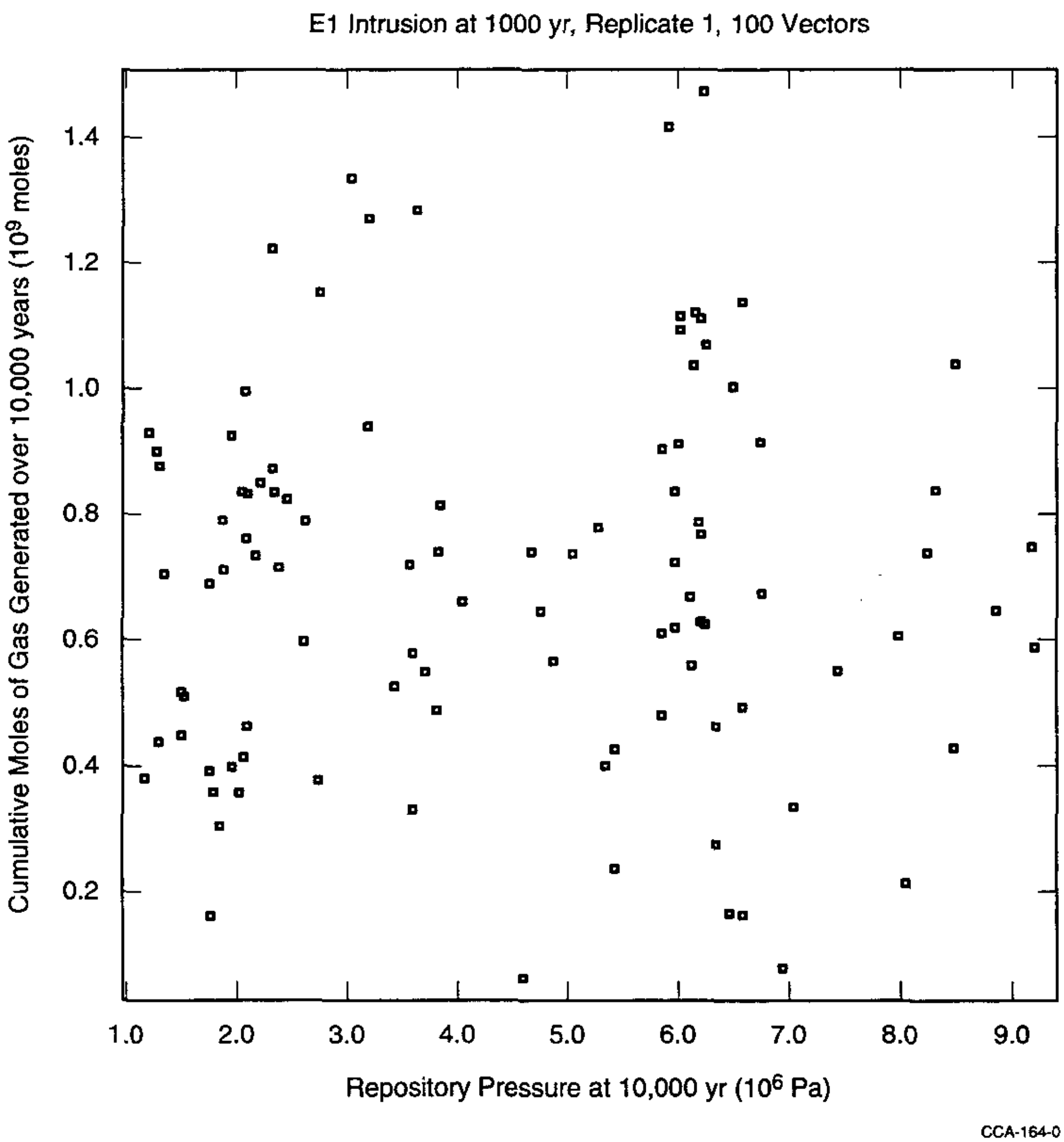

Figure 9-21. Scatterplot Showing Relationship of Total Moles of Gas Generated to Final Repository Pressure (E1 Intrusion at 1000 years)

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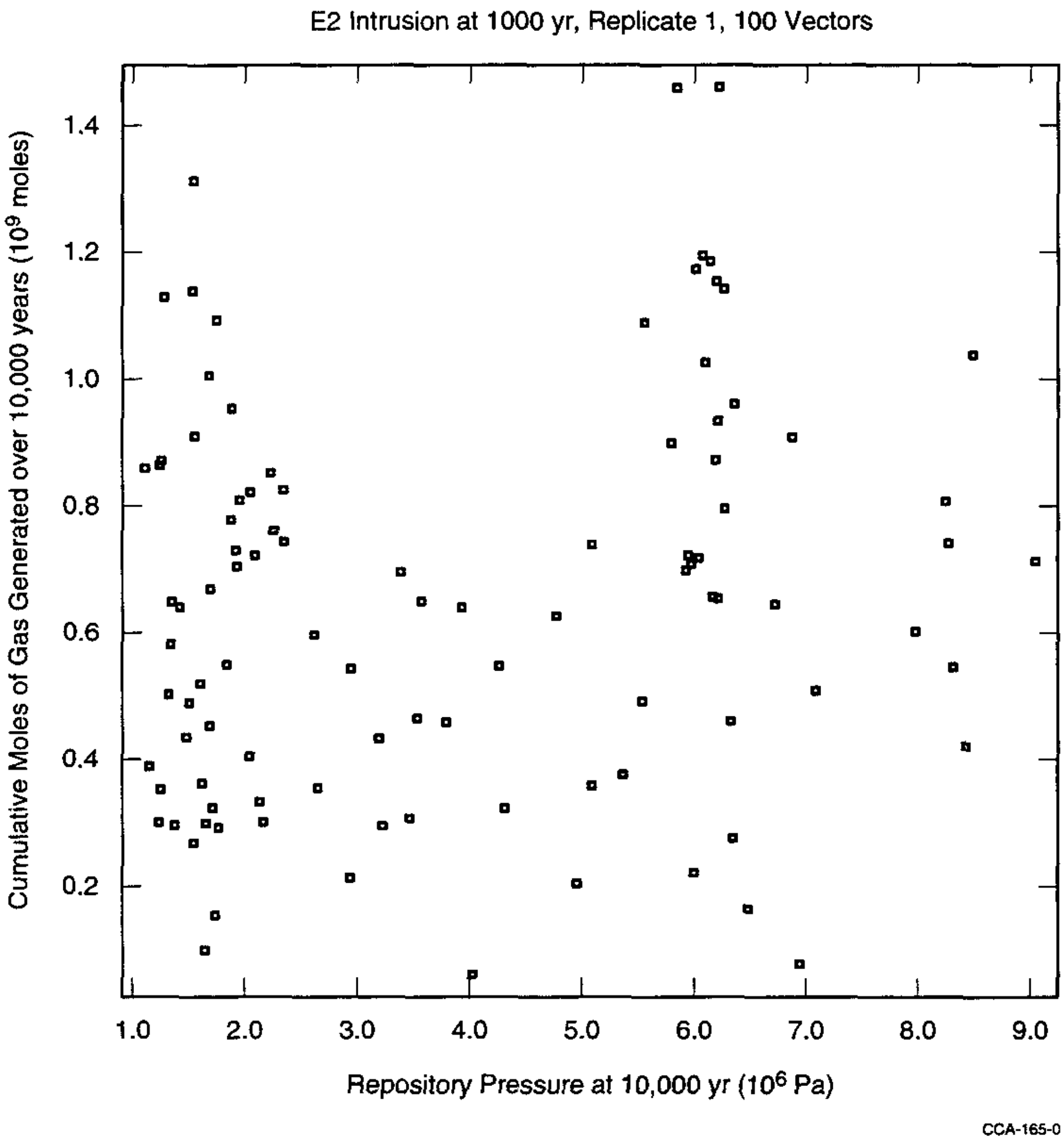

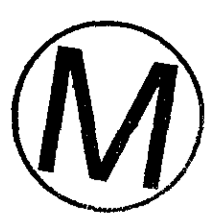

Figure 9-22. Scatterplot Showing Relationship of Total Moles of Gas Generated to Final Repository Pressure (E2 Intrusion at 1000 years)

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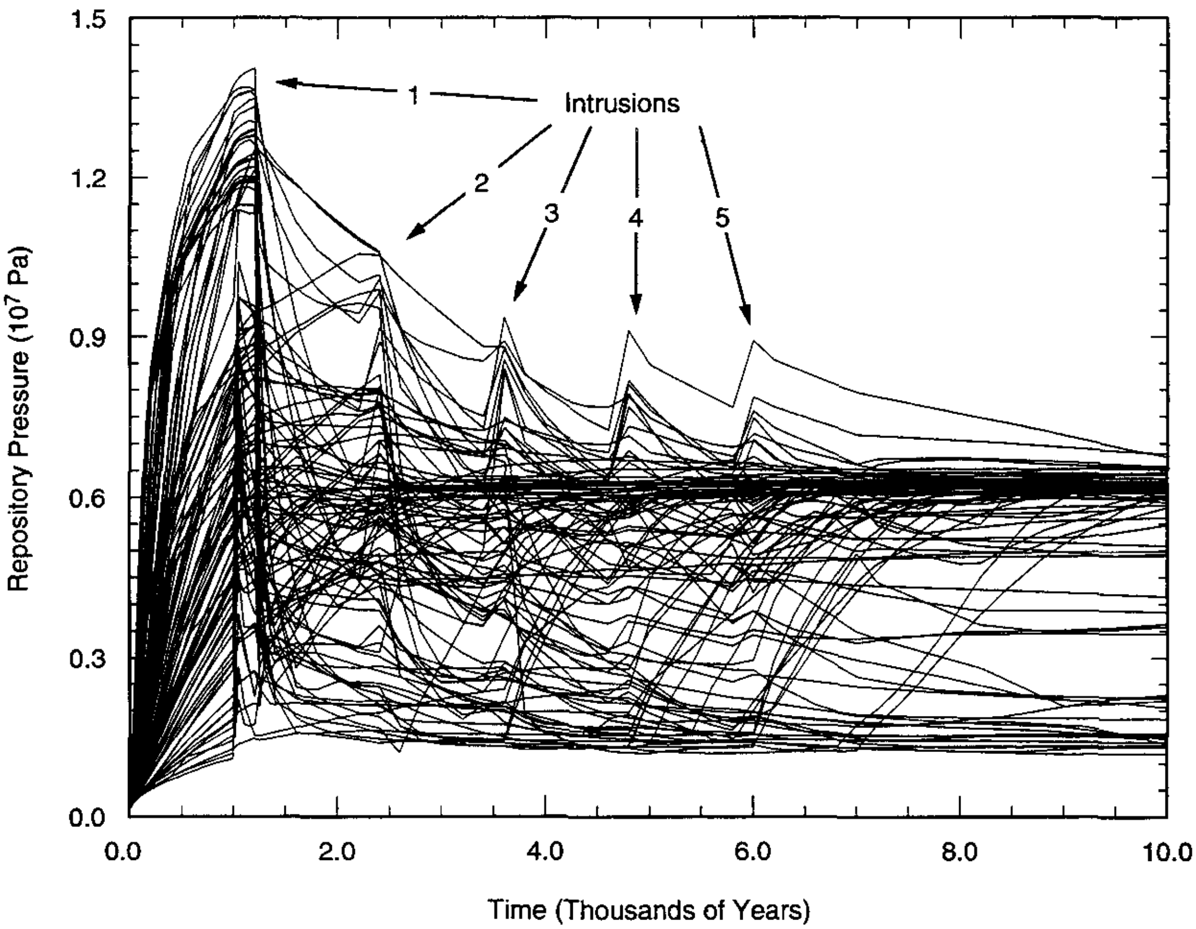

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Figure 9-23. The Effect of Multiple Intrusions on Repository Pressure

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2) There is at least a stoichiometric amount of MgO available with respect to the maximum quantity of CO_2 that may be generated.

3) The rate of reaction of MgO and/or $Mg(OH)_2$ with CO_2 is equal to or greater than the maximum CO_2 generation rate.

4) Stable magnesium carbonate containing phases will exist under anticipated repository conditions. (This addresses in particular, Concern 3 above.)

The first requirement above is satisfied by the emplacement strategy being pursued. The MgO backfill will be placed in intimate contact with the waste via bags on top of the waste stack, bags within the seven packs, and bags along the ribs of the repository. Additionally, as room closure progresses, the waste and backfill will be further mixed via compression and consolidation of the waste and rupture of the waste drums and packaging. The mean residence time of brine in the repository is a few hundred years. Over this time scale, the brine chemistry will be significantly homogenized over an approximately 1 meter spatial scale (the approximate height of the waste after compression and compaction by room closure) by diffusion. Thus, there are no flow paths which can bypass the backfill.

The second requirement is being satisfied by the specification for the amount of backfill to be emplaced. Even if all of the cellulosics, rubbers, and plastics were to be converted to CO_2, the specification for the amount of MgO backfill to be emplaced is at least a two-fold excess of MgO above the stoichiometrically required amount.

The third requirement is addressed through an understanding of the chemical processes which will occur in the repository. The MgO backfill is expected to react with any brine or humidity in the air entering the repository via the following reaction:

$$MgO + H_2O \rightarrow Mg(OH)_2$$

This reaction is based on thermodynamic principles, the fact that MgO is commonly used as a desiccant, and the well known deliquescent behavior of alkaline earth oxides which react with water to form the alkaline earth hydroxides.

Any CO_2 which may be generated in the repository can react with either the MgO or $Mg(OH)_2$ via the following equations:

$$MgO + CO_2 \rightarrow MgCO_3$$

or

$$Mg(OH)_2 + CO_2 \rightarrow MgCO_3 + H_2O$$

Both of these reactions are thermodynamically favorable. Therefore, the issue comes down to the rate at which the reaction(s) may occur. Assuming that reaction rates in solution are relatively fast when compared to the geologic time scale, the rate limiting factor is the rate at which magnesium ions leave the surface of the MgO. The rate at which MgO dissolves has been previously studied (see Terry 1983, 315 – 344). Extending the cited values to the pH range expected in an MgO backfilled repository provides an average rate of MgO dissolution of 1.5×10^{-12} moles per square centimeter per second. The total quantity of cellulosics, rubbers, and plastics which are anticipated to be placed in the repository is 2.7×10^{7} kilograms (166 kilograms per cubic meter average cellulosics, rubbers, and plastics loading in a 1.6×10^{5} cubic meters total waste volume) (DOE 1995a). The maximum rate of CO_2 generation is 9.51×10^{-9} moles CO_2/kg/sec (see Appendix PAR). Thus, the maximum CO_2 generation rate for the entire repository is 0.2 moles CO_2/sec.

Given the maximum rate of CO_2 generation and the maximum rate of MgO dissolution (as a function of surface area), the theoretical minimum particle size which will have sufficient surface area to ensure reaction with the CO_2 as it is generated can be calculated. First, the minimum surface area per gram (that is, specific surface area) is calculated by dividing the total surface area required by the total number of grams of MgO emplaced. The total surface area required is given by:

$$(2.6 \times 10^{-1} \text{ moles } CO_2 \text{ generated/sec}) \times (1 \text{ mole MgO/1mole } CO_2) \times$$
$$(1/1.5 \times 10^{-12} \text{ moles MgO/cm}^2\text{/sec}) = 1.76 \times 10^{11} \text{ cm}^2 \text{ MgO}$$

The total number of grams of MgO emplaced is given by:

$$(83{,}150 \text{ tons MgO}) \times (2000 \text{ lbs/ton}) \times (453\text{g/lb}) = 7.5 \times 10^{10} \text{ g MgO}$$

Thus, the minimum required surface area per gram of MgO is:

$$(1.76 \times 10^{11} \text{ cm}^2 \text{ MgO}) / (7.5 \times 10^{10} \text{ g MgO}) = 2.3 \text{ cm}^2\text{/g MgO}$$

Assuming a spherical particle, the surface area is $= 4\pi r^2$. Using "P_m" for the mass of a particle, the density can be expressed as:

$$\text{density} = P_m /(4/3\pi r^3)$$

Rearranging for the mass of a particle provides:

$$P_m = (4/3\pi r^3)(\text{density}) \quad \text{(eq. A)}$$

The specific surface area per gram may be expressed as:

$$\text{specific surface area} = 4\pi r^2 / P_m \qquad \text{(eq. B)}$$

Now, dividing equation A by equation B gives:

$$P_m/(\text{specific surface area}) = [(4/3\pi r^3)(\text{density})] / [4\pi r^2/P_m]$$

Solving for "r" provides the maximum particle radius which can accommodate the maximum CO_2 generation rate

$$[P_m/(\text{ specific surface area})] [4\pi r^2/P_m] = [(4/3\pi r^3)(\text{density})]$$

$$[4\pi r^2/(\text{ specific surface area})] = [(4/3\pi r^3)(\text{density})]$$

$$[1/(\text{ specific surface area})] = [(r/3)(\text{density})]$$

$$r = 3/[(\text{ specific surface area})(\text{density})]$$

Utilizing a crystalline density of 3.53 g/cm^3 provides

$$r = 3/[(2.3\ \text{cm}^2/\text{g})(3.53\ \text{g/cm}^3)]$$

or

$r = 0.37$ cm

Therefore, as long as the particles of the MgO backfill are no greater than 0.37 centimeter radius (or 0.74 centimeter in diameter), there will be sufficient surface area for the MgO dissolution to maintain pace with the maximum CO_2 generation. This minimum surface area is conservative in that it assumes only the exterior surface is available for reaction and a crystalline material is used. In reality, the particles of MgO will be amorphous and thus will have a much higher effective surface area as there will be some porosity (possibly of the order of 50 percent) to the particles.

The fourth and final requirement states that magnesium carbonate containing phases will be formed and will be stable under expected repository conditions. To demonstrate this, multiple thermodynamic modeling codes (for example, FMT [Novak 1995], EQ3/6 [Wolery 1992; Wolery and Daveler 1992], Geochemist's Workbench [Bethke 1994]) have been utilized. These modeling codes take into consideration many potential mineral phases (for example, 50 mineral phases were considered within the EQ3/6 simulation) and utilize a Gibbs free energy minimization method to predict the most stable phase for a given set of conditions. In each case, the modeling simulation predicts that magnesite and brucite will be formed within the system and that these phases are thermodynamically stable regardless of whether a Salado or Castile brine composition is used. If the formation of magnesite is suppressed within the calculations, other magnesium carbonate containing phases form which provide approximately the same chemical conditions as when magnesite is allowed to form.

Since the chemical conditions must be maintained over the repository life-time, the long-term stability of the mineral phase must also be considered. The most compelling arguments for the long-term stability of any mineral phase involve natural analogues. In this case, the most compelling case for a natural analog is the natural occurrence of magnesite in the Salado formation itself (Stein 1985). Therefore, the DOE maintains that magnesium carbonate containing phases will be stable under anticipated repository conditions.

For simulations of the equilibrium conditions which are expected in the WIPP repository, the Harvie, Møller, and Weare database (Harvie et al. 1984) was used which contains the approximately fifty mineral phases listed in Table 9-2. This database is not unique to EQ3/6 (Wolery 1992; Wolery and Daveler 1992), but is used by most codes seeking to model high ionic strength solutions. The Harvie, Møller, Weare database has been shown to be appropriate for systems similar to WIPP (Felmy and Weare 1986) and is well accepted within the scientific community. Since the Harvie, Møller, Weare database and the codes which utilize it are based on equilibrium thermodynamics, a kinetically unfavorable transition is not automatically accounted for as appropriately noted by the CMPR panel. To simulate such effects, the formation of the more thermodynamically stable, yet potentially kinetically unfavorable phase is suppressed and the system allowed to re-establish equilibrium. These studies were performed for the WIPP system with MgO backfill. What was found was that, upon suppression of the two potentially kinetically unfavorable phases (that is, magnesite and dolomite), other magnesium carbonate containing phases (for example, hydromagnesite) are formed which yield approximately the same chemical conditions as when these phases are enabled. Therefore, the DOE analysis did take into consideration the possibility of kinetically unfavorable phases and found no significant impact.

In the MgO backfilled WIPP system, there will always be a brucite phase formed due to the large excess of MgO being added to the system. This brucite phase establishes one dimension of the phase diagram for the system as shown in Figure 9-24. The formation of magnesite in the repository will yield the conditions as shown at the intersection of the brucite and magnesite lines, corresponding to a log fCO_2 of approximately -6.4. If the formation of magnesite does not occur, as simulated by its suppression, the conditions in the repository will correspond to those along the brucite line where it intersects with the next magnesium carbonate containing phase, in this case hydromagnesite, yielding a log fCO_2 of approximately -5.6. This small difference in fCO_2, if indeed it occurs, is not sufficient to cause significant changes in the actinide solubility.

The formation of metastable carbonate phases and their ability to freeze the reaction progress is the subject of much uncertainty and speculation. The formation of magnesite at low temperatures, for example, is subject to some question due to kinetic effects (Peterson et al. 1966; Christ and Hostetler 1970). However, low temperature authigenic magnesite is found in hypersaline environments (Graf et al. 1961; Von der Borch 1965; Christ and Hostetler 1970), which are similar to the expected repository environment. Sayles and Fyfe (1973) have

Table 9-2. Harvie, Møller, Weare Database

Name	Formula
Anhydrite	$CaSO_4$
Aphthitalite (Glaserite)	$NaK_3(SO_4)_2$
Antarcticite	$CaCl_2 \bullet 6H_2O$
Aragonite	$CaCO_3$
Arcanite	K_2SO_4
Bischofite	$MgCl_2 \bullet 6H_2O$
Bloedite	$Na_2Mg(SO_4)_2 \bullet 4H_2O$
Brucite	$Mg(OH)_2$
Burkeite	$Na_6CO_3(SO_4)_2$
Calcite	$CaCO_3$
Calcium Chloride Tetrahydrate	$CaCl_2 \bullet 4H_2O$
Calcium Oxychloride A	$Ca_4Cl_2(OH)_4 \bullet 13H_2O$
Calcium Oxychloride B	$Ca_2Cl_2(OH)_2 \bullet H_2O$
Carnallite	$KMgCl_3 \bullet 6H_2O$
Dolomite	$CaMg(CO_3)_2$
Epsomite	$MgSO_4 \bullet 7H_2O$
Gaylussite	$CaNa_2(CO_3)_2 \bullet 5H_2O$
Glauberite	$Na_2Ca(SO_4)_2$
Gypsum	$CaSO_4 \bullet 2H_2O$
Halite	NaCl
Hexahydrite	$MgSO_4 \bullet 6H_2O$
Hydromagnesite*	$Mg_5(CO_3)_4(OH)_2 \bullet 4H_2O$
Kainite	$KMgClSO_4 \bullet 3H_2O$
Kalicinite	$KHCO_3$
Kieserite	$MgSO_4 \bullet H_2O$
Labile Salt	$Na_4Ca(SO_4)_3 \bullet 2H_2O$
Leonite	$K_2Mg(SO_4)_2 \bullet 4H_2O$
Magnesite	$MgCO_3$
Magnesium Oxychloride	$Mg_2Cl(OH)_3 \bullet 4H_2O$
Mercallite	$KHSO_4$
Mirabilite	$Na_2SO_4 \bullet 10H_2O$
Misenite	$K_8H_6(SO_4)_7$
Nahcolite	$NaHCO_3$
Natron	$Na_2CO_3 \bullet 10H_2O$
Nesquehonite	$MgCO_3 \bullet 3H_2O$
Picromerite (Schoenite)	$K_2Mg(SO_4)_2 \bullet 6H_2O$
Pirssonite	$Na_2Ca(CO_3)_2 \bullet 2H_2O$
Polyhalite	$K_2MgCa_2(SO_4)_4 \bullet 2H_2O$
Portlandite	$Ca(OH)_2$
Potassium Carbonate	$K_2CO_3 \bullet 3/2\ H_2O$

Table 9-2. Harvie, Møller, Weare Database (Continued)

Name	Formula
Potassium Sesquicarbonate	$K_8H_4(CO_3)_6 \cdot 3H_2O$
Potassium Sodium Carbonate	$KNaCO_3 \cdot 6H_2O$
Potassium Trona	$K_2NaH(CO_3)_2 \cdot 2H_2O$
Sesquipotassium Sulfate	$K_3H(SO_4)_2$
Sesquisodium Sulfate	$Na_3H(SO_4)_2$
Sodium Carbonate Heptahydrate	$Na_2CO_3 \cdot 7H_2O$
Sylvite	KCl
Syngenite	$K_2Ca(SO_4)_2 \cdot H_2O$
Tachyhydrite	$Mg_2CaCl_6 \cdot 12H_2O$
Thenardite	Na_2SO_4
Thermonatrite	$Na_2CO_3 \cdot H_2O$
Trona	$Na_3H(CO_3)_2 \cdot 2H_2O$

* Hydromagnesite is not part of the original HMW database, but was added to account for the possibility of its presence as a metastable phase. Other, potentially more favorable magnesium carbonate phases (for example, artinite) could have been added but hydromagnesite was chosen due to it being the commonly cited precursor to magnesite in natural systems.

studied the kinetics of formation of magnesite and have shown that high ionic strength solutions, such as those in the expected repository environment, catalyze the formation of magnesite.

It is therefore the DOE's position that magnesite will be formed in the WIPP repository given the strong thermodynamic driver, the long regulatory period of interest, and the demonstrated catalytic effect of high ionic strength solutions. Even if magnesite were to be kinetically inhibited, other magnesium carbonate containing phases such as hydromagnesite, whose formation is not known to be kinetically hindered, will form and control the chemical environment.

M

Peer Reviewer Consideration of Response

The DOE understood the issue and the response reasonably addressed this gas generation concern.

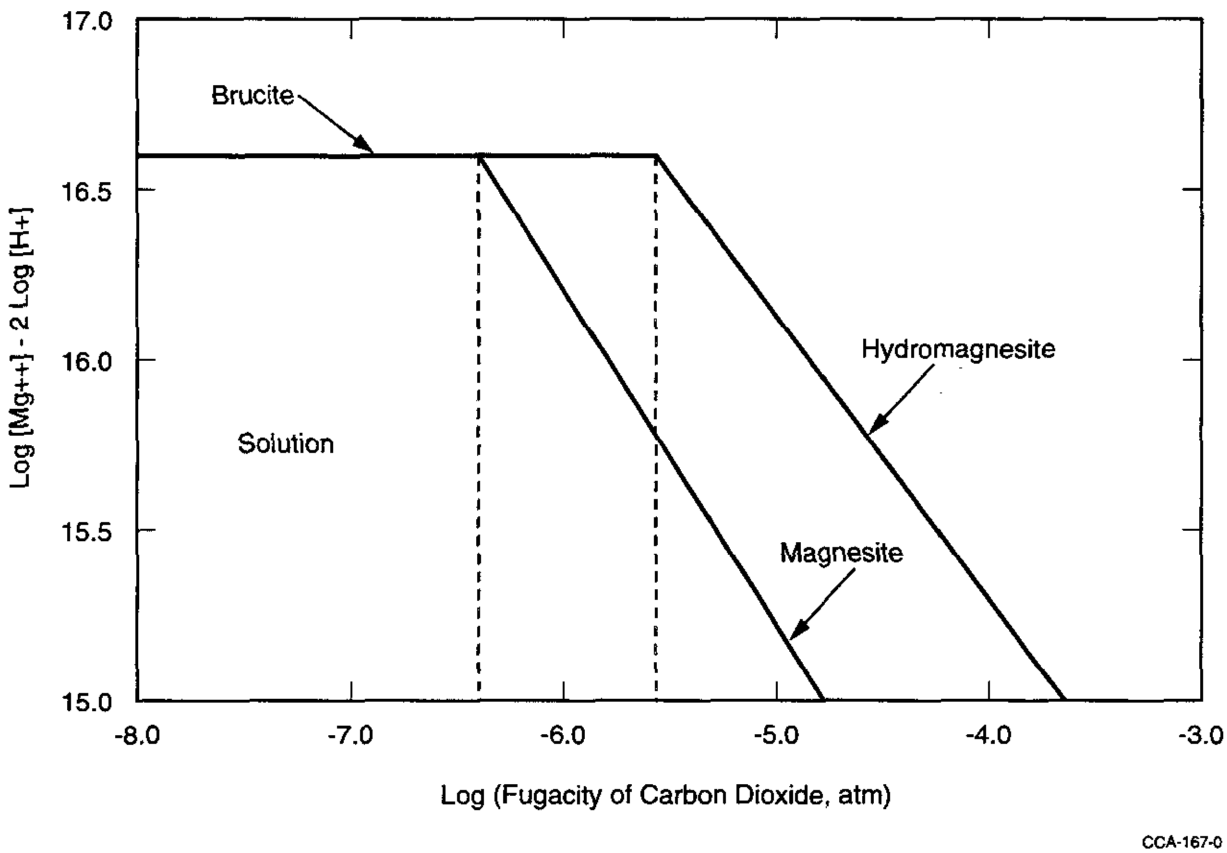

Figure 9-24. Phase Diagram for the MgO - CO_2 System

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9.3.1.2.10.3 Third Peer Review Panel Concern - Gas Generation

> *An adequate basis has not been presented for ignoring the effects of heat generation from corrosion and microbial actions. Higher ambient repository temperatures could increase the rates of chemical reactions, fluid flow, and halite creep.*

Statement of Issues (Note: For the purpose of this response, the above gas generation concern has been combined with the chemical conditions concern regarding the combined temperature increase and its effect on repository conditions [see Section 9.3.1.2.11.1].)

The net effect of potential temperature increases in the repository has not been adequately described and accounted for.

Response to Issues (Note: For the purpose of this response, the above gas generation concern has been combined with the chemical conditions concern regarding the combined temperature increase and its effect on repository conditions [see Section 9.3.1.2.11.1].)

There are several reactions which could potentially contribute heat to the repository system. These reactions include:

$$MgO + H_2O \rightarrow Mg(OH)_2 \qquad \text{Rxn. 1}$$

$$Mg(OH)_2 + CO_2 \rightarrow MgCO_3 + H_2O \qquad \text{Rxn. 2}$$

$$Fe + H_2O \rightarrow Fe(OH)_2 + H_2 \qquad \text{Rxn. 3}$$

$$C_6H_{10}O_5 + H_2O \rightarrow 3CH_4 + 3CO_2 \qquad \text{Rxn. 4}$$

$$Al + H_2O \rightarrow Al(OH)_3 + 1.5H_2O \qquad \text{Rxn. 5}$$

Evaluation of the ability of each of these reactions to produce heat while conservatively accounting for the repository's ability to dissipate the resulting heat generated has provided the following maximum temperature increases (Wang 1996b):

Reaction Number	Maximum Temperature Increase (K)
1	5
2	0.8
3	2
4	1
5	7

In the worst case, a temperature increase of 7 K could be experienced. However, these temperature extremes will not persist, if they are ever reached at all. Since all but Reaction 2 consume brine, they will be competing with each other for any brine that may enter the repository, an effect which will therefore temper the heat increase which could be predicted based on the most exothermic reaction alone. It should also be noted that all of the above reactions consume brine for the maximum temperature increases noted to be realized, all of the brine entering the repository would be consumed by the reactions; thus, no brine would be available for transport of actinides out of the repository region. To evaluate the worst case possible, for the maximum temperature increase to be realized from the corrosion of aluminum, all of the aluminum would have to be corroded within 2.5 years, after which the heat would be dissipated very rapidly. Therefore, if such a condition were to be created, it would be transitory on the repository time scale and its influence inconsequential.

The effect of small temperature increases arising from exothermic reactions has previously been screened out of the performance assessment on the basis of low consequence to factors such as creep closure, seal performance, transport, etc. (see Appendix SCR, Section SCR.2.5.7). The effect of heat generated by radiolysis has been considered as part of the repository conditions (Brush 1990) and utilized in the specification of experimental parameters, thus yielding data consistent with the anticipated conditions. Additionally, the small temperature increases cited above for exothermic reactions are insignificant to the thermodynamic modeling of solubility. For example, a temperature increase of 7 K (the maximum temperature increase possible) would result in an approximately 3 percent change in the free energy of formation of any species contained within the model. This is well within the model parameter bounds.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

DOE Technical Position versus Panel Issue

Further consideration of the DOE's response to the panel has resulted in a revision of the DOE technical position. Text of the revised DOE response to the peer panel (Wang 1996 [located as attachment to Bennett et al. memorandum]) and a supporting memorandum by Bennett et al. (1996) are provided in Appendix PEER. Text provided above ("Response to Issues") is consistent with the original response to the panel. However, as noted by Bennett et al. (1996), anoxic corrosion of iron was incorrectly described as an exothermic reaction. It should properly be identified as an endothermic reaction. As reported by Bennett et al. (1996), the maximum temperature rise possible in the repository should be 5 or 6 K, depending on whether MgO hydration or aluminum corrosion is the dominant reaction consuming brine.

9.3.1.2.11 Peer Review Panel Concern - Chemical Conditions

9.3.1.2.11.1 First Peer Review Panel Concern

> *The combined temperature increase (due to radioactive decay and exothermic reactions) and its effect on repository conditions has not been adequately addressed. Significantly higher repository temperatures could accelerate chemical reactions, fluid flow, and halite creep rates.*

Statement of Issue

This concern is addressed in Section 9.3.1.2.10.3 (Third Peer Review Panel Concern - Gas Generation).

Response to Issue

This concern is addressed in Section 9.3.1.2.10.3 (Third Peer Review Panel Concern - Gas Generation).

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

DOE Technical Position versus Panel Issue

This concern is addressed in Section 9.3.1.2.10.3 (Third Peer Review Panel Concern - Gas Generation).

Second and Third Peer Review Panel Concerns - Chemical Conditions

> *Phase equilibria have not been critically assessed within the chemical parameters of the conceptual model. A major element stable phase that was overlooked could significantly alter the chemical conditions of the repository and vary the actinide source terms.*
>
> *The MgO backfill has not been demonstrated to be able to react completely with CO_2 generated by microbial action. If the MgO backfill did not react as planned, the pH buffering capability of the repository would be significantly compromised, and could result in underestimating the actinide source terms.*

Statement of Issues

These issues are addressed in Section 9.3.1.2.10.2 (Second Peer Review Panel Concern - Gas Generation).

Response to Issues

These issues are addressed in Section 9.3.1.2.10.2 (Second Peer Review Panel Concern - Gas Generation).

Peer Reviewer Consideration of Response

The DOE understood the issue; however, the panel determined that the DOE response did not reasonably address their phase-equilibria concern. The panel did conclude that the response reasonably addressed their concern regarding the MgO backfill/CO_2 concern.

DOE Technical Position versus Panel Issues

The DOE believes the phase-equilibria concern is adequately addressed in Section 9.3.1.2.10.2 (Second Peer Review Panel Concern - Gas Generation).

9.3.2 Waste Characterization Analysis Peer Review

40 CFR § 194.27(a)(2) states that a compliance application shall include documentation of peer review conducted for "*waste characterization analyses as required in §194.24(b).*" 40 CFR § 194.24 (b) states:

> "*The Department shall submit in the compliance certification application the results of an analysis which substantiates:*
>
> > *(1) That all waste characteristics influencing containment of waste in the disposal system have been identified and assessed for their impact on disposal system performance. The characteristics to be analyzed shall include, but shall not be limited to: solubility; formation of colloidal suspensions containing radionuclides; production of gas from the waste; shear strength; compactability; and other waste-related inputs into the computer models that are used in the performance assessment.*
> >
> > *(2) That all waste components influencing the waste characteristics identified in paragraph (b)(1) of this section have been identified and assessed for their impact on disposal system performance. The components to be analyzed shall include, but shall not be limited to: metals; cellulosics; chelating agents; water and other liquids; and activity in curies of each isotope of the radionuclides present.*
> >
> > *(3) Any decision to exclude consideration of any waste characteristic or waste component because such characteristic or component is not expected to significantly influence the containment of the waste in the disposal system.*"

A Waste Characterization Peer Review (WCPR) Plan (see Appendix PEER) was prepared and approved in accordance with the requirements of TP 10.5. The DOE convened a four-member peer review panel, in accordance with the guidance of NUREG-1297, to perform the review. The panel members were:

Duane C. Hrncir (Panel Chairman), University of Texas, Dallas
Evaristo J. Bonano, Beta Corporation International
James F. Bresson, Informatics Corporation
Patricia J. Robinson, Energy, Inc.

Dr. Hrncir is an Associate Professor of Chemistry at the University of Texas at Dallas. He holds a Ph.D. in inorganic chemistry and has 24 years of experience in research involving the interactions of metals and organics with mineral surfaces and the controls these interactions have on speciation and transport in aquatic environments.

Dr. Bonano is President and Chief Executive Officer of Beta Corporation International in Albuquerque, NM. He holds a Ph.D. in Chemical Engineering. His areas of expertise include transport phenomena, waste management, risk and performance assessment, regulatory compliance, elicitation and use of expert judgments, decision analysis, and environmental management.

Mr. Bresson is a senior scientist with Informatics Corporation in Albuquerque, New Mexico. He holds the degree Masters of Public Health, with an emphasis in radiological and environmental health. He has more than 35 years experience as a health physicist working on radioactive waste management and was involved in development of the WIPP Waste Acceptance Criteria and the first WIPP Waste Certification Program.

Ms. Robinson is President and CEO of Energy, Inc. in Albuquerque, New Mexico. She has a B.S. in Chemical Engineering and a pending M.S. in Nuclear Engineering from the University of California at Berkeley. Her 18-year career has been focussed on the resolution of technical problems and issues related to the generation and management of high-level and low-level radioactive wastes for the nuclear power industry.

All panel members had substantial academic qualifications and expertise in one or more of the fields required for this peer review, and all were independent of the WIPP project. The panel's report (see Appendix PEER) provides additional information regarding the technical qualifications of the panel members. Documentation of the independence of the panel members is also provided in Appendix PEER.

The panel focused its efforts primarily on Appendix WCA, in accordance with the WCPR plan, but also reviewed numerous other documents attached to Appendix WCA by reference as well as an early draft of Appendix SOTERM, on which Appendix WCA depended for a substantial amount of data. The panel's report was published in August 1996 (a copy is provided in Appendix PEER).

In the Executive Summary/Conclusions, the report states that, overall:

> *"It is the opinion of the Panel that Appendix WCA (draft, dated July 26, 1996) meets its goal in some areas, is weak but defensible in others, and is inadequate in others."*

9.3.2.1 General Results

The following excerpts are from the WCPR report. They address those areas that the panel considered adequate.

- ***"Radionuclide Inventory and Release Limits****. The analysis performed in estimating the parameters needed to establish the radionuclide inventory and release limits for estimating the CCDF was very thorough and systematic. This is a solid piece of work.*

- ***Solubility****. The median values for actinide solubility are reasonable.....*

- ***Colloids.*** *The experiments dealing with colloids in the repository were well done.*

- ***Production of Gas****. Appendix WCA adequately identifies the major issues of gas generation in the waste.*

- ***Permeability****. There are experimental data to support the conclusions about permeability discussed in Appendix WCA. The Panel concurs with the conclusions.*

- ***Heat Generation****. The analyses presented in Appendix WCA concerning heat generation are well done. The conclusion that this characteristic will have a negligible effect on performance is justified.*

- ***Metals****. The assumption that low valent metals in the repository will maintain a reducing atmosphere in the repository is substantiated by experimental data.*

- ***Cellulosics****. Cellulosics will be microbially degraded to carbon dioxide and methane. They also may provide a source of humic colloids. Treatment of these issues by Appendix WCA has been discussed in the appropriate sections above.*

- ***Water and Other Liquids****. The Panel agrees with the findings in Appendix WCA. Water in the waste is not an issue in repository performance.*

- ***Exclusion of Waste****. (1) The analysis performed to support the exclusion of radionuclides is methodical, complete and well done. (2) The exclusion of hazardous wastes is justified."*

9.3.2.2 Waste Characterization Peer Review Panel Concerns

The WCPR panel concluded that several areas they examined were inadequate. The WCPR panel's concerns ("Peer Review Panel Concerns" -- presented in italics below), the DOE's interpretation of the panel's concerns ("Statement of Issue"), the DOE's response to the panel's concerns ("Response to Issue"), and the panel's reaction to the interpretation and responses ("Peer Reviewer Consideration of Response") are provided below. The panel concluded that the responses reasonably addressed their concerns, except for their issues on actinide solubility and production of gas. In those two instances, the DOE developed additional information ("DOE Technical Position versus Panel Issue") which provides the DOE's justification for using the unresolved analyses. In some instances, a single response addressed more than one concern.

The DOE responses were provided to the panel as individual memoranda. For incorporation into this application, the responses have been edited to remove the memorandum format, consolidate references, replace first-person text, insert cross-references where appropriate, and correct typographical errors. Substantive technical content of the response has not been changed.

9.3.2.2.1 Peer Review Panel Concern - Radionuclide Inventory and Release Limits

> *"Radionuclide Inventory and Release Limits. The analysis used to determine the heterogeneous source term for the intrusion scenario was not clearly presented in Appendix WCA, resulting in an inability to judge its validity and degree of conservation."*

Statement of Issue

None provided

Response to Issue

Information about waste radioactivity has been compiled at the waste-stream level from different processes at the generator sites that create TRU waste. Radioactivity loading for each radionuclide and the total waste volume are provided for each waste stream. For the compliance certification application calculations, 569 CH-TRU waste streams and one RH-TRU waste stream are used in the direct release scenario. While 569 represents the true numbers of CH-TRU waste streams, RH-TRU waste has been lumped into one waste stream. This is because the total activity of RH-TRU waste is about one-percent of the total activity of CH-TRU waste, and it is assumed that variability of activity level in this small fraction has negligible effects.

In a rotary drilling operation, the volume of material brought to the surface as cuttings is the cylinder defined by the thickness of the unit being drilled and the diameter of the drill bit. The quantity of radionuclides released as cuttings is therefore a function only of the activity loading of the intersected waste and the diameter of the intruding drill bit.

In the compliance certification application calculations, containers are assumed to be emplaced in the disposal rooms from various waste streams in a random manner. Because waste containers are to be stacked three-high for disposal, a drill bit is assumed to penetrate three containers. Each of the three containers penetrated by the drill bit can come from different waste streams with different activities associated with them. The waste streams penetrated are randomly sampled with a probability distribution according to the relative quantity (volume) of each waste stream. Figure 9-25 shows the resulting cumulative probability distribution function of the radioactivity loading (in terms of EPA unit per cubic meter of waste) of the 569 CH waste streams through time. Waste stream activities are maintained in performance assessment calculations at 100, 125, 175, 350, 1,000, 3,000, 5,000, 7,500, and 10,000 years. Activities for cuttings calculations at other times are interpolated from these values.

Additional analysis is contained in the WIPP Performance Assessment Analysis Report for EPAUNI: Estimating Probability Distribution of EPA Unit Loading in the WIPP Repository for Performance Assessment Calculations (in the SWCF, Albuquerque, New Mexico).

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response

9.3.2.2.2 Peer Review Panel Concern - Solubility

9.3.2.2.2.1 First Peer Review Panel Concern

> *The median values for actinide solubility are reasonable, but the uncertainty ranges about the median are too low and inconsistent with earlier results from the expert judgment panel study.*

Statement of Issue

A discrepancy exists between what the previous expert judgment panel determined as a reasonable range for actinide solubilities in the WIPP and the range of uncertainty currently being applied by the Actinide Source Term Program in Performance Assessment.

Response to Issue

The peer review panel was provided an early version of Appendix SOTERM which mistakenly stated that the uncertainty associated with an FMT model predicted solubility is one order of magnitude or less. An analysis by Bynum et al. (1996) has establisned the

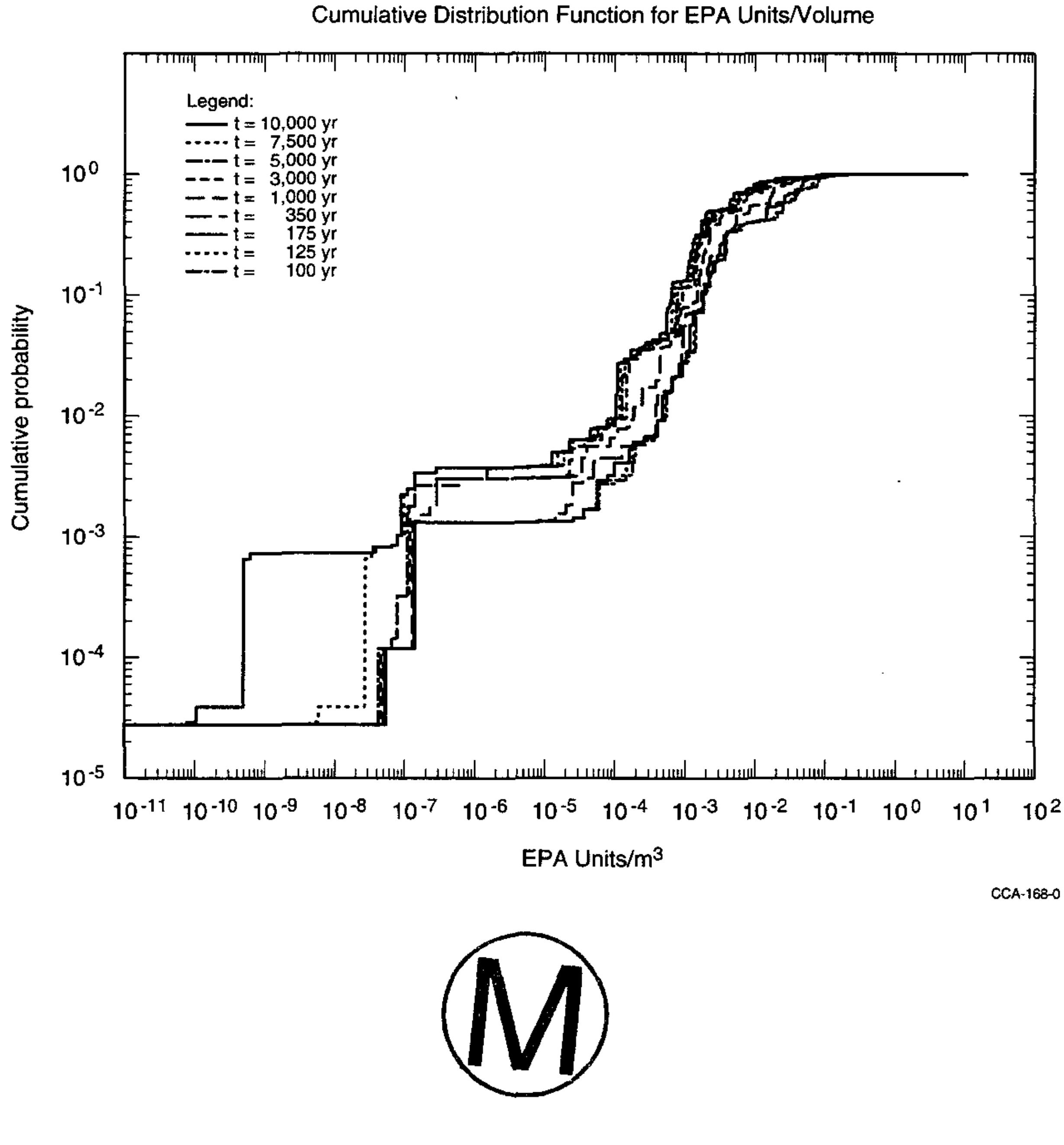

Figure 9-25. Cumulative Distribution Function (CDF) for CH-TRU EPA Units/Volume at Various Times

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uncertainty range to be from -2 to +1.4 orders of magnitude based on a comparison of approximately 150 data points of model predictions or curve fits to direct experimental observations. This error has been corrected in Appendix SOTERM and thus the model uncertainty range being used is approximately 3.4 orders of magnitude. While this is somewhat closer to the ranges of solubility utilized by the expert judgment panel, there still remains a significant difference.

There are two types of uncertainty which must be considered for an analysis of actinide solubility in the WIPP. The first of these centers around the ability to understand how accurately, given a set of chemical conditions, the dissolved species model (as implemented by FMT [Novak 1995]) can predict the actinide solubility. This is referred to as the model uncertainty. The second type of uncertainty, which will be called system uncertainty, involves how well the system is understood, and how the system effects impact the prediction of actinide solubility. In the WIPP repository, in the presence of MgO backfill, the chemical conditions are well understood and defined within a reasonably narrow range. Therefore, the system uncertainty is minimized, with the remaining system uncertainty (that is, oxidation state distribution and brine composition) being dealt with through sampling as described elsewhere. The model uncertainty, when combined with the system uncertainty yields a predicted range of plutonium concentrations of 6×10^{-11} to 1.1×10^{-4}, which is comparable to the range established by the expert judgement panel (2.5×10^{-17} to 5.5×10^{-4}), when discounting the values below the lower limit of detection for the common analytical technique for actinides, 10^{-9}.

The expert judgment panel study considered a wide range of chemical conditions, most of which are not pertinent to the current repository design. The expert judgment panel adopted the approach of selecting two solids, one yielding radionuclide concentrations at high values (a highly soluble solid) and one yielding radionuclide concentrations at low values (a sparingly soluble solid). This process allowed the expert judgment panel to consider conditions, and combinations of conditions, which are not possible within the WIPP. For example, the expert judgment panel considered low pH values and oxidizing conditions. This approach led to a very large system uncertainty (for example, is the repository oxidizing or reducing, is the repository acidic or basic, etc.).

Therefore, it is not appropriate to compare the model uncertainty established for the FMT predicted solubilities with the range of solubilities established by the expert judgment panel. The expert judgment panel did not undertake the defining of the uncertainty of a solubility prediction given a specific set of chemical conditions, and therefore provided no data appropriate for comparison to the model uncertainty utilized in the performance assessment calculations.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

M

9.3.2.2.2.2 Second Peer Review Panel Concern - Solubility

> *The issue of actinide solubility is not adequately addressed in Appendix WCA because the controlling assumption concerning MgO chemistry in the repository has no experimental data to support it.*

Statement of Issues (Note: For the purpose of this response, the above solubility concern has been combined with the first production-of-gas concern regarding the reaction of carbon dioxide with the MgO backfill [see Section 9.3.2.2.4.1].)

The WCPR panel, while recognizing that the fundamental chemistry behind the MgO backfill concept is sound, would feel more comfortable with the significant role that the MgO is playing in the repository, if that chemistry were confirmed with direct experimental observations at WIPP-like conditions.

Response to Issues (Note: For the purpose of this response, the above solubility concern has been combined with the first production of gas concern regarding the reaction of carbon dioxide with the MgO backfill [see Section 9.3.2.2.4.1].)

The arguments for the use of MgO are reasonable and conservative due to (a) the availability of experimental data on the chemical phenomena under a variety of conditions; (b) the soundness of the chemical arguments, which are summarized below; and (c) the conservatism built into the reaction rates and the repository loading of MgO.

The MgO backfill is expected to react with any brine or humidity in the air entering the repository via the following reaction:

$$MgO + H_2O \rightarrow Mg(OH)_2$$

This reaction is based on thermodynamic principles, the fact that MgO is commonly used as a desiccant, and the well known deliquescent behavior of alkaline earth oxides to react with water to form the alkaline earth hydroxides. This behavior is documented in the literature (Aldrich 1994; Terry 1983; Bates and Jackson 1987) and forms what the DOE feels to be a reasonable basis for expecting this reaction to proceed as indicated.

Any CO_2 which may be generated in the repository can react with either the MgO or $Mg(OH)_2$ via reactions such as:

$$MgO + CO_2 \rightarrow MgCO_3$$

or

$$Mg(OH)_2 + CO_2 \rightarrow MgCO_3 + H_2O$$

Both of these reactions are thermodynamically favorable and are known to occur (Budavari et al. 1989; DOI 1975). Therefore, the issue comes down to the rate at which the reaction(s) may occur. Since MgO is deliquescent, solid-gas reactions need not be considered and reactions always involve a liquid phase. Assuming that reaction rates in solution are relatively fast when compared to the geologic time scale, the rate limiting step is the magnesium ions leaving the surface of the MgO. The rate at which MgO dissolves has been previously studied (Terry 1983). Extending the cited values to the pH range expected in an MgO backfilled repository provides an average rate of MgO dissolution of 1.5×10^{-12} moles per square centimeter per second. The total quantity of cellulosics, rubbers, and plastics which are anticipated to be placed in the repository is 2.7×10^7 kilograms (166 kilograms per cubic meter average cellulosics, rubbers, and plastics loading times 1.6×10^5 cubic meters total waste volume) (DOE 1995a). The maximum rate of CO_2 generation is 9.51×10^{-9} moles CO_2/kg/sec (see Appendix PAR). Thus, the entire repository maximum CO_2 generation rate is 2.6×10^{-1}moles CO_2/sec.

Given the maximum rate of CO_2 generation and the maximum rate of MgO dissolution (as a function of surface area), we can calculate the theoretical minimum particle size which will have sufficient surface area to ensure reaction with the CO_2 as it is generated. First, the minimum surface area per gram (that is, specific surface area) is calculated by dividing the total surface area required by the total number of grams of MgO emplaced. The total surface area required is given by:

$$(2.6 \times 10^{-1} \text{ moles } CO_2 \text{ generated/sec}) \times (1 \text{ mole MgO/1mole } CO_2) \times$$
$$(1/1.5 \times 10^{-12} \text{ moles MgO/cm}^2\text{/sec}) = 1.76 \times 10^{11} \text{ cm}^2 \text{ MgO}$$

The total number of grams of MgO emplaced is given by:

$$(83{,}150 \text{ tons MgO}) \times (2000 \text{ lbs/ton}) \times (453\text{g/lb}) = 7.5\text{xx } 10^{10} \text{ g MgO}$$

Thus, the minimum required surface area per gram of MgO is:

$$(1.76 \times 10^{11} \text{ cm}^2 \text{ MgO}) / (7.5 \times 10^{10} \text{ g MgO}) = 2.3 \text{ cm}^2\text{/g MgO}$$

Now, assuming a spherical particle, the surface area = $4\pi r^2$. Using "P_m" for the mass of a particle, we can express the density as:

$$\text{density} = P_m / (4/3\pi r^3)$$

Rearranging for the mass of a particle provides:

$$P_m = (4/3\pi r^3)(\text{density}) \qquad \text{(eq. A)}$$

The specific surface area per gram may be expressed as:

$$\text{specific surface area} = 4\pi r^2 / P_m \qquad \text{(eq. B)}$$

Now, dividing equation A by equation B gives:

$$P_m / (\text{specific surface area}) = [(4/3\pi r^3)(\text{density})] / [4\pi r^2 / P_m]$$

Solving for "r" provides the maximum particle radius which can accommodate the maximum CO_2 generation rate:

$$[P_m / (\text{ specific surface area})]\, [4\pi r^2 / P_m] = [(4/3\pi r^3)(\text{density})]$$

$$[4\pi r^2 / (\text{ specific surface area})] = [(4/3\pi r^3)(\text{density})]$$

$$[1/(\text{ specific surface area})] = [(r/3)(\text{density})]$$

$$r = 3/[(\text{ specific surface area})(\text{density})]$$

Utilizing a crystalline density of 3.53 g/cm^3 provides

$$r = 3/[(2.3\ cm^2/g)(3.53\ g/cm^3)]$$

or

$$r = 0.37\ cm$$

Therefore, as long as the particles of the MgO backfill are no greater than 0.37 centimeter radius (or 0.74 centimeter in diameter), there will be sufficient surface area for the MgO dissolution to maintain pace with the maximum CO_2 generation. This minimum surface area is conservative in that it assumes only the exterior surface is available for reaction and a crystalline material is used. In reality, the particles of MgO will be amorphous and thus, will have a much higher effective surface area as there will be some porosity (possibly of the order of 50 percent) to the particles.

For the MgO backfill to function as designed it must be shown that magnesium carbonate containing phases will be formed and will be stable under expected repository conditions. To demonstrate this, multiple thermodynamic modeling codes (for example, FMT [Novak 1995], EQ3/6 [Wolery 1992; Wolery and Daveler 1992], Geochemist's Workbench [Bethke 1994]) have been utilized. These modeling codes take into consideration many potential mineral phases (see Table 9-2; see Section 9.3.1.2.10.2) and utilize a Gibbs free energy minimization method to predict the most stable phase given a set of conditions. The database for the brine components for these codes is well documented (Harvie et al. 1984; Harvie and Weare 1980; Pitzer 1991), and has been proven to be appropriate in conditions very similar to those expected in WIPP (Felmy and Waere 1986). In each case, the modeling simulation predicts that magnesite and brucite will be formed within the system and that these phases are thermodynamically stable regardless of whether a Salado or Castile brine composition is used. By design of the system (that is, by utilizing a large excess of MgO), brucite will always be present in the system as long as water, in the form of brine in this case, has entered the repository and will thus set one dimension of the phase diagram. The formation of magnesite at low temperatures is however subject to some question due to kinetic effects (Peterson et al. 1966; Christ and Hostetler 1970). To address this potential issue the formation of magnesite was suppressed within the modeling calculations, and it was found that other magnesium carbonate containing phases form which provide approximately the same chemical conditions as when magnesite is allowed to form.

Figure 9-24 (see Section 9.3.1.2.10.2) presents an abbreviated phase diagram for the system. This phase diagram is abbreviated in that calcium containing phases are omitted since (1) the formation of dolomite is not kinetically favorable, and (2) the conditions will be dominated by the magnesium chemistry due to its extreme excess and the rapid consumption of any $Ca(OH)_2$ by relatively small quantities of CO_2 which may be generated. This phase diagram shows that under the worst case, hydromagnesite will form yielding an fCO_2 of approximately an order of magnitude greater than that found when magnesite is allowed to form. This possible increase of carbon dioxide fugacity is not sufficient to cause a significant increase in the actinide solubility.

Since the chemical conditions must be maintained over the repository life-time, the long-term stability of the mineral phase must also be considered. The most compelling arguments for the long-term stability of any mineral phase involve natural analogues. In this case, the most compelling case for a natural analog is the natural occurrence of magnesite in the Salado formation itself (Stein 1985).

Based on the above arguments and observations, the DOE maintains that magnesium oxide will function as an assurance measure in the postclosure repository, forming magnesium carbonate containing phases that will be stable under anticipated repository conditions. The combination of these magnesium carbonate containing phases and brucite will buffer the chemical conditions within the ranges utilized for the dissolved actinide solubility predictions, thus performing effectively as a chemical control.

<u>Peer Reviewer Consideration of Response</u>

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The DOE understood the issues; however, the panel determined that the response did not reasonably address their concern.

<u>DOE Technical Position versus Panel Issues</u> (Note: For the purpose of this response, the above solubility concern has been combined with the first production of gas concern regarding the reaction of carbon dioxide with the MgO backfill [see Section 9.3.2.2.4.1].)

The arguments for the use of MgO are reasonable and conservative due to (a) the availability of experimental data on the chemical phenomena under a variety of conditions; (b) the soundness of the chemical arguments, which are summarized in the response to WCA Concerns 3 and 5; and (c) the conservatism built into the reaction rates and the repository loading of MgO.

The DOE asserts that it has presented sufficient technical data to support its position that the implementation of a MgO backfill will control the repository chemical environment to a region of low actinide solubility through control of pH and CO_2. As the peer review panel notes, the conclusions regarding the impacts of magnesium oxide backfill are "based on sound chemistry." This sound chemistry is supported by geochemical modeling, which has been demonstrated by others to be adequate for systems similar to the WIPP. The panel did not dispute the adequacy of the basic chemistry or modeling but stated its desire to see further experimental confirmation.

9.3.2.2.3 Peer Review Panel Concern - Colloids

> *The uncertainty given for the colloid actinide source term is not adequate for purposes of PA calculations because the number of experiments performed does not generate meaningful statistical samples from which an uncertainty could be adequately calculated.*

Statement of Issue

The panel's concern pertains to the treatment of uncertainties associated with the six sets of parameters developed to quantify the mobile colloidal actinide source term. Two sets of parameters, CONCMIN and CONCINT, are sets of constant values describing concentrations of actinides associated with mineral fragment type colloids and with actinide intrinsic colloids, respectively. Two other sets of parameters, PROPHUM and PROPMIC, are proportionality constants describing the supplemental proportion of actinides, relative to the dissolved actinide source term, which are associated with humic substances and microbes, respectively. Two additional sets of parameters, CAPHUM and CAPMIC, are sets of values representing the maximum concentration of actinides associated with humic substances and microbes, respectively. Values within each parameter set are by actinide element or by actinide oxidation state.

Response to Issue

Parameter values for the six parameters listed above were developed from carefully planned experiments designed to provide reasonable bounding values. In all cases, the parameter values submitted to the WIPP Performance Assessment Department have measures of conservatism incorporated into them, and are essentially maximum values. The main source of uncertainty are due to our ability to quantify the exact nature of colloidal particles during the 10,000-year performance period of the WIPP. In comparison, uncertainty due to analytical and modeling error is negligible. The discussion which follows focuses on some of the major areas of conservatism leading to the development of maximum parameter values.

The two most important contributors to the mobile colloidal actinide source term are humic- and microbial actinides; actinide intrinsic colloids and mineral-fragment bound actinides have only a very small contribution. In spite of some speculation that humics and microbes will not be present in appreciable concentrations during the 10,000-year performance period, the project has bounded their effects by assuming that they are present for the duration. Microbes are present at their maximum ("stationary phase") concentrations established under optimal growth conditions. Humics are limited by their solubilities. It is quite possible that humics may not sustain that concentration because of slow kinetics of formation accompanied by rapid destabilization by brine constituents.

The microbe filtration experiments conducted at LANL and BNL provided the basis for the PROPMIC and CAPMIC parameter values. In those experiments, two WIPP-relevant microbe cultures were used: a pure microbe culture (WIPP-1A), and a mixed innoculum (BAB). The cultures had markedly different extents of bioaccumulation. In the WIPP system, it is more likely that a mixed culture will be present. For the PROPMIC values, the project elected to be conservative and use the values from the WIPP-1A culture. Experiments were conducted under optimal conditions for growth with ample nutrients. The CAPMIC term was determined directly for Th and U, but was determined by extrapolation for Np and Pu. In the latter case, an order-of-magnitude measure of conservatism was added to the extrapolated value to be safe. A CAPMIC term was not developed for Am. In the performance assessment calculations, the CAPMIC term was arbitrarily set at a high value so that CAPMIC for Am was never exceeded. (In fact, it turns out that CAPMIC was never exercised in the performance assessment calculations for any of the actinides.)

Because of the uncertainty in predicting which type of humic substance will be present in the repository environment, the project assumed an equal probability of occurrence of three representative types: *aliphatic humic acid, aromatic humic acid, and fulvic acid.* In cases where data were available for all three types, namely the III and VI oxidation states, a triangular distribution was defined. For oxidation states IV and V, information was not available for fulvic acids, the least powerful complexant, and parameter values were developed from the more strongly complexing humic acids. Consequently, PROPHUM values used for Th(IV), U(IV), Np(IV), Pu(IV), and Np(V) are conservative because they do not include the "diluting effect" of fulvic acids. In general, but particularly for PROPHUM constants for oxidation states III, V, and VI, actinide complexation was measured at very dilute actinide concentrations. As actinide concentrations increase, the extent of binding will decrease because of oligoelectrolyte effects. In other words, as pristine humics begin to complex actinides, they tend to fold in on themselves, decreasing the accessibility of sites for further complexation, and eventually leading to a compact form which is less likely to complex actinides and more likely to precipitate. The experimental approach itself leads to conservatism. Further, the estimated values for the III and the VI oxidation states (determined from experiments with Am and U, respectively) were conducted under relatively acidic conditions. The values reported to performance assessment were based on those conditions, despite the fact that under the higher pH conditions of the repository environment, hydrolysis will render those actinides much less reactive, thereby reducing the extent of complexation by humics. For the IV oxidation state, the proportionality constant was developed from published information on Th(IV) behavior in sea water, which has a slightly basic pH. It is suspected, however, that under basic pH conditions, Th will be highly hydrolyzed, and will be present as species such as $Th(OH)_3^+$ or $Th(OH)_4^0$ or perhaps even $Th(OH)_5^-$. Under those conditions, "complexation" by humics will not occur by chemical reaction (that is, chemisorption), but instead by weak electrostatic effects (physisorption). The binding strength of the "complexes" is not likely to be very strong, and the extent of "complexation" will be less than that indicated by the parameter values provided to performance assessment.

The maximum value supplied to performance assessment for humic-actinide complexation, HUMCAP, was based on bounding calculations using site densities determined from titration experiments. Like the actinide complexation experiments described above, the site density titrations represent an ideal case. In reality, when the available binding sites on the humics are about 50 percent filled, the humic will tend to precipitate due to oligoelectrolyte effects (that is, charged sites will affect neighboring sites). A conservatism factor of two to four is also incorporated in the HUMCAP parameter, through the assumption that sorbing actinides have univalent charge (that is, one equivalent per mole).

A large number of experiments were conducted with the Pu(IV)-polymer, as a function of Pu(IV) saturation conditions (that is, from undersaturation and from oversaturation), pH conditions, ionic strengths, and time. For the Pu(IV) isotope used, and the analytical method used, the minimum detection limit was 1×10^{-9} M. Under MgO backfill conditions, the pH of the repository is anticipated to be about 9.3. Experiments on Pu(IV)-polymer concentration conducted as a function of pH show a very well-defined sympathetic trend in Pu(IV)-polymer concentration and hydrogen ion concentration (that is, concentration decreases with increasing pH). Under MgO-mediated pH conditions, the well-defined line drops below the minimum detection limit, and extrapolates to a value on the order of 10^{-10} M. The extrapolated value was *not* used in performance assessment calculations. Instead, the minimum analytical detection limit was used, 1×10^{-9} M. It is likely that some measure of conservatism stems from that approach.

The concentration of actinides associated with mineral fragment colloids was based on knowledge gained from approximately one-hundred individual experiments with different colloidal particles, pH conditions, and WIPP-relevant electrolytes. The final experiments used to develop performance assessment parameters were replicates of previous experiments using a substantially more sensitive analytical technique. The bounding approach used to estimate associated actinide concentrations assumes that all mineral fragment colloids present in the repository have fairly strong sorption (that is, 1 binding site per square nm of surface area). Most mineral fragment colloids will not sorb as strongly as iron corrosion products and clay minerals. Other colloidal particles present, for example disaggregated minerals associated with the rock and native groundwaters, will be sorbed less strongly. Consequently, the approach used provides a maximum, but reasonable, concentration of actinides associated with mineral colloids.

Perhaps the greatest conservatism results from disregarding attenuation of colloidal particles during transport through the waste itself or through the backfill material in intrusion boreholes. The project recognizes that work conducted over the past two decades in colloid geochemistry has demonstrated that filtration in the subsurface is not 100 percent efficient. Nevertheless, it is well-accepted that filtration in the subsurface through materials such as the borehole backfill material will result in attenuation of a substantial concentration of colloidal particles (and their associated actinides) over a relatively short transport distance.

In conclusion, the colloid source term parameter values are bounding values incorporating a significant degree of conservatism.

<u>Peer Reviewer Consideration of Response</u>

The DOE understood the issues and provided a reasonable response.

9.3.2.2.4 <u>Peer Review Panel Concern - Production of Gas</u>

9.3.2.2.4.1 First Peer Review Panel Concern

> *The issue of the reaction of carbon dioxide with the MgO backfill is not adequately resolved in Appendix WCA, because of a lack of experimental data which demonstrated that this chemistry occurs under conditions anticipated in the repository.*

<u>Statement of Issue</u>

This issue is addressed in Section 9.3.2.2.2.2 (Second Peer Review Panel Concern - Solubility).

<u>Response to Issue</u>

This issue is addressed in Section 9.3.2.2.2.2 (Second Peer Review Panel Concern - Solubility).

<u>Peer Reviewer Consideration of Response</u>

The DOE understood the issue; however, the panel concluded that the response did not reasonably address their concern.

<u>DOE Technical Position versus Panel Issue</u>

This issue is addressed in Section 9.3.2.2.2.2 (Second Peer Review Panel Concern - Solubility).

9.3.2.2.4.2 Second and Third Peer Review Panel Concerns - Production of Gas

Appendix WCA does not adequately address the fate of microbially generated methane.

The treatment of gas generation in Appendix WCA is generally well done. However, the Appendix does not deal with the disposition of the generated methane. The gas will be produced on a mole per mole basis with carbon dioxide and yet there is no mention of its fate in the repository.

Statement of Issues

None provided.

Response to Issues

Methylation reactions of actinides are not expected to occur under WIPP repository conditions. Even if they were to occur, the products would not be stable in brine. Therefore, the only significant impact of methane generation is on repository gas pressure.

Microbially generated methane contributes to the total gas pressure generated in the WIPP repository. Because methane is produced by the microbial metabolic reaction (Wang and Brush 1996a),

$$C_6H_{10}O_5 \rightarrow 3CO_2 + 3CH_4$$

the rate of methane production by this reaction is about the same as the rate of cellulose degradation. Although methane can be produced by reaction of hydrogen with CO_2, Wang and Brush (1996a) neglect this pressure-reducing reaction in their calculations. In performance assessment, this rate is incorporated as part of the gas generation calculated by the code BRAGFLO. The parameters used by BRAGFLO to calculate gas generation are given in Table 6-9 (see Chapter 6.0).

For the purposes of calculating repository pressure and gas flow, the density and viscosity of any gas generated, including methane, are assumed to be those of hydrogen (see Section 6.4.3.4). The gas produced in the repository contains methane in half of the performance assessment realizations. The viscosity of hydrogen at 15 megapascals (lithostatic pressure), 6×10^{-6} ft-lb/sec, is less than half the viscosity of a gas mixture that contains 50 percent mole fraction hydrogen, 15×10^{-6} ft-lb/sec (see Appendix MASS; Section 3.2). At about half lithostatic pressure, the viscosity of a 50 percent mole fraction mixture is about 14.5×10^{-6} ft-lb/sec. Calculations of viscosity and compressibility of these mixtures were made using a National Institute of Standards and Technology (NIST) program entitled SUPERTRAPP (Vaughn 1996; Friend and Huber 1994). Viscosity has an inverse relationship to gas flow rate, and is proportional to the square of the repository pressure, so that assuming the viscosity of hydrogen for all generated gas yields a conservative result.

The compressibility factor of a gas is (Perry and Chilton 1973)

$$z = PV/RT \tag{31}$$

so that at constant temperature and a given pressure, the compressibility factor is inversely related to the gas density. The compressibility factor of hydrogen at 15 megapascals is 1.1, while that of 50 percent mole fraction hydrogen at 15 megapascals is 1.0 (Vaughn 1996). Like viscosity, compressibility is inversely related to gas flow rate, and is proportional to the square of the repository pressure. However, the difference between the compressibility of pure hydrogen and that of a 50 percent mixture is small, so that the effect of assuming the compressibility of hydrogen is minor.

Early in the regulatory period, there is likely to be relatively little hydrogen compared to methane. However, both the viscosity and density of methane are higher than those of hydrogen, so that predictions of gas flow and gas pressure would still be conservative.

Peer Reviewer Consideration of Response

The DOE understood the issues and provided a reasonable response.

9.3.2.2.5 Peer Review Panel Concern - Compressibility

> *Appendix WCA references studies describing the analysis of waste compressibility; however, it fails to provide any discussion of the results of these studies.*

Statement of Issue

In Section WCA 5.2.1 (see Appendix WCA) laboratory tests on waste compaction are referenced (Butcher et al. 1991) and a waste compaction model is also referenced (Weatherby et al. 1991; Callahan 1993). However, Appendix WCA does not give any values for the compressibility, nor does it describe the model, thus making it difficult for the panel to review. The panel states that they concur that "this modeling combined with experimental data is an appropriate method" but also that they "do not have information to assess the reasonableness or accuracy of compactibility related parameters". They also lack "for example" a discussion "or references on the effect of compactibility on porosity."

They note that the basis for the compressibility is derived "from experiments and models which assume a distribution of metals, plastics, combustibles, cellulosics and sludges is representative." Although they accept that this distribution is uncertain, they conclude that the "assumptions made are considered appropriate and conservative."

Response to Issue

The values used for compressibility of the waste are based on a series of laboratory experiments carried out on simulated waste materials. These experiments consisted of a series of loading tests during which the materials representing various components of the waste were compacted uniaxially and deformation was measured as a function of applied load and time (some of the materials showed creep). The compaction curves for the individual materials were then combined as a volume weighted average, based on the expected proportions of the various materials in the waste. Two models were developed to represent this compaction, a nonlinear elastic model (Callahan 1993) and a volumetric plasticity (crushable foam) model (Weatherby et al. 1991). Due to certain physical consistency limitations of the nonlinear elasticity model, calculations for performance assessment use the volumetric plasticity model, which has been shown to reasonably represent the expected behavior of the waste, and has been checked against data for drum compaction described by Butcher et al. (1991).

Details of the crushable foam model are given in Labreche et al. (1993). The constitutive relationship for volumetric yield can be written as:

$$F_v = \sigma_m - f(\epsilon_v)$$

where:

σ_m = the mean applied stress;
ϵ_v = the volumetric strain; and,
$f(\epsilon_v)$ = describes the volumetric hardening by a set of pressure-volumetric strain relations (that is data pairs in tabular form).

Figure 9-26 illustrates this relationship.

The estimates for compaction described here are for as-received waste, with no correction for waste decomposition or corrosion with time. This is based on an assumption that the waste degrades before it reaches its fully compacted state. An analysis of the results for the compaction of limonite and magnetite (two possible corrosion products of iron) in Butcher et al. (1991), also indicated that the difference between reacted and unreacted compaction states at lithostatic pressure was too small to attempt to compensate for in closure calculations.

Clearly the porosity of the compacted waste will depend to some extent on the compressibility of the waste, although it will also depend on the generation of gas and the resulting pressure conditions. This is discussed further under the issue on porosity.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

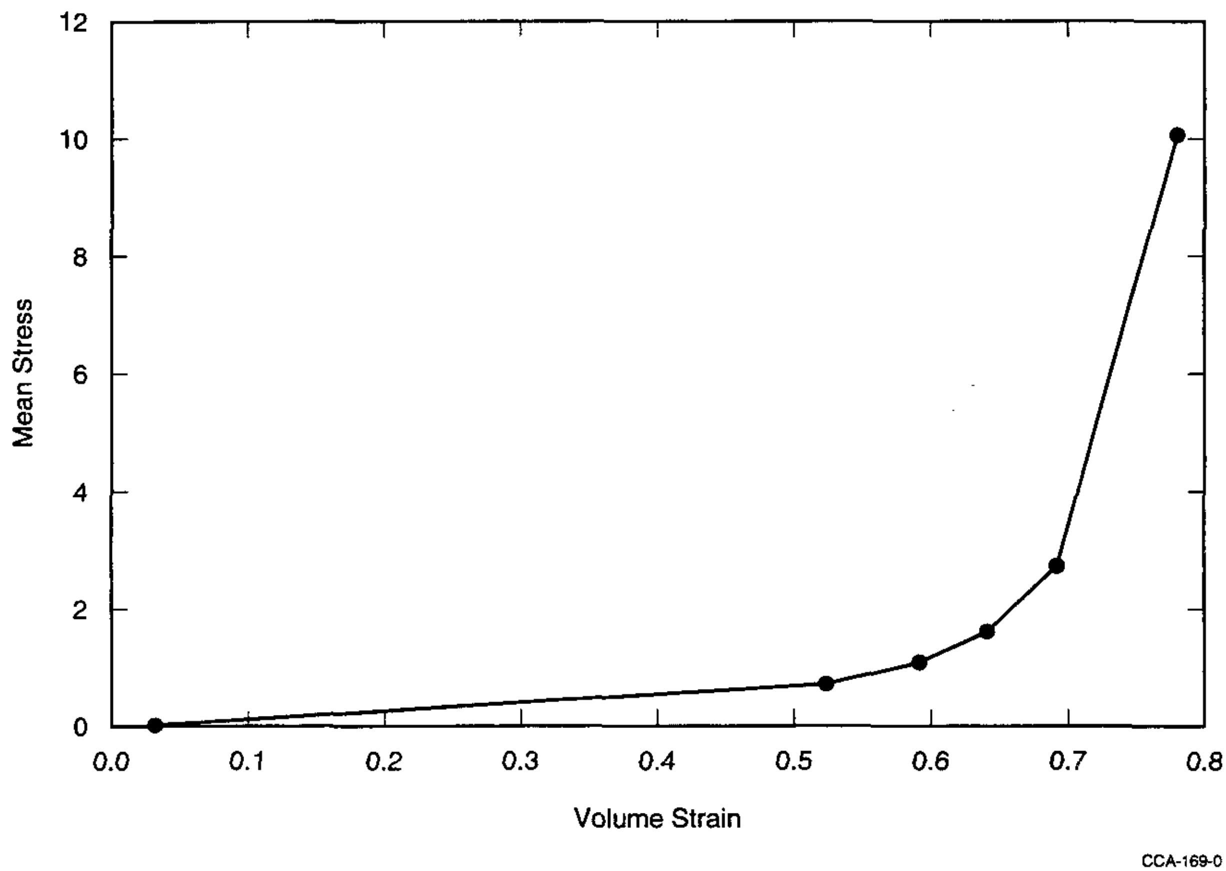

Figure 9-26. Relationship between Mean Applied Stress and Volume Strain, Volumetric Plasticity Model for Waste Compaction

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9.3.2.2.6 *Peer Review Panel Concern - Strength*

Appendix WCA references a study on waste strength, but fails to discuss the results of this study in the context of its impact on disposal system performance.

Statement of Issue

In Section WCA.5.2.2 (see Appendix WCA), a tensile strength of the waste of one-psi is argued by Berglund et al. (1996; Appendix PEER, Section PEER.2). The application of this is discussed in Appendix CUTTINGS, which is also referenced. However, Appendix WCA does not give any synopsis of these arguments, or the impact of the strength values, thus making it difficult for the panel to review. The panel states that the discussion of waste strength properties was "insufficient to assess reasonableness for inclusion in PA", and the panel "unanimously agreed that strength properties should be included for inclusion in PA".

Response to Issue

Waste strength influences the performance of the repository in two ways. First, during a drilling intrusion solid waste may be removed from the sides of a drillhole by erosion by the circulating drilling mud. In this case, the amount of material removed depends in part on the erosional strength of the waste, which is qualitatively related to the shear strength. Second, during a gas blowout event, material may be removed by "lofting" in the gas stream, a process known as spalling. In this case, the quantity of material removed is related to the tensile strength of the waste materials.

The values for the erosional strength of the waste were examined by Butcher (1994). In this memorandum, he argued that from a mechanical standpoint, the degraded waste would be similar to a clay-sand mixture. Based on literature values, he estimated that the strength of such a mixture would range between 0.1 and 1 pascal, with a median value of 1 pascal.

A value of 1 pound per square inch (6,895 pascals) has been chosen for the tensile strength of decomposed waste for the purpose of computing spall releases resulting from a drillbit intrusion into a pressurized waste panel. Such spall releases occur only if the gas pressure exceeds the hydrostatic drilling mud pressure of approximately 8 megapascals. A chemical reaction between the waste and brine from the surroundings is necessary to generate the gas to raise the waste pore pressure to these levels. Without brine inflow, little gas will be generated and waste decomposition will be negligible. Thus, the phenomenon of spall requires both brine inflow and waste decomposition.

The future state of decomposed waste is both time dependent and uncertain. Therefore, a decomposed state consisting of graded granular materials is assumed. This is consistent with the granular nature of decomposed geologic materials and corresponds to an end state of the decomposition process. Such materials lack significant composite strength from the interleaving of components and is the state found to be most troublesome in oil production where sand is produced from poorly consolidated sand layers. The value of 1 pound per square inch chosen for cementation strength for the decomposed waste can be reasonably expected to be conservative, that is, lower than those data values found for many weak materials that are naturally occurring or that have been manufactured. Data to support this value can be found in the literature for the strengths of soils, laboratory produced mixtures of salt and clay, and mixtures of various materials with MgO; the latter added as a backfill material to the waste. The memorandum by Berglund et al. (1996; see Appendix PEER) discusses this in more detail.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.2.2.7 Peer Review Panel Concern - Porosity

> *There are conflicting statement in Appendix WCA concerning the importance of porosity to the performance of the repository. As a result, the Panel was unable to evaluate the treatment of this parameter.*

Statement of Issue

In Section WCA.5.2 (see Appendix WCA), the physical properties of the solid waste with "Expected Significant Effect on .... Performance" include ".... the porosity of the waste," while those with "Expected Negligible Effect on ... Performance" include "Porosity:....". The panel, understandably, were confused by this contradiction, and the lack of any discussion on this property.

Response to Issue

This apparent contradiction arises out of the lack of clarity in the use of the porosity in Tables WCA 2-1 and WCA 2-2, and in the text. As indicated in Table WCA 2-1, compressibility of the waste is important because of its effect on creep closure (the stiffer the waste the more closure will be delayed and reduced), as well as the resulting effect on strength. Time dependent porosity is important here in that it controls the amount of volume available for gas and brine, and thus effects the build-up of pressure.

The lack of clarity appears because Table WCA 2-2 indicates that "porosity" has negligible effect on performance. This is true in respect to the dependence of permeability of the waste on porosity. The system is relatively insensitive to permeability of the waste, because this permeability is much greater than either the panel closures or the DRZ, and in this sense only the system is insensitive to the porosity.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.2.2.8 *Peer Review Panel Concern - Metals*

> *The position taken in Appendix WCA concerning the uptake of organic ligands by the transition metals is not defensible due to lack of experimental data. It is not correct to apply results from experiments performed in low ionic strength solutions to WIPP brines."*

Statement of Issue (Note: For the purpose of this response, the above metals concern has been combined with the chelating agents concern regarding the reaction of transition metals with organic ligands [see Section 9.3.2.2.9].)

A sufficient case has not been made to give the panel an adequate degree of comfort with ignoring the effect of organic ligands.

Response to Issue (Note: For the purpose of this response, the above metals concern has been combined with the chelating agents concern regarding the reaction of transition metals with organic ligands [see Section 9.3.2.2.9].)

The panel was provided a version of Appendix SOTERM which contained an early version of the discussion of organic ligands and their effect on repository performance. The most recent text of Section 5 of Appendix SOTERM provides additional information to satisfy the panel's concerns. An excerpt of that text is provided below:

SOTERM.5 The Role of Organic Ligands

Organic ligands may be a component of the wastes to be disposed of in the WIPP. Because organic ligands may complex with actinides and increase dissolved actinide concentrations, the effect of organic liquids was evaluated. Organic ligands also complex strongly with multivalent metal cations. The multivalent metal cations thereby compete with the actinides, and an assessment of this effect was performed. The analysis, summarized here, demonstrates that organic ligands will not be available to complex the actinides and thus will not impact dissolved actinide concentrations in the WIPP.

A number of organic compounds are capable of forming strong complexes with actinide ions, thereby stabilizing the actinide in solution. In general, the reactions that take place for one-to-one complexes are:

$$An^{n+} + L^{m-} \rightleftharpoons AnL^{(n+m)}, \qquad (5\text{-}1)$$

where An is a general symbol for any actinide, with charge n, and L is a general symbol for an organic ligand with charge m. The apparent stability constant for this reaction is

$$\beta = [AnL^{(n+m)}]/[An^{n+}][L^{m-}] . \quad (5\text{-}2)$$

The square brackets indicate concentration. This equilibrium constant is sometimes referred to as an association constant.

The Transuranic Waste Baseline Inventory Report (DOE 1996, Appendix B4) initially identified about 60 organic compounds among the non-radioactive constituents of TRU waste to be emplaced in the WIPP (Drez 1991; Brush 1990). Ten of these compounds have the potential to increase radionuclide solubility (Choppin 1988). Screening studies of these compounds have been conducted by Florida State University. Deprotonation and complexation experiments have been performed with five of these: acetate, citrate, oxalate, lactate, and EDTA. Four of these (acetate, citrate, oxalate, and EDTA) were identified in the waste inventory of the WIPP (DOE 1996, 3–12; Section WCA.8.11) as the only water-soluble organic ligands present in significant quantities. Lactate was not included because none was identified in the initial inventory, and estimating its concentration resulting from both production and consumption by microbes is not possible. These organic ligands are capable of significantly enhancing dissolved actinide concentrations, are potentially present in the repository, and are generally representative of any organic ligand that could be present in the WIPP.

Ligand concentrations in the repository were estimated using inventory amounts of ligands and a brine volume of 29,841 m^3, the smallest quantity of brine required to be in the repository which will support transport away from the repository (Larson 1996). As per BIR, Rev. 2, Page 3-1, a scaling factor of 2.05 was applied to all values. The results are listed in Table SOTERM-4.

Table SOTERM-4. Organic Ligand Concentrations in Inundated Repository

Organic Ligand	Inventory Amount (G)	Organic Concentration (molality)	Organic Concentration (scaled)
acetate	1.3×10^{6}	5.2×10^{-4}	1.1×10^{-3}
oxalate	1.6×10^{6}	2.3×10^{-4}	4.7×10^{-4}
citrate	1.4×10^{8}	3.6×10^{-3}	7.4×10^{-3}
EDTA	2.3×10^{4}	2.0×10^{-6}	4.2×10^{-6}

Apparent stability constants for organic ligand-actinide complexation and deprotonation constants for the organic acids were determined at Florida State University using potentiometric titration and a solvent extraction technique. The results of these studies are summarized in Table SOTERM-5.

Table SOTERM-5. Apparent Stability Constants for Organic Ligands and Actinides in NaCl Media

Organic Ligand	Actinide Ion	NaCl (molality)	$\log_{10}$ of Apparent Stability Constants	
			log β_1	log β_2
Acetate	Am^{3+}	0.3 to 5	1.44 - 2.2	
	Th^{4+}	0.3 to 5	3.68 - 4.18	6.56 - 7.66
	NpO_2^+	0.3 to 5	1.05 - 1.8	
	UO_2^{2+}	0.3 to 4	2.23 - 3.09	5.12 - 5.72
Lactate	Am^{3+}	0.3 to 5	1.75 - 2.55	3.4 - 3.8
	Th^{4+}	0.3 to 5	3.83 - 4.28	6.43 - 7.23
	NpO_2^+	0.2 to 5	1.43- 1.95	
	UO_2^{2+}	0.3 to 5	2.45 - 2.73	
Oxalate	Am^{3+}	0.3 to 5	4.17 - 4.63	7.77 - 8.6
	Th^{4+}	0.3 to 5	7.04 - 7.47	13.42 - 13.95
	NpO_2^+	1.0 to 5.0	3.62 - 4.63	6.96 - 7.07
	UO_2^{2+}	0.3 to 5	5.82 - 6.7	
Citrate	Am^{3+}	0.3 to 5	4.84 - 5.9	
	Th^{4+}	0.1 to 5	9.31 - 10.18	17.33 - 19.12
	NpO_2^+	0.1 to 5	2.39 - 2.56	
	UO_2^{2+}	0.3 to 5	7.07 - 7.32	
EDTA	Am^{3+}	0.3 to 5	13.76 - 15.1	
	Th^{4+}	0.3 to 5	15.56 - 16.94	30.77 - 33.21
	NpO_2^+	0.3 to 5	5.45 - 6.7	
	UO_2^{2+}	0.3 to 4	10.75 - 12.16	10.77 - 12.12

Complexation constants for each organic-actinide binding reaction were determined using the Pitzer formalism. The NONLIN computer code was used to calculate Pitzer interaction parameters and standard chemical potentials (Moore 1996). The parameters were added to the existing FMT data base for inorganic compounds and equilibrium calculations were performed. In FMT modeling calculations including organic ligands, all four of the water-soluble organic ligands identified in the WIPP inventory were included together at the expected concentrations so that competition among complexing sites could be examined (Novak et al. 1996). Calculations were done separately for Salado and Castile brines, using the brine formulations given by Brush (1990, 17-28). Complexation constants for magnesium with the organic ligands were measured at Florida State University and the results are listed in Table SOTERM-6. These results were included in the calculations so that magnesium (backfill component) competition with the actinides for ligand complexation could be evaluated. The FMT output is the calculated equilibrium solubility of the actinide as a function of the repository conditions.

Table SOTERM-6. Apparent Stability Constants for Magnesium Complexation with Organic Ligands at High Ionic Strength

Organic Ligand	NaCl (Molality)	$\log_{10}$ of Apparent Stability Constant
acetate	5	0.690
oxalate	5	2.20
citrate	3	2.02
EDTA	5	6.66

As the iron and steel in the repository corrode, additional transition metal ions will dissolve. These ionic species include iron (Fe), nickel (Ni), chromium (Cr), vanadium (V), and manganese (Mn), because the steels used for the waste drums contain on average at least 0.001 weight percent of Ni, Cr, V, and Mn as minor constituents (NIST 1995). Because at least 1.9×10^9 moles of steels will be disposed of in the WIPP, there should be at least 1×10^4 moles of Ni, Cr, V, and Mn in the repository. There are also expected to be > 6×10^7 moles of Pb. Additionally, these and other metals will be present in some of the waste forms; however, these additional quantities in the waste were not considered in this evaluation because insufficient data were available.

The complexation constants for the various metals cited above with the four representative organic ligands are listed in Table SOTERM-7. To assess the ability of these metals to complex with the organic ligands, competition calculations with EDTA (selected because it is the most strongly complexing of the four organic ligands under consideration) in low ionic strength NaCl solution saturated with iron hydroxide, nickel hydroxide and magnesium oxide (backfill) were performed. The calculations showed that under these conditions 99.8 percent of the EDTA was complexed by Ni, thus effectively rendering the EDTA unavailable for complexation with the actinides and rendering complexation of actinides by organic ligands inconsequential. Although these results are approximate because complexation constants for low ionic strength media were used, the fact that a single metal cation could bind more than 99 percent of the EDTA strongly suggests that the full range of metals that will be present will readily overwhelm the complexation sites of the organic ligands. Additionally, at higher ionic strength, iron and nickel have much higher solubility than in dilute solutions. Variation in ionic strength is not expected to change the complexation constants sufficiently to reduce this effect on the organics.

In addition to the calculations using the HYDRAQL code, simple scoping type equilibrium calculations were performed including several of the expected transition metals. The following equations were solved simultaneously:

Table SOTERM-7. Apparent Stability Constants for Organic Ligands with Metals (Martell and Smith 1982, 75, 284, 307, 328).

Organic Ligand	Metal	Ionic Strength (molality)	$\log_{10}$ of Apparent Stability Constant
EDTA	Fe^{2+}	0.1	14.3
	Ni^{2+}	0.1	13.6
	Cr^{2+}	0.1	18.4
	Mn^{2+}	0.1	13.9
	V^{2+}	0.1	12.7
	Cu^{2+}	0.1	18.9
	Pb^{2+}	0.1	18
Citrate	Fe^{2+}	0.1	4.4
	Ni^{2+}	0.1	5.4
	Mn^{2+}	0.1	4.15
	Cu^{2+}	0.1	5.9
	Pb^{2+}	0.1	4.08
Oxalate	Fe^{2+}	1.0	3.05
	Ni^{2+}	0.0	5.16
	Cr^{2+}	0.1	3.85
	Cu^{2+}	0.1	4.84
	Pb^{2+}	0.16	4.00
Acetate	Fe^{2+}	0	1.4
	Ni^{2+}	0	1.43
	Cr^{2+}	0.3	1.25
	Mn^{2+}	0.16	0.8
	Cu^{2+}	0	2.22
	Pb^{2+}	0.1	2.15

$$\beta_{Fe(II)} = [EDTA\text{-}Fe^{2-}] / [EDTA^{4-}][Fe^{2+}]$$

$$\beta_{Ni(II)} = [EDTA\text{-}Ni^{2-}] / [EDTA^{4-}][Ni^{2+}]$$

$$\beta_{Mg(II)} = [EDTA\text{-}Mg^{2-}] / [EDTA^{4-}][Mg^{2+}]$$

$$\beta_{Th(IV)} = [EDTA\text{-}Th] / [EDTA^{4-}][Th^{4+}]$$

along with mass balance equations for each metal. The nickel concentration of 3.65×10^{-4} used in the calculations was determined by taking the minimum number of moles of nickel expected in the repository, dividing by the available repository volume reported by Weiner (1996) and converting the value to molality. An approximation of 1×10^{-4} molal was chosen for the iron concentration. All other values for component concentrations and apparent stability constants are reported above. To approximate the effect of ionic strength on the apparent stability constants for nickel and iron the values used were an order of magnitude lower than those reported in Table WCA-10. These calculations do not include all possible metal ions expected under repository conditions, for example calcium and chromium are not included. Therefore, these results are considered conservative. The results indicate more than 97 percent of the total EDTA is complexed by the transition metals. Thus the excess of nonradioactive metals present in the repository will overwhelm the complexation sites of the organic ligands and complexation of the organic ligands with actinides will be negligible.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.2.2.9 Peer Review Panel Concern - Chelating Agents

> *The position that transition metals will react with the organic ligands in the waste to render them unavailable for reaction with actinides should be justified with experiments done in high ionic strength brines."*

Statement of Issue

This issue is addressed in Section 9.3.2.2.8 (Peer Review Panel Concern - Metals).

Response to Issue

This issue is addressed in Section 9.3.2.2.8 (Peer Review Panel Concern - Metals).

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response.

9.3.3 Engineered Alternatives Cost/Benefit Study Peer Review

Per the criteria of 40 CFR § 194.27(a)(3), a compliance application shall include documentation of peer review that has been conducted for *"(e)ngineered barrier evaluation as required in §194.44."* 40 CFR § 194.44(b) states

> *"In selecting any engineered barrier(s) for the disposal system, the Department shall evaluate the benefit and detriment of engineered barrier alternatives, including but not limited to: Cementation, shredding, supercompaction, incineration, vitrification, improved waste canisters, grout and bentonite backfill, melting of metals, alternative configurations of waste placement in the disposal system, and alternative disposal system dimensions. The results of this evaluation shall be included in any compliance application and shall be used to justify the selection and rejection of each engineered barrier evaluated."*

In September 1989, the DOE established the Engineered Alternatives Task Force (EATF) to identify and screen potential engineered alternatives (EAs) with respect to both effectiveness and feasibility of implementation in addressing concerns about gas generation and human intrusion. EAs are engineered barriers, waste modifications, facility modifications, process changes, or any other approach that enhances disposal system performance or reduces uncertainty in the predictions of disposal system performance.

The EATF, in turn, chartered an Engineered Alternatives Multi-disciplinary Panel that qualitatively screened an initial 64 alternatives to 36. The EATF then combined these candidates into 14 logically consistent and potentially actionable EAs. These 14 candidates, plus a base case, were evaluated with respect to relative effectiveness and feasibility in addressing gas generation and inadvertent human intrusion impacts. The EATF issued its final report in July 1991 (DOE 1991a). A subsequent peer review of the EATF Report is documented below (Section 9.4.4).

The DOE prepared the Engineered Alternatives Cost/Benefit Study (EACBS) Final Report (DOE 1995b, see Appendix EBS) in 1995. The EACBS Report includes a qualitative assessment of estimated costs, potential risks and benefits, and relative repository performance impacts resulting from the implementation of engineered alternatives.

The EACBS differs from the 1991 EATF in two fundamental ways. First, in the EACBS, EAs are assessed against eight factors specified in 40 CFR § 194.44(c)(1) that provide the data and information for use in selecting or rejecting an EA. The eight factors are:

- Long term repository performance
- Uncertainty in compliance assessment
- Impact on public and worker exposure
- Impact on waste removal
- Transportation risk
- Public confidence
- Impact on system cost and schedule
- Impact on other disposal systems

Second, the 1991 EATF study was aimed at identifying alternatives which, if needed, would improve disposal system performance to the point where compliance with quantifiable standards was achieved. The EACBS begins with the assumption that compliance is achieved and the comparison of alternatives is to assist future decision making should a need for additional EAs be identified.

An EACBS Peer Review Plan (see Appendix PEER) was developed and approved in accordance with the requirements of TP 10.5. The plan describes the peer review process used to ensure a sound technical basis for the selection or rejection of EAs should it be determined that additional engineered barriers are needed to satisfy the requirements of 40 CFR Part 191.

An independent peer review committee was assembled by the Waste-Management Education and Research Consortium (WERC) to provide the DOE with a review of the EACBS Final Report. The peer review was conducted in 1996, in a manner that was consistent with NUREG-1297 (NRC 1988) guidance and the requirements of TP 10.5 (DOE 1996b).

The purpose of the peer review of the EACBS was to assess the validity of the assumptions and the technical approach used in the EACBS and to evaluate the adequacy of the work. The peer review panel review focused on determining the reasonableness of the report's conclusions.

In accordance with the provisions of TP 10.5, a peer review panel was selected. The nine-member panel was composed of the following individuals:

Rohinton K. Bhada (Chairman), New Mexico State University
Catherine T. Aimone-Martin, New Mexico Institute of Mining and Technology
Arturo Duran, Environmental Consulting and Engineering
Douglass J. Kuhns, Lockheed-Martin Idaho Technologies Corporation
Cindy R. Lewis, Parsons Engineering Science, Inc.
James D. Navratil, Rust Federal Services
Jamal Rostami, Earth Mechanics Institute
Dennis M. Smith, Technical & Management Systems and Services, Inc.
Krishan K. Wahi, Geological Repository Assessment Methodologies, Inc.

Dr. Bhada has a Ph.D. in chemical engineering and an MBA in management. He is a registered professional engineer and was awarded the title of Diplomate of the American Association of Environmental Engineers. Dr. Bhada had 29 years of experience at the Babcock and Wilcox Company, where he worked primarily in the areas of pollution control and energy conversion, before he joined New Mexico State University in 1988.

Dr. Aimone-Martin has a Ph.D. in mineral resources engineering and management and civil (geotechnical) engineering. She is currently an Associate Professor and the Department Chair of the Mineral and Environmental Engineering Department at the New Mexico Institute of Mining and Technology where she has been since 1981.

Mr. Duran has an MS in chemical engineering and seven years of environmental experience as a private consultant and as a project manager with the EPA. Mr. Duran has worked as a project manager on more than 50 environmental projects including site investigations, feasibility studies, landfill closure, remedial design, construction and operation of groundwater and soil treatment systems and permitted RCRA treatment, storage and disposal facilities.

Ms. Lewis has a BS in chemical engineering and is a chemical engineer and risk assessment specialist for Parsons Engineering Science, Inc. She has provided guidance and technical support for risk assessments conducted as part of environmental restoration efforts for the DOE and the Department of Defense.

Mr. Kuhns has an MS in safety science and is currently an advisory scientist and engineer for the Lockheed-Martin Idaho Technologies Corporation at the Idaho National Engineering Laboratory (INEL), which he joined in 1989. At INEL, Mr. Kuhns has held a number of positions in the environmental restoration/waste management arena.

Dr. Navratil has a Ph.D. in chemistry and is the Chief Scientist with Rust Federal Services. He has more than 25 years of extensive experience with radioactive, hazardous and mixed wastes, actinide chemistry and radionuclide solubilities.

Mr. Rostami has an MS in mining engineering and is currently a senior research associate at Earth Mechanics Institute. He has worked at various capacities in the Iranian Institute of Mineral Research and Application in the field of mineral processing.

Mr. Smith has an MS in environmental chemical hazard analysis and is currently president of Technical & Management Systems & Services Inc., an environmental management consulting firm. He has nearly 20 years of environmental science and engineering experience with 13 years in the hazardous waste industry. Mr Smith is a board certified industrial hygienist.

Dr. Wahi has a Ph.D. in mechanical engineering and is the President/Owner of Geological Repository Assessment Methodologies, Inc., which provides waste management and environmental restoration consulting and support services. He has 20 years of experience in nuclear waste management, specializing in geomechanics, numerical modeling, performance assessment of geological repositories and coupled processes.

Panel members have established academic qualifications, as well as substantial relevant experience, and are independent of the WIPP project. Additional information regarding the technical qualifications of the panel members is provided in the final peer review report (see Appendix PEER). A letter from the Peer Review Manager regarding the verification of independence for panel members is also presented in Appendix PEER (Additional information regarding the independence of the panelists is available in the CAO Record Center.) All technical disciplines needed to perform the review were represented.

After orientation and training as required by TP 10.5, the panel was briefed by the EACBS report authors and DOE staff. To review the large amount of information provided in the EACBS and supporting documentation, the peer panel divided itself into three subcommittees to address specific factors of the study. The subcommittees were formed on the basis of the expertise that was most appropriate for each set of factors. Eventually, all subcommittee findings were reviewed by the entire peer panel.

9.3.3.1 General Results

Following completion of its review, the panel prepared a final report on July 10, 1996. The results of the EACBS peer review evaluation are summarized in Table 9-3 and a copy of the complete report is provided in Appendix PEER. The following conclusions are presented in the final report:

- the information presented within the EACBS is of high quality,
- the approach taken is valid,
- the conclusions drawn are reasonable, and
- the analysis was conducted in accordance with 40 CFR § 194.44 criteria.

The EACBS panel report also identifies several findings/concerns/issues. The DOE developed a response to the issues identified in the panel report. The panel's concerns and the DOE responses are discussed in the following sections.

9.3.3.2 Engineered Alternatives Cost/Benefit Study Peer Review Panel Concerns

The DOE conducted an evaluation to assess the relative benefit and associated cost of various engineered alternatives (EAs) for the disposal system. The analytical methodology and final results of the Engineered Alternatives Cost Benefit Study (EACBS) were critically reviewed for technical merit, adequacy, and accuracy of results by a team of outside experts.

The EACBS panel expressed several concerns regarding the EACBS. The EACBS panel's concerns ("Peer Review Panel Concerns" -- presented in italics) and the DOE's response to the panel's concerns ("Response to Issue") are presented below. The panel members were asked to review the DOE responses and determine whether they agreed with the responses. The panel's reaction to the responses is provided below ("Peer Reviewer Consideration of Response"). In those instances where panel members disagreed, from a technical-based perspective, with the DOE response, the DOE developed additional information which describes the justification for its final technical position on the concern ("DOE Technical Position versus Panel Issue").

For incorporation into this application, the DOE responses were edited to insert cross-references where appropriate and correct typographical errors. Substantive technical content of the responses has not been changed.

The individual comments are listed first, followed by the response. Comments are arranged by topics that start with the engineered alternatives identification and screening process and are followed by the eight factors evaluated in the EACBS report. In several cases, the peer

Table 9-3. Summary of the Peer Review of the EACBS Evaluation Factors and Criteria

Engineered Alternatives Evaluation Factors	A. Adequacy of Requirements and Criteria	B. Validity of Assumptions	C. Alternative Interpretations	D. Uncertainty of Results and Consequences if Wrong	E. Appropriateness and Limitations of Methodology and Procedures	F. Adequacy of Application	G. Accuracy of Calculations	H. Validity of Conclusions
Evaluation of the EA Screening Process	Generally considered to be adequate, although some other potential EAs could have been added.	Evaluation was qualitative and was to assess assurance, not compliance. This assumption was prescribed by law and was therefore considered valid	None.	The screening process was conservative in nature and was thus more inclusive than exclusive.	The screening process was considered to be appropriate. A better description of the process would have enhanced the report.	The sequence of comparing, scoring, prioritizing, etc. was adequate to achieve the results.	The use of algorithms and professional judgement were deemed appropriate.	The final list of EAs selected for further analysis was reasonable.
1. Long Term Repository Performance	Adequate	Broad Level: Appropriate. Detailed Level: Intrusion scenarios assumed to occur at 5,000 years; and actinide solubility assumptions were conservative. Broad Level: Appropriate; Detailed Level: Uncertainty in creep parameters was not considered. Differences in creep closure estimates could affect the quantity and rates of release; early intrusion could result in significantly different releases; and EAs with plasma processing or clay backfill were not credited with enhanced Pu immobilization.	Different creep closure models or model coefficients may affect the relative benefits of EAs; and the effects of future mining nearby could have been considered as an additional human intrusion scenario.	Uncertainty will result due to the uncertainty of input parameters; however, no severe consequences if wrong; conservative parameter estimates were used.	Use of the DAM model to predict performance was appropriate; however, important advances in creep modeling were not used. Model did not (and cannot) consider stratigraphy (e.g., anhydrite layers) in the mechanical response calculations.	Compressive strengths of waste/backfill EAs is misleading; and intrusion before creep closure not adequately analyzed.	Creep rate calculations checked and qualitatively agree.	Effectiveness of some EAs may have been underestimated due to simultaneous consideration of pre-closure and post-closure risks.
2. Uncertainty in Compliance Assessment				Relative nature of analysis allows meaningful conclusions to be drawn. Discussion of uncertainty in the results does not fully reflect the uncertainty analysis that was in fact carried out.		Methods used are completely applicable for comparative screening process		

Table 9-3. Summary of the Peer Review of the EACBS Evaluation Factors and Criteria (Continued)

Engineered Alternatives Evaluation Factors	A. Adequacy of Requirements and Criteria	B. Validity of Assumptions	C. Alternative Interpretations	D. Uncertainty of Results and Consequences if Wrong	E. Appropriateness and Limitations of Methodology and Procedures	F. Adequacy of Application	G. Accuracy of Calculations	H. Validity of Conclusions
3. Worker and Public Risk	Adequate	Risk assumptions are conservative, conventional, and adequate for the work performed.	None.	Uncertainties err on the side of safety and risks are likely overstated.	Methodology did not account for risks inherent in current waste handling methods. For example, relative risks could have been different for these EAs having long development/processing time.	Methods are applicable for the comparative screening process.	Calculations are reasonable and consistent.	Risk conclusions for CH waste appear valid. Risk conclusions for RH waste are absent.
4. Impact on Waste Removal	200 year period for waste removal requires justification; different time frames have a major impact on the methods used for retrieval.	Assumed excavation technology is appropriate, but the data used in the calculations is not state-of-the-art. For long term retrieval, assumptions and methodology used for mining rate and time estimates are correct; quantitative studies are needed. Short-term retrieval method, rate, and schedule not addressed.	Alternative methods for recovery based on different time frames could have been performed.	Uncertainty associated with the compressive strength of the EAs is not critical to the relative comparison of EAs. The waste is removable with today's technology and the decisions made based on the EACBS are not irreversible.	Methodology was appropriate to estimate time required for long-term removal; however, some of the assumptions, data, and terminology were not suitable for the application.	Time of waste removal was not adequately addressed.	Overall, calculations could not be checked for accuracy; there is no reference to machine type, specifications, and utilization.	Although the quantitative results of the analysis can not be directly used for assessment of the EAs, the general conclusions based on a qualitative comparison with the baseline are valid and acceptable for long-term removal. Consideration of short-term removal could change the results.

Table 9-3. Summary of the Peer Review of the EACBS Evaluation Factors and Criteria (Continued)

Engineered Alternatives Evaluation Factors	A. Adequacy of Requirements and Criteria	B. Validity of Assumptions	C. Alternative Interpretations	D. Uncertainty of Results and Consequences if Wrong	E. Appropriateness and Limitations of Methodology and Procedures	F. Adequacy of Application	G. Accuracy of Calculations	H. Validity of Conclusions
5. Transportation Risk	Adequate	Risk analysis assumes 20 year active life, yet the WIPP operational window is for 33 to 35 years. Transportation is by truck only, no explanation why rail is not evaluated. Overall, however, risk assumptions are conservative, reasonable and well within contemporary transportation risk analysis.	There is no reasonable alternative interpretation.	Population densities will be different if the period of transportation and disposal is greater than 20 years. An added risk could occur for those EAs which have a longer time frame.	The methodologies were considered to be generally appropriate. Limitations include addressing only CH waste, a "bounding" accident not being evaluated, and lack of justification for selected values. The limitations should not compromise the EA evaluation so long as the 20 versus 35 year issue is recognized.	Methods used are applicable for comparative screening process	Calculations appear to be reasonable and consistent with the methodology.	The conclusions drawn for purposes of a qualitative comparison of the transportation risks of the various EAs appears valid.
6. Public Confidence in the Performance of the Disposal System	Adequate	Assumptions regarding the public's concerns as to content, categorization, timeliness, and affected in-state population are reasonable. Although out of state populations were not addressed, this is not considered to be a major deficiency.	Slightly different interpretations are possible, but would not affect the conclusions of the study.	Uncertainty is low regarding the public's position on the EAs and slight misinterpretations are not considered serious.	The methodology used to assess public confidence was appropriate. A limitation is the lack of opportunity for out of state public comment.	Application of the methodology was considered proper.	Categorization of public comments was checked and determined to be relatively accurate with only minor discrepancies.	The conclusions appear appropriate.
7. System Cost and Schedule	Adequate	Cost and schedule assumptions are considered to be valid with uncertainty of approximately 30 percent associated with the uncertainty of the waste inventories.	A few alternate interpretations may originate from the guidance documents. However, they would have little effect on the study's results.	The estimated costs and schedules were reasonable.	The methodology for cost and schedule evaluation is considered appropriate.	Methodologies were appropriately applied.	Spot checks determined that calculations were performed according to accepted methods and procedures.	In general, the conclusions are valid.

Table 9-3. Summary of the Peer Review of the EACBS Evaluation Factors and Criteria (Continued)

Engineered Alternatives Evaluation Factors	A. Adequacy of Requirements and Criteria	B. Validity of Assumptions	C. Alternative Interpretations	D. Uncertainty of Results and Consequences if Wrong	E. Appropriateness and Limitations of Methodology and Procedures	F. Adequacy of Application	G. Accuracy of Calculations	H. Validity of Conclusions
8. Impact on Other Disposal Systems	Adequate	The assumptions of waste type and volume have uncertainties associated with them that may impact other disposal systems. The assumptions used appear reasonable.	The uncertainties associated with waste volume can be interpreted in different ways. Some interpretations will result in higher volumes while others will result in lower volumes.	Uncertainty of results are +10% to -25% based on waste volume uncertainty. No serious negative consequences should occur because of this uncertainty.	Procedures used are technically defensible. A limitation of the methodology is the reliance on the accuracy of waste volume.	The techniques used were adequate to meet the intended goal.	The basis of calculations was not provided in the EACBS; however, using reasonable assumptions, data spot checks were found to be accurate.	The conclusions reached are valid and support the end use of the report.

review panel recommended clarification changes to the text of the EACBS report. The DOE has determined after a review of the peer review panel comments, that no revision of this report is necessary at this time. However, the DOE will ensure that these recommendations are kept in mind when discussions of the EACBS are included in regulatory documents.

9.3.3.2.1 *Peer Review Panel Concerns - Results of the Engineered Alternatives Identification/Screening Process*

In general, the peer panel members thought that the identification/screening process was adequate. However, members felt that the EACBS report was not clear on the description of the screening process and expressed difficulty in understanding the steps and criteria involved. Only after presentations were made by and interactive discussions were held with those involved in the actual EACBS identification/screening process did the members come to a mutual understanding of how the process was carried out. Among the comments made by the panel are the following:

9.3.3.2.1.1 First Peer Review Panel Concern - Results of the Engineered Alternatives Identification/Screening Process

> *"Clarification is needed in the text of the report on the steps involved in the identification/screening process, including steps that occurred after the Engineered Alternatives Task Force performed their initial evaluation. Better define what is meant by "screening," "optimization," and "prioritization." Clearly state the criteria used for each stage of the process."*

Response to Issue

The DOE understands the confusion surrounding these terms, particularly in light of the multiplicity of the agencies and organizations that have expressed interest in how EAs should be applied to the WIPP. In this application, the DOE has attempted to use these terms in a fashion that is consistent with the EPA's usage in 40 CFR Part 194 and the CAG (EPA 1996c). The three processes are documented in the EACBS. The specifics of the screening process and original prioritization are found in Appendix D. The optimization process is briefly described in Appendix D, however this process included management decisions not defined in the report.

Peer Reviewer Consideration of Response

Four panel members commented on the DOE response to this concern. Two members agreed with the response and one disagreed. The fourth panelist, although agreeing that the information in the response was adequate, believed that this information should be provided in the main part of the EACBS.

DOE Technical Position versus Panel Issue

The DOE has clarified the process in Section 7.4.3.1 of this application, which includes a description of the DOE Management Assessment used to determine the final 18 EA used in the analysis.

9.3.3.2.1.2 Second Peer Review Panel Concern - Results of the Engineered Alternatives Identification/Screening Process

> *"Some concern was expressed that the screening process was conducted independent of a consideration of the eight factors used in evaluating the EAs. If the screening process and evaluation of EAs according to the eight factors had been iterative, the list of EAs analyzed as well as the results of both the screening process and the evaluation of the EAs may have been different. However, this would probably be an endless process of iterations and not justified because of cost and time involved."*

Response to Issue

In an effort to ensure a reasonable menu of alternatives for potential selection of engineered barriers, the DOE elected to separate the screening process from the actual factor analyses. The key screening criteria for selecting EAs for detailed factor analysis was therefore the impact on improving long-term performance, with additional concern given to technological and regulatory feasibility of implementation. The selected alternatives were then evaluated with respect to the eight factors. Factors such as waste retrieval or public perception were not considered in the selection criteria because these factors are not related to compliance with 40 CFR Part 191.

Peer Reviewer Consideration of Response

Three panel members commented on the response. One panelist agreed with the response as written and one other disagreed. The third commenter agreed with the response but believed that the DOE should make a stronger case that the EACBS considered the breadth of plausible alternatives.

DOE Technical Position versus Panel Issue

The DOE developed the screening process that used a qualitative assessment of the potential benefits on the WIPP disposal system. Good engineering practices were used in this assessment. A pure quantitative rating could not be justified because it would require a complete analysis of each EA by all eight factors. The intent of the screening process was to identify EAs with the highest potential to benefit the disposal system and further analyze their impacts within the multifactor analysis.

9.3.3.2.1.3 Third Peer Review Panel Concern - Results of the Engineered Alternatives Identification/Screening Process

> *"Remote-handled waste was not considered. This issue may have implications to the compliance application."*

Response to Issue

The inventory of remote-handled (RH) waste was combined with the contact-handled (CH) waste and was not considered separately in the EACBS. RH-TRU waste constitutes a maximum of five percent of the inventory by volume. This material is practically identical to CH-TRU waste except that it is contaminated with short-lived beta-gamma emitters as well as the long-lived actinides present in CH-TRU waste. There is therefore no need to consider RH-TRU waste separately from a long-term performance stand-point. There may have been some differences in the treatment costs for the RH fraction because of the possible need for a greater degree of shielding, and there may have been additional worker risks involved because of the presence of penetrating radiation. The Engineered Alternatives Screening Working Group concluded therefore, that the limited volume of RH did not justify separate consideration of this small fraction of the inventory.

Peer Reviewer Consideration of Response

The only panel member who commented on the response agreed in part with the response; however, the panelist suggested that, for completeness, a factor approach be used that could weigh the risk and cost of handling RH-TRU waste into each engineered alternative under evaluation.

DOE Technical Position versus Panel Issue

Because the inventory of RH-TRU wastes is a small percentage of the total WIPP waste inventory, is limited by the land withdrawal area, and will decay to CH-TRU waste levels in a relatively short time period, the DOE believes that RH-TRU wastes need not be considered separately in the EACBS.

9.3.3.2.2 Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

These factors focused primarily on the analyses performed with the Design Analysis Model (DAM) computer simulation program. This program was used to predict the future performance of the repository with different engineered alternatives given three different human intrusion scenarios. Values for several parameters are required as input to the model. Many input parameters were treated as being uncertain; that is, ranges and distributions were assigned to such parameters. Other parameters were given constant (single point) values. The panel members checked many of these parameters, as well as quality assurance documentation for the computer simulation itself. No major discrepancies or errors were noted. It was noted by the panel members that much of the information used in the model was selected to be consistent with the performance assessment being conducted by SNL. The DAM was chosen to determine relative repository performance because it parallels SNL's performance assessment work in a less complex manner allowing various changes to the inputs to be run quickly on a PC format.

9.3.3.2.2.1 First Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

> *"The simplifying assumptions used in the model are valid given that the results are to be used in a relative, not absolute, manner. Actual calculated releases of radionuclides, although not absolute, are acceptable for comparison purposes."*

<u>Response to Issue</u>

The DOE agrees. The relative approach was designed to produce a ranking of the alternatives in a cost-effective manner without the need to apply a full performance assessment to each EA.

<u>Peer Reviewer Consideration of Response</u>

The only panelist who commented on this response agreed with the DOE response.

9.3.3.2.2.2 Second Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

> *"Creep closure modeling did not consider uncertainty in creep parameters nor did it incorporate important advances in creep modeling. Different time periods for closure would have likely resulted which may have changed the relative ratings of the EAs, but the conclusions will probably not change."*

<u>Response to Issue</u>

The DOE agrees with this statement. The creep algorithm in the DAM uses the Chabannes Equation as a functional form, but the values of the creep constants employed in the equation are based on a multivariate regression of many years of creep closure data obtained from extensiometer and closure measurements from the actual rooms and drifts excavated at the WIPP repository horizon. This semi-empirical approach has been benchmarked against the SANCHO code (a precursor to the SANTOS code; see Appendix PORSURF) and was shown to produce comparable results. The DOE maintains that the use of the Chabannes Equation, coupled with closure constants based on empirical observations, produces results that are adequate for implementation in the DAM, which was used for relative comparisons only.

Peer Reviewer Consideration of Response

Two panel members commented on this response: one agreed with the response and the other did not.

DOE Technical Position versus Panel Issue

The DOE maintains that the use of the Chabannes Equation, coupled with closure constants based on empirical observations, produces results that are adequate for implementation in the DAM, which was used for relative comparisons only. The time variations were investigated and the conclusions are discussed in Section 3.1.3.1 of the EA report.

9.3.3.2.2.3 Third Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

> *"The EACBS report assessed the effect of human intrusion at 5000 years as well as additional simulations for the baseline and nine selected alternatives at 200, 2000, and 7000 years. This assessment concluded that the Measures of Relative Effectiveness (MREs) are insensitive to the time of intrusion once the physical properties (density and permeability) of the composite material in the room reaches a steady-state condition. This occurs some time between 200 and 2000 years. One exception is the MREs at 200 years which differ by several percent from the MREs at later years because the composite material in the rooms at 200 years is still in the process of consolidating from creep closure, and this consolidation occurs at different rates for each alternative. Consolidation of the composite material is complete by 2000 years, so the MREs remain constant thereafter. Had the analysis included radionuclide transport within the Culebra, it is likely that the results would have shown a stronger sensitivity to the time of intrusion (e.g., within a few hundred years)."*

Response to Issue

The DOE agrees that results become insensitive to the time of intrusion at a point somewhere between 200 and 2,000 years after facility closure. However, there are two factors that strongly support the DOE's approach. First, the complexity that would be required in the calculation scheme to model the brine-gas-creep closure interactions and produce higher resolution are not justified to resolve minimal percentage point differences in MRE's. Secondly, characteristics of specific EAs that affect releases due to intrusions are, for the most part, insensitive to the state of consolidation in the repository; therefore, simplifying the analysis by "skipping" the 200 to 2,000 year interval does not result in a loss of the important information that is necessary to make reasonable comparisons of the alternatives.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.2.4 Fourth Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

> *"The uncertainty analysis in the EACBS report focused on uncertainty associated with input parameters. Uncertainty associated with the model itself and with the future state of the disposal system were not considered."*

Response to Issue

The DOE agrees. Uncertainties in the conceptual model and alternative future states of the disposal system were outside the scope of the EACBS. These types of uncertainties are, of course, incorporated in the final performance assessment calculations in the application, as they are important to a reasonable prediction of repository performance, but not necessary for reasonable selections among EAs.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.2.5 Fifth Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

> *"Because the study focuses on potential benefits of EAs beyond the baseline design, consequences of reaching a wrong conclusion are not expected to be severe."*

Response to Issue

The DOE agrees. The consequences of reaching a wrong conclusion are actually non-existent because before an alternative is implemented, it will be incorporated into performance assessment.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.2.6 Sixth Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

> *"Lack of a user's manual for the DAM code makes it difficult to independently verify calculations in the EACBS report."*

Response to Issue

Unfortunately, the DAM was prepared prior to the conduct of EACBS. DAM was an existing tool selected for use in the EACBS. The code is fully documented, checked, and has been verified in calculation briefs. The code documentation is on file and was reviewed by a subcommittee of the peer review panel.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.2.7 Seventh Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

> *"The comparative, unweighted approach used for evaluating alternatives results leads to an inevitable trade-off between long-term performance and short-term risk. The DOE can avoid this pitfall by separately evaluating the merits of each EA in the post-closure phase only. Specifically, by comparing only the first two columns of results in Figure E-4 (of the EACBS report), one can more clearly see the long-term benefits offered by each EA."*

Response to Issue

While the DOE agrees with this observation, the objective of the EACBS was to compile and present information on the eight factors for each of the EAs to support decisions regarding the selection of an EA. Assigning such weighing factors or discussing trade-offs between long-term performance versus short-term risks was a process that was appropriately left to the DOE decision maker and was beyond the scope of the EACBS.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.2.8 Eighth Peer Review Concern - Evaluation of Factors 1 and 2: Impacts on Long-Term Repository Performance and Uncertainty in Compliance Assessment

> *"The effectiveness of EAs with clay backfill or vitrification treatment was underestimated because the enhanced immobilization of actinides within these matrices was not assumed."*

Response to Issue

The DOE agrees. With respect to clay backfill, it was stated in Section 3.1.1 of the EACBS report (Appendix EBS) that, although clay minerals have a well known affinity to adsorb actinides, the lack of data under saturated brine conditions makes it difficult to take credit for this process in a defensible way. This approach is consistent with the performance assessment methodology which also concluded that data to quantify actinide sorption on the various substrates under WIPP-specific physicochemical conditions are not available, and their acquisition is not practicable. Therefore, predicting sorption under WIPP-specific conditions is not feasible. It was also explained in the EACBS report that the net effect of not considering this process is to minimize the predicted effectiveness of EAs that involve the addition of clay to the drums or backfill.

Peer Reviewer Consideration of Response

Two panel members commented on this response: one agreed with the DOE response and the other did not.

DOE Technical Position versus Panel Issue

The DOE maintains its position that there are not enough data available under WIPP-specific conditions to take credit for this process in a defensible way.

9.3.3.2.3 Peer Review Panel Concern - Evaluation of Factor 3: Impact of Engineered Alternatives on Worker and Public Risk

9.3.3.2.3.1 First Peer Review Panel Concern - Evaluation of Factor 3: Impact of Engineered Alternatives on Worker and Public Risk

> *"An evaluation of the risks associated with the processing of remote-handled (RH) waste is absent. It would be helpful to include a discussion of the possible relative comparison between the risk associated with CH and RH wastes. For example, one can draw conclusions based on radionuclide difference, radionuclide mobility, potential for release, transport mechanisms, and exposure scenarios associated with both waste processing and long-term performance."*

Response to Issue

The inventory of RH-TRU waste was combined with the CH-TRU waste and was not considered separately in the EACBS. RH-TRU waste is limited by statute to comprise no more than five percent, by volume, of the total WIPP waste inventory. This material is practically identical to CH-TRU waste except that it is contaminated with short-lived beta-gamma emitters as well as the long-lived actinides present in CH-TRU waste. These beta-gamma emitters will rapidly decay during the 100-year postclosure period during active institutional control. Therefore, there is no need to consider RH-TRU waste separately from a long-term performance stand-point.

Peer Reviewer Consideration of Response

The only panel member who commented on this response partially agreed with the DOE response. That panelist made the same comment as was expressed for the RH concern discussed in Section 9.3.3.2.1.3.

DOE Technical Position versus Panel Issue

Because the inventory of RH-TRU wastes is a small percentage of the total WIPP waste inventory, is limited by the land withdrawal area, and will decay to CH-TRU waste levels in a relatively short time period, the DOE believes that RH wastes need not be considered separately in the EACBS.

9.3.3.2.3.2 Second Peer Review Panel Concern - Evaluation of Factor 3: Impact of Engineered Alternatives on Worker and Public Risk

> *"Many of the assumptions used in assessing worker and public risk appear to be borrowed from the Environmental Management Programmatic Environmental Impact Statement (EMPEIS). While these assumptions may be valid, additional discussion of them in the text of the EACBS would provide further clarification."*

Response to Issue

Many of the assumptions and initial analysis parameter values were, as the panel has noted, taken from the Environmental Management Programmatic Environmental Impact Statement. The reason this consistency was important was to keep the EACBS risk analysis consistent with important aspects of other related DOE risk evaluations nationwide. The entire suite of WIPP National Environmental Policy Act (NEPA) documents is available for review in several locations. The DOE did not see the need to discuss these assumptions in any greater detail within the EACBS.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.3.3 Third Peer Review Panel Concern - Evaluation of Factor 3: Impact of Engineered Alternatives on Worker and Public Risk

> *"Additional risks posed by allowing the waste to remain above ground for longer time periods necessitated by some of the EAs were not evaluated. This could underestimate risks associated with those EAs."*

Response to Issue

The purpose of the EACBS study was to determine relative risks from various TRU waste processing and disposal alternatives, and did not directly include waste storage impacts as noted. It is true that in some cases waste would be stored above ground for a longer time period for some of the EAs, particularly when a given treatment process has not yet been fully developed for TRU waste. However, ultimately, a long-term disposal decision would be needed. The scope of the EACBS was to look at alternatives to support the disposal decision. It is assumed that the waste containers would be stored for an additional time period that was within the expected lifetime of the container, and therefore no repackaging related risks would be included. It is further assumed that workers will continue to limit their exposure to stored waste containers in accordance with the as low as reasonably achievable policy. Therefore, the loss of resolution did not affect the DOE decisions in important ways.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.4 Peer Review Panel Concern - Evaluation of Factor 4: Waste Removal Impact

The evaluation of Factor 4 was conducted in the context of 40 CFR § 194.44, assuming that the removal of the emplaced waste and backfill (after the regulatory closure) is possible. The factor considers the impact of EAs on waste removal after 200 years with no justification. The methodology used and the conclusions made based on a qualitative comparison using the volume and the time required for removal are acceptable. However, the following comments were made with respect to this factor:

9.3.3.2.4.1 First Peer Review Panel Concern - Evaluation of Factor 4: Waste Removal Impact

> *"Short-term removal of the waste and backfill (from regulatory closure of the repository to geological closure of the rooms) was not considered. Had the short term removal scenarios been considered, the results of relative comparison may be different."*

Response to Issue

The DOE agrees with this statement. However, waste removal should not significantly influence the selection of an EA since the regulations clearly state that no additional actions are needed for mined geologic repositories to meet removal requirements. Therefore, an arbitrary point in time at 200 years after facility closure was chosen for convenience to evaluate the differences between the EAs with respect to the relative ease attributed to waste removal. It was beyond the scope of the EACBS to evaluate these differences as a function of time. A separate report has been prepared to demonstrate that it is technically feasible to remove the waste should a future generation decide to do so. It is included as Appendix WRAC (Waste Removal After Closure).

Peer Reviewer Consideration of Response

Two panel members commented on the DOE response: one agreed with the DOE response and one did not.

DOE Technical Position versus Panel Issue

The DOE recognizes that the EPA requires an assessment of the feasibility of removing wastes from the repository after closure, and that these effects should be considered when selecting an engineered barrier alternative. The DOE has conducted this required assessment and has concluded that, using current technology for mining (a provision of 40 CFR § 194.25[a]), wastes of any form can be retrieved from the underground. This does not imply that removal of wastes would be simple or without risk. If fact, the level of risk and the cost are the uncertain variables in the various scenarios (that is, waste in degraded steel drums versus vitrified waste forms). Undoubtedly, a substantial level of radiological controls will be required to protect workers, and the process would span many years. Because of the effective design, construction, and management of the WIPP facility, combined with the demonstration of compliance with the long-term performance standards of 40 CFR 191 (see Section 6.5), the DOE does not believe that removal of wastes will be necessary. Therefore, this factor was not given special attention when selecting the current suite of engineered barriers.

9.3.3.2.4.2 Second Peer Review Panel Concern - Evaluation of Factor 4: Waste Removal Impact

> *"If waste removal had been one of the evaluation criteria, different alternatives may have reached the detailed evaluation stage (e.g., the EAs which passed through each screening process may have included one or more additional alternatives than the EAs contained in the final list)."*

Response to Issue

As stated above, the DOE chose not to emphasize removal in order to be consistent with the disposal standards. The standards require only that removal be possible, not easy, inexpensive, or free of risk. Therefore, the DOE believed it was best to ensure that there was no selection bias introduced based on removal.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.4.3 Third and Fourth Peer Review Panel Concerns - Evaluation of Factor 4: Waste Removal Impact

"The results of implementing any of the EAs would not be irreversible and waste could be removed after disposal, using current technology.

The assumptions and conclusions should be used for comparative purposes only. Some assumptions used for quantitative calculations were inappropriate for the circumstances but serve the purpose for a comparative study."

Response to Issues

These statements are correct. The goal for the study was indeed to produce relative results for comparison purposes only. Particular assumptions such as the use of current technology (continuous mining techniques) to remove the waste 200 years from final facility closure are consistent with EPA guidance for future state assumptions applicable to similar processes such as future drilling.

Peer Reviewer Consideration of Response

Two panel members commented on the above response. One panelist agreed with the DOE response, while the other believed that a study of the relative impacts of EAs on waste removal was within the scope of the EACBS.

DOE Technical Position versus Panel Issue

As stated previously, the DOE agrees that the Factor 4 analysis can be used only for comparative purposes. The specifics as to which technology should be used are not important. As the commenter noted, they serve the purpose for a comparative study.

9.3.3.2.5 Peer Review Panel Concern - Evaluation of Factor 5: Impact of Engineered Alternatives on Transportation Risk

9.3.3.2.5.1 First Peer Review Panel Concern - Evaluation of Factor 5: Impact of Engineered Alternatives on Transportation Risk

"The "worst-case" accident considered in the reference document for the EACBS (the Final Supplemental Environmental Impact Statement) appears to have been eliminated from consideration in the EACBS with no justification. RADTRAN accounts for accident severity categories within its code. Therefore, modeling of an additional worst-case accident would not provide substantive additional information."

Response to Issue

The "worst-case" accident scenario and analysis was required for NEPA documentation at the time the Final Environmental Impact Statement (FEIS) was prepared. Such an analysis is no longer required. Consequently, a worst case analysis was not performed as part of the EACBS. As noted, such a bounding approach would not have provided important additional information for the purpose of the EACBS.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.5.2 Second Peer Review Panel Concern - Evaluation of Factor 5: Impact of Engineered Alternatives on Transportation Risk

> *"For chemical hazards, risks are calculated solely on a consideration of wasteform characteristics. Transportation-related aspects of the scenario (e.g., mileage, population, density) were not included; an accidental release was simply assumed. The full range of transportation impacts cannot, therefore, be evaluated."*

Response to Issue

In general, transportation routes, population density, and highway mileage traveled during transport are basically constants in the relative comparison of exposure risk among the different waste forms generated by the different EAs. For this reason, the calculation of the full range of impacts would not change the outcome of the analysis in important ways. It was therefore not included in the EACBS.

Peer Reviewer Consideration of Response

Two panel members commented on the above DOE response. One agreed with the DOE response and the other did not.

DOE Technical Position versus Panel Issue

Transportation routes, population density, and highway mileage are the same for each alternative when considered in the same processing scenario. For example, transportation routes are the same for all alternatives in the decentralized scenario. The same is true for the centralized scenario as well as the regionalized scenarios. All waste must follow the same routes, through the same towns, for the same number of miles within each scenario. Therefore, the exclusion of chemical risk assessments for transportation scenarios does not affect the overall results of the EACBS.

9.3.3.2.5.3 Third Peer Review Panel Concern - Evaluation of Factor 5: Impact of Engineered Alternatives on Transportation Risk

"The analysis in the EACBS relies heavily on previous work done in the WIPP Final Environmental Impact Statement (FEIS) and the Final Supplemental Environmental Impact Statement (FSEIS). However, methods used in the previous reports varied; information was not provided in the EACBS to indicate which methods came from original documents and what the justification was for using the methods selected in the EACBS."

Response to Issue

The FEIS (DOE 1980a) was issued in 1980, and the Final Supplement Environmental Impact Statement (FSEIS) (DOE 1990a) was issued in 1990. The DOE methodology for evaluating transportation risk has not significantly varied or changed over the past 14 years. There has, however, been some degree of refinement to the methodology, numerical models, and assumptions used to estimate transportation risk. Transportation risks will be updated for the baseline case in the Disposal Phase Supplement Environmental Impact Statement (SEIS). Transportation risk methodologies were derived from these NEPA analyses sources. This was done to ensure important consistencies between risk evaluation methods were preserved. The method justifications can be reviewed in the NEPA documentation. Including these justifications in the EACBS is not believed to be important considering the purpose of the study.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.5.4 Fourth Peer Review Panel Concern - Evaluation of Factor 5: Impact of Engineered Alternatives on Transportation Risk

"The risk analysis assumes a 20-year life for transportation and disposal of waste; however, the operational window for WIPP is approximately 35 years. Additional population densities might affect the impact analysis of alternatives that require treatment and greater than 20 years to complete transportation and disposal. The panel members do not feel that the apparent discontinuity in this assumption is limiting to the assessment of transportation-related risks."

Response to Issue

The DOE agrees. The transportation risk as presented is not time dependent. As calculated, the risk is based on the total number of shipments to WIPP, thus the total risk posed by the waste does not change appreciably with respect to time. The annual risk could change if the number of shipments per unit time varies, but the annual risk calculations were not needed, and were therefore not included in the analysis for the EACBS. Population densities, as noted, could change over time (35 years), but such change would affect all alternatives equally, thus the EACBS conclusions would still be valid and accurate.

Peer Reviewer Consideration of Response

The only panel member who commented on this response agreed with the DOE response.

9.3.3.2.6 Evaluation of Factor 6: Impact of Engineered Alternatives on Public Confidence

The peer review panel did not find any particular areas of concern with the public confidence evaluation, and felt that the methods used and conclusions reached were appropriate and reasonable. There are no specific comments or areas of concern in need of response.

9.3.3.2.7 Evaluation of Factor 7: Total System Cost and Schedule Estimates

The peer review panel found no significant flaws in the cost and schedule analysis. The panel agreed that the development of cost and schedule estimates was reasonable, appropriate, and defensible. There were no specific comments or areas of concern in need of response for this factor.

9.3.3.2.8 Peer Review Panel Concern - Evaluation of Factor 8: Impact on Other Waste Disposal Programs

The peer review panel concluded that the analysis for impacts to other waste disposal programs was conducted using the best available information. However, they felt that the evaluation should be updated as more recent and accurate data become available to ensure adequate facilities and resources are available for disposal. The following comments were offered:

9.3.3.2.8.1 First Peer Review Panel Concern - Evaluation of Factor 8: Impact on Other Waste Disposal Programs

> *"Except for plasma arc, all other EAs that included treatment are assumed to result in waste volumes similar to cementation processes used at Rocky Flats (an increase of 75 percent). An additional 30 percent of secondary waste is anticipated to be generated, resulting in a total of 2.275 drums from the treatment of a single drum."*

Response to Issue

The first sentence is correct: except for plasma arc, all other EAs that include treatment are assumed to result in secondary waste volumes similar to cementation processes at Rocky Flats (0.75 drums of secondary waste generated per drum of waste treated). However, additional secondary waste is generated in the waste characterization step that precedes treatment, which is the same for the baseline and all EAs. Thirty percent of stored waste and ten percent of projected waste passes through the waste characterization step; for this waste, 0.75 drums of secondary waste will be generated per drum of waste characterized. The total secondary waste generated will not be as high as the 2.275 drums per input drum, as stated, but will be on the order of 0.975 drums per input drum for stored waste and 0.825 drums per input drum for projected waste (stored waste: 0.75 drums per input drum generated from treatment plus 0.75×30 percent generated from characterization = 0.75 + 0.225 = 0.975).

The peer review subcommittee apparently misinterpreted the term "secondary waste." Secondary waste includes wastes generated indirectly as a result of processing TRU waste, (for example, waste from processing related glovebox operations), and does not include waste volume increases or decreases directly related to the treatment operation. These wastes are considered "primary wastes." A cementation treatment process would generate more primary waste than, say, supercompaction, but the secondary wastes were assumed to be generated at the same rate regardless of the treatment process. This is valid because the majority of the secondary wastes result from processing related to glovebox operations for TRU waste and are not process-specific. For example, secondary wastes include leaded glovebox gloves, glovebox and plenum filters, line and non-line combustibles, protective equipment (PE), and empty glass and plastic containers. It was also assumed that the characterization step generates secondary wastes at the same rate as cementation and the other treatment processes because it would be conducted in a glovebox.

<u>Peer Reviewer Consideration of Response</u>

The two panel members who commented on this response agreed with the DOE response.

9.3.3.2.8.2 Second Peer Review Panel Concern - Evaluation of Factor 8: Impact on Other Waste Disposal Programs

"The EACBS report for this factor is difficult to follow at times and could benefit from clarification and the use of examples to show how waste volume estimates were made."

<u>Response to Issue</u>

The DOE appreciates the feedback. There will be a clear explanation of waste volume estimating processes in Section 4.1.3 of this application.

<u>Peer Reviewer Consideration of Response</u>

The two panel members who commented on this response agreed with the DOE response.

9.3.3.2.8.3 Third Peer Review Panel Concern - Evaluation of Factor 8: Impact on Other Waste Disposal Programs

"It is not clear by reading the EACBS report how the volumes of waste destined for WIPP are factored into the report. A best estimate of waste to be disposed should be provided for WIPP operations personnel."

Response to Issue

The methods used to estimate waste volumes and the incorporation of these estimates into the EA study was not important. The DOE will include a clear description of these methods in the compliance certification application where they are much more important. (This information is presented in Chapter 4.0 and Appendix BIR.) Disposal estimates will be gathered annually by the DOE and reported in the BIR. This mechanism will ensure that the operations personnel are provided with the most current inventory estimates.

Peer Reviewer Consideration of Response

The two panel members who commented on this response agreed with the DOE response.

9.3.3.2.8.4 Fourth Peer Review Panel Concern - Evaluation of Factor 8: Impact on Other Waste Disposal Programs

"Percentages of secondary waste generated vary widely with respect to the type of EA implemented. However, the report uses 50-percent figure for both low-level and low-level mixed secondary waste. The use of the actual average percentages would provide a more accurate estimate of waste volumes generated."

Response to Issue

The 50-percent figure was a simplifying assumption that was made in the absence of real data. This assumption is also conservative; making the waste type unimportant.

Peer Reviewer Consideration of Response

The two panel members who commented on this response agreed with the DOE response.

9.3.3.2.8.5 Fifth Peer Review Panel Concern - Evaluation of Factor 8: Impact on Other Waste Disposal Programs

"The actual waste that may be generated by implementing an EA may be as much as 10 percent higher or 25 percent lower than the estimated volumes after treatment, which are provided in the EACBS. This uncertainty is acceptable at this time, as no

definitive information is available to provide a more accurate estimate. These estimates should be revisited and revised as more information becomes available."

<u>Response to Issue</u>

The DOE agrees and has plans to identify any significant, new waste inventory information as it becomes available. The reevaluations will focus on validation of the decisions made based on the EACBS and will be based on the most current BIR information.

<u>Peer Reviewer Consideration of Response</u>

The two panel members who commented on this response agreed with the DOE response.

9.3.3.2.8.6 Sixth Peer Review Panel Concern - Evaluation of Factor 8: Impact on Other Waste Disposal Programs

"The report could benefit by a discussion of other possible impacts on the different DOE disposal systems, not just waste generation."

<u>Response to Issue</u>

The analyses, as performed in the EACBS, were designed to meet the general criteria of 40 CFR Part 194, to address the additional waste generation associated with waste treatment and the implementation of EAs. Such other possible impacts were not believed to be important to the decisions made based on the EACBS. Such impacts are appropriately captured in the EMPEIS where their impacts are more important.

<u>Peer Reviewer Consideration of Response</u>

The only panelist who commented on the above response believed that, although the panel did not identify significant items needing to be addressed, the EACBS should discuss other possible impacts for completeness.

<u>DOE Technical Position versus Panel Issue</u>

The DOE maintains that its original response adequately addresses the issue.

9.3.4 Engineered Systems Data Qualification Peer Review

An Engineered Systems Peer Review (ESPR) Plan (see Appendix PEER) was developed and approved in accordance with the requirements of TP 10.5. The plan describes the peer review process used to ensure that the data used in the models describing engineered systems for rock mechanics and shaft/borehole seals in the performance assessment are qualified for use in the demonstration of compliance.

The DOE used an Independent Review Team (IRT) to carefully review the existing data that was necessary to support the performance assessment. Much of the existing data were qualified because the IRT determined that the quality assurance program in place at the time of its collection was equivalent to American Society of Mechanical Engineers (ASME) nuclear quality assurance (NQA) requirements. It was determined however, that some data used to describe engineered systems could not be qualified in that manner.

40 CFR § 194.22(b) states that:

> *"Any compliance application shall include information which demonstrates that data and information collected prior to the implementation of the quality assurance program required pursuant to paragraph (a)(1) of this section have been qualified in accordance with an alternate methodology, approved by the administrator or the administrator's authorized representative, that employs one or more of the following methods: peer review, conducted in a manner that is compatible with NUREG-1297...."*

The purpose of the ESPR was to seek qualification of scientific data by systematically reviewing parameters and subsystems used in the models describing engineered systems. The conceptual models used in the performance assessment of the engineered systems include components of

- disposal room geometry,
- creep closure,
- repository fluid flow,
- shafts and shaft seals, and
- DRZ.

The review was conducted by four panel members. The panel members and their affiliation were

Dermot Ross-Brown (Chairman), Independent Consultant
John Gibbons, Independent Consultant
Darrell Porter, Science Applications International Corporation
John Schatz, Independent Consultant

Dr. Ross-Brown has a Ph.D. in rock mechanics and more than 30 years experience as a mining/civil engineer. He has been heavily involved in nuclear waste disposal since 1975, including planned repositories in salt, granite and tuff.

Dr. Gibbons has over 25 years of experience consulting to the nuclear industry. He has been involved in several research and field studies of the behavior and geology of bedded salt deposits since 1965. Since 1976, Dr. Gibbons has also been a principal investigator for hydrogeology in many low-level nuclear waste and uranium mine and mill tailings projects in the southwestern United States.

Dr. Porter has 34 years of experience in rock mechanics. During the past 13 years, he has supported the U.S. Geological Survey in its site characterization program for the Yucca Mountain project.

Dr. Schatz has 29 years of experience in rock properties testing and analysis, including nuclear waste-related activities at the national laboratories and in commercial industry. Dr. Schatz has been involved in IRT panels, which reviewed the existing WIPP data and its associated QA program.

The panel members have well established academic and professional credentials and were independent of the WIPP performance assessment activities. Additional information concerning the panel member qualifications is provided in the peer review report (see Appendix PEER). Documentation of panel member independence also presented in Appendix PEER. All of the technical disciplines needed to perform this task were represented on the panel.

Prior to beginning their review, the panel members received administrative orientation and training on the ESPR Plan, 40 CFR Parts 191 and 194, the QAPD, NUREG-1297 and TP 10.5. The panel reviewed information packages provided by SNL for each parameter. In addition, technical reports and documents obtained from the SNL waste management library and records center were used to supplement the information in the parameter packages provided. Both formal and informal technical discussions were held with SNL principal investigators to more fully understand the concepts, parameter derivation, and application in the performance assessment.

The panel performed an in-depth critique of assumptions, alternate interpretations, methodology and acceptance criteria employed, and of conclusions in the original work. According to the "Description of Work Performed" in their final report, the panel members considered:

- sources of the parameters and data, for example, professional judgment, published source material, field tests, laboratory experiments, etc.;

- appropriateness of the parameters and data for their intended use; and

- assumptions, calculations, extrapolations interpretations, methods, appropriateness, validity, sensitivities, and conclusions pertinent to the parameters and data used as input to the WIPP Performance Assessment.

The data that were considered by the panel supported the models describing engineered systems and were used to derive parameter values that are incorporated into the models. In some instances, parameters were consolidated into parameter groups.

Fourteen parameters (several of which were actually groups of closely related parameters) were evaluated by the panel. The panel qualified seven of the parameters and two of the parameter groups (properties of halite and anhydrite, and data on final porosity surface). In the panel's opinion, minor changes should be made to two of the parameters (pore volume compressibility of Salado mass concrete (SMC) and permeability of consolidated waste), and further analysis by SNL is needed on two other of the parameter groups (permeability of crushed salt and the strength of the waste for spalling ("blowout") releases. The panel concurred with SNL's general treatment of the remaining parameter (general treatment of the DRZ). Table 9-4 lists the parameters reviewed by the panel and summarizes the panel's conclusions regarding their adequacy.

Table 9-4. Summary of Qualification Status of Parameters, as a result of the Engineered Systems Peer Review

Subsystem	Parameter Name	Qualification Status of Parameters
Shaft/shaft	Porosity of SMC	Qualified
Seal	Pore Volume Compressibility of SMC	Minor change to value suggested*
	Bulk Modulus of Crushed Salt	Qualified
	Permeability of Crushed Salt	Requires further analysis by SNL*
	Permeability of SMC	Qualified
	Permeability of Compacted Clay	Qualified
Disposal	Initial Density of Waste	Qualified
Room/ Rock	Mechanical Properties of Waste	Qualified
Mechanics	Initial Water Content of Waste	Qualified
	Permeability of Consolidated Waste	Minor change to value suggested*
	Strength of Waste for "Blowout"	Insufficient data to qualify*
	Properties of Halite and Anhydrite	Qualified, based on limited review**
	Data on Final Porosity Surface	Qualified, based on limited review**
DRZ	Characterization of DRZ	Concepts qualified

* The panel subsequently determined, on the basis of additional input from the DOE, that the DOE responses had reasonably addressed their concerns.

** The panel chose to consider these parameters from an overview approach, however, the panel was able to qualify these parameters.

Initially, the ESPR panel failed to qualify four of the parameters (or parameter groups) which they reviewed. Where appropriate, the DOE interpreted the ESPR panel's concern and in all four cases developed a WIPP project response. The ESPR panel's concerns (in italics), the DOE's interpretations of the panel's concerns ("Statement of Issue"), where appropriate, and their responses ("Response to Issue") are provided below. The panel then reviewed the response to determine whether the DOE understood the issue and provided a reasonable response ("Peer Reviewer Consideration of Response").

The DOE responses were provided to the panel as individual memoranda. For incorporation into this application, the responses have been edited to remove the memorandum format, consolidate references, replace first-person text, insert cross-references where appropriate and correct typographical errors. Substantive technical content of the responses has not been changed.

Based on the additional information the DOE provided in response to the panel's concerns, the panel subsequently concluded that the DOE had reasonably addressed their concerns for all the parameters and parameter groups. The data used to derive the parameters and parameter groups that were reviewed by the ESPR panel were therefore qualified per 40 CFR § 194.22(b).

At the completion of the review, the panel prepared a documented summary of its work and an evaluation of the selected parameters reviewed by the panel. A copy of the Engineered Systems Data Qualification Peer Review Report, dated July 1996, is provided in Appendix PEER. The following provides the initial evaluation of each parameter (or parameter group) that was qualified by the peer review as quoted from the "Executive Summary" of the ESPR Report:

- *"Porosity of Salado Mass Concrete (SMC). The panel is able to qualify the value of 5%. However, this value is not a unique property of SMC; rather, it is a property that needs to be controlled in the field during the mixing and placing of the concrete".*

- *"Bulk Modulus of Crushed Salt. The panel was able to qualify the values for this parameter (ranging from 5.74 to 20.67 GPa) at five different time intervals during the consolidation process."*

- *"Permeability of SMC. The panel concurs with the selected values for this parameter. Up to 400 years, this is a triangular distribution with a best estimate of* 1.78×10^{-19} m^2. *After 400 years, the SMC is assumed to deteriorate and acquire the permeability of a dense soil with a best estimate value of* 1×10^{-14} m^2*."*

- *"Permeability of Compacted Clay. The panel is able to qualify the value of* 5×10^{-19} m^2 *for the bentonite seals. The validity of this number depends to a large extent on how the bentonite is emplaced during construction and its consistency, particularly with regard to density."*

- *"Initial Density of Waste. The panel concurs with the average value of 559.5* kg/m^3 *that is in use for the current inventory when used as input to room porosity calculations."*

- *"Mechanical Properties of Waste. The panel is able to qualify five elastic-plastic constants for the waste, together with a pressure-relative density table for the waste during the consolidations process. These values are appropriate for use in disposal room closure calculations."*

- *"Initial Water Content of Waste. The panel is able to qualify the value of 1.5%, which represents the initial waste container saturation by volume."*

- *"Properties of Halite and Anhydrite. The panel is able to qualify these parameter values for use in mechanical response models used for room closure predictions."*

- *"Data on Final Porosity Surface. The porosity surface is a valid method of describing disposal room closure as an input to BRAGFLO. The panel is able to qualify the final porosity surface as defined in WPO#35697."*

- *"Characterization of Disturbed Rock Zone. The panel concurs with the engineering concepts regarding the DRZ and its impacts on effective shaft sealing. The panel was not asked, however, to qualify any parameter values."*

9.3.4.1 Peer Review Panel Concern - Pore Volume Compressibility of SMC

There was little data in the data package to enable this value to be calculated. The panel was able to find some new data that Sandia should consider in deriving a modified value for this parameter.

Statement of Issue

There were little data in the data package to enable this value to be calculated. The Panel was able to find some new data which the DOE should consider in deriving a modified value for this parameter.

Response to Issue

A slightly different value for compressibility of SMC was derived by the panel. The panel concurred with the calculational methods. Their calculation yielded a value of 0.9 GPa^{-1} as compared to a value of 1.2 GPa^{-1} from Form 464 prepared by SNL for performance assessment calculations. The reason for the discrepancy is twofold: the DOE provided the panel with the most recent data (Pfeifle et al., 1996), which was not available at the time the probability distribution function (PDF) was developed. They interpreted values for Poisson's Ratio slightly differently based on this newest data. The panel further calculated a range of values, and the value of 1.2 GPa^{-1} is on the high end of their range. The difference between the panel's value and the one provided to performance assessment is approximately 33 percent, around the range of uncertainty of the value for porosity.

Performance assessment calculations have shown that model performance measures are insensitive to the storage capacity of the seals (WIPP Performance Assessment Department 1992). Porosity and rock compressibility are both used in the development of the rock storage parameter. Although there is some uncertainty in these parameters, the purposes of performance assessment are adequately met through provision of engineering values for these parameters. Consequently this parameter will not be changed at this time. A revisit to the existing data will be made before the next set of performance assessment calculations.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response. Therefore, the data included in this package are qualified per 40 CFR § 194.22(b).

9.3.4.2 Peer Review Panel Concern - Permeability of Crushed Salt

Based on current data, the Form 464 values may be too low, but new data being analyzed by SNL may establish the validity of these values or lead to a modification of them. The panel was unable to form a conclusion until this analysis is completed.

Statement of Issue

The ESPR panel has suggested that the permeability versus fractional density data be reviewed, and consideration given to development of two trend lines as a means to interpret the permeability versus fractional density of the compacted crushed salt shaft seal component, and that more data and analysis is necessary in order to justify the interpretation taken in development of the PDFs.

Response to Issue

The PDF (best estimate and upper and lower bounds) on the Form 464 for the permeability of crushed salt is appropriate, because the range of values incorporated into the PDF take into account virtually all of the data obtained, and any reasonable extrapolation thereof. To justify this point, first an explanation will be given as to why the interpretation of the permeability versus density function, given in Figure 9-27, was selected as opposed to the interpretation suggested as a possibility by the peer review panel, given in Figure 9-28. Then, further justification will be given for the selection of the interpretation given in Figure 9-27.

The panel raised the issue that since the data fall into what, at a first glance, appear to follow two trends, why not draw a line through each? This interpretation was not taken because conditions which fell outside the range of scientific expectation were not included in the development of the permeability versus fractional density relationship for crushed salt, and consequently not in the development of the PDF for the permeability of crushed salt. The following discussion explains this interpretation in more detail.

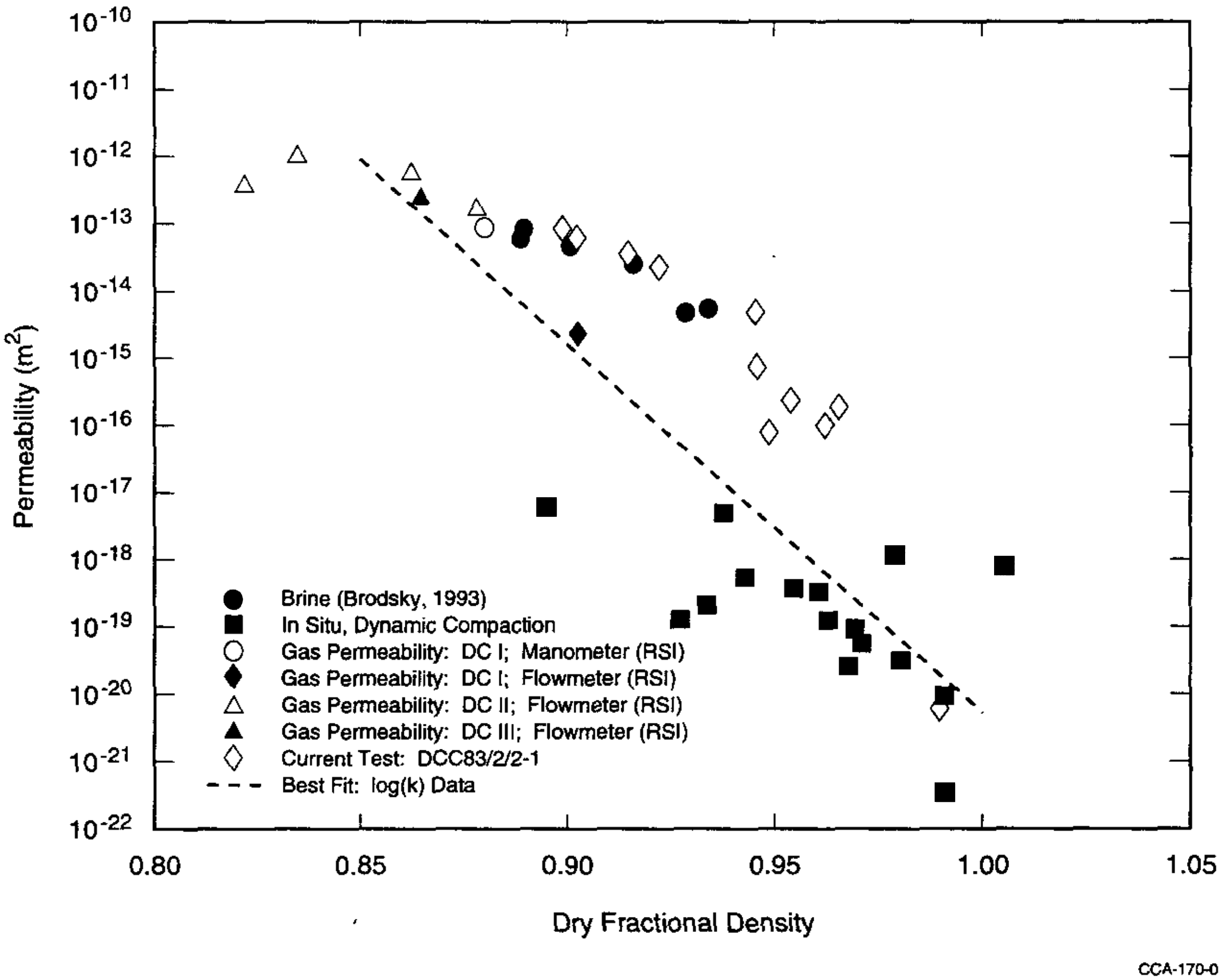

Figure 9-27. Permeability versus Fractional Density for WIPP Crushed Salt

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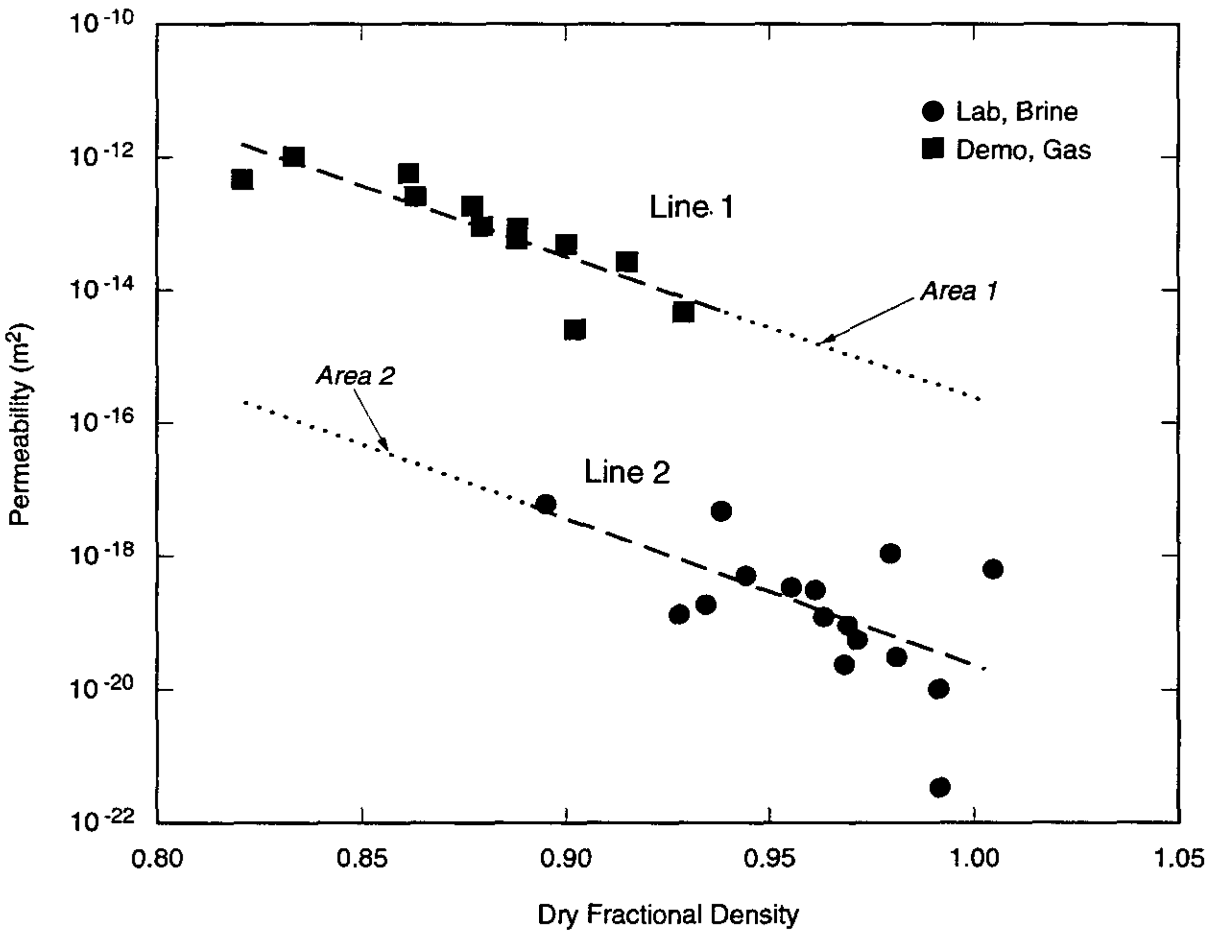

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Figure 9-28. Crushed Salt Permeability Data with Two Power-Law Trend Lines Representing Brine Permeabilities on Lab-Prepared Samples and Gas Permeabilities on Field Demonstration Samples

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The objectives of PDF development is to provide an engineering approximation for the properties of the seal materials for use within the WIPP Performance Assessment conceptual models. As such, these properties need not incorporate behaviors which fall outside the range of reasonable expectation. The data given in Figure 9-27 are a result of: (1) gas permeability measurements performed on dynamically-compacted crushed salt (data at low densities, Hansen and Ahrens 1996); and (2) brine permeability measurements performed on loose mine-run salt consolidated under conditions of hydrostatic and shear consolidation stresses (data at high densities, Brodsky 1994). If the permeability function was developed solely on the basis of the dynamically-compacted specimens, as shown in Line 1 in Figure 9-28, estimates of the salt column permeability at intact densities would be on the order of 10^{-15} square meters, instead of 10^{-21} square meters, which is generally considered reasonable for intact salt. This interpretation is not defensible, due to the extrapolation shown as Area 1 in Figure 9-28. In addition, Line 1 in Figure 9-28 is not considered applicable to the material used in the shaft seal components because the dynamically compacted specimens used in these tests were dry (significantly more so than will be the crushed salt seal material). Laboratory experiments have demonstrated that the dry consolidation process will not continue, even at high confining pressures, beyond a fractional density of about 0.95, making Area 1 in Figure 9-28 physically unattainable. To achieve fractional densities higher than 0.95 requires the addition of small quantities of brine.

When brine is added to a consolidating crushed salt component, the deformation process more closely resembles the process that occurred in the Brodsky tests (high density data on Figure 9-27). Since the use of Line 1 alone would result in predictions considered indefensible, it was not used alone to develop the ranges for the PDF. Figure 9-29 depicts the 5 percent and 95 percent predictor lines for the salt permeability which were used in the development. Because extrapolation of this data to intact densities is not reasonable, the proposed extrapolation (Area 1 of Figure 9-28) was not included in the range of values used in development of the PDF. Similarly, if the PDF was developed solely on the basis of the Brodsky tests (Line 2 in Figure 9-28), the initial permeability of the salt column would be approximately 100 times less than that expected on the basis of full-scale experiments. Using this line alone would not yield a defensible result, and therefore this line alone was not used to develop the ranges for the PDF. The same rationale for exclusion of Area 1 on Figure 9-28 led to exclusion of Area 2 on Figure 9-28; hence, it was not included in the range of values for the PDF. The panel also asked that since the data appear so dissimilar, why draw a line through them? The explanation is that the data from the dynamically compacted specimens with fractional densities of about 0.90 are representative of conditions expected for early times after seal emplacement and the Brodsky data for fractional densities greater than about 0.95 are representative of conditions expected for the long term. Therefore, lacking any data to the contrary, a best fit line was drawn through these data. The basis for these expectations, and why the single line is actually a more accurate interpretation of the permeability versus fractional density function than the data may indicate are presented in the following paragraphs.

The properties of the dynamically compacted specimens will closely approximate those present in the WIPP compacted salt columns immediately following seal system construction, that is, low density and relatively high permeability. Permeability tests were performed on several specimens recovered from the large-scale dynamically compacted crushed salt experiments to establish this initial high permeability. Permeability estimates derived from Brodsky's experiments are considered representative of the intrinsic permeability of the compacted crushed salt at high fractional densities, that is, long term. These laboratory tests entailed hydrostatic and shear consolidation of partially to fully saturated mine-run salt, followed by brine flow testing. This procedure emulates conditions expected in the WIPP shafts within several decades of construction of the compacted salt columns. Since the data sets closely approximate the conditions at the WIPP at both initial emplacement times (low densities) and long term (high densities), both data sets are applicable and were included in the analysis of the permeability versus fractional density for the crushed salt seal material. Therefore, virtually all the data from these two tests were included in the ranges used in development of the PDF, as can be seen in Figure 9-29.

The range used to establish PDF bounds (5 percent and 95 percent predictor lines on Figure 9-28) covers nearly six orders of magnitude at a given fractional density, and is quite conservative. A question arises as to how the permeability transitions from the initially high values measured for dynamically compacted crushed salt to the low values reported for mine-run salt. Data were obtained in this transition region by performing permeability tests on dynamically compacted crushed salt specimens that were further consolidated under high hydrostatic stress. Unfortunately, these specimens were quite dry. The field test chamber for the dynamic compaction demonstration was heated, and the test required over 3 months to complete. Initial moisture was unavoidably lost and cores extracted from the test chamber may have lost additional moisture during transport and sample preparation. It is known that the initial moisture content of the compacted salt mass was considerably higher than that of test specimens. The materials specification for the WIPP shaft seal call for a moisture content of 1.5 percent by weight for the actual crushed salt seal component.

The consolidation data acquired for the dynamically compacted specimens indicate that the crushed salt material consolidates more slowly or requires greater pressure than anticipated to achieve higher densities. Optical and scanning microscopy of deformed and undeformed samples of crushed salt was performed to document the deformational processes that produce consolidation (void space reduction) and provide an explanation for these apparently anomalous data.

As observed through microscopy, consolidation is dominated by pressure solution and redeposition, a mechanism of mass movement facilitated by the presence of moisture on grain boundaries. As shown by Holcomb and Shields (1987), dry salt aggregate does not effectively consolidate. Because the dynamically compacted specimens were dry, the effective process of void space reduction-pressure solution/redeposition was not active during consolidation, but is expected to be very active in the WIPP seal components. Further, the consolidation was accomplished by crystal plasticity which is not effective in filling minute void spaces on grain

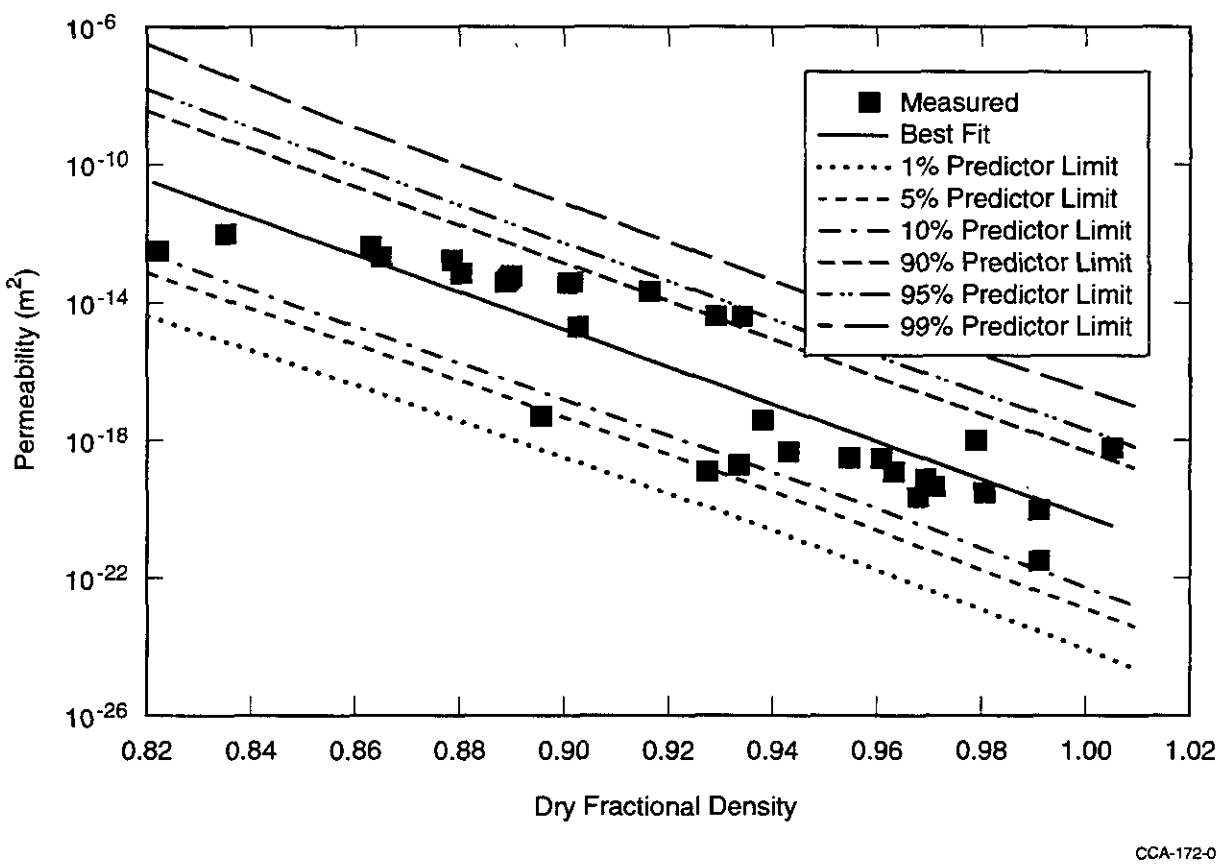

Figure 9-29. Measured and Predicted Permeability versus Fractional Density for the Compacted Crushed Salt Columns

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boundaries. Therefore, at equivalent densities, dry consolidated salt would remain more permeable than wet-deformed salt. The consolidation process expected in the shaft is fluid-aided pressure solution. The placed shaft seal salt will not dry in a manner similar to the large-scale compaction test, will retain moisture, and will consolidate readily to low permeability.

More recent experiments conducted on dry compacted specimens (Stuhrenberg and Zhang 1995) further substantiate that moisture content and particle size significantly impact the initial permeability and consolidation processes of crushed salt. At moisture contents similar to those of the dynamically compacted specimens, comparable permeabilities to the dynamically compacted specimens were measured. They also showed that permeability decreased as the maximum particle size decreased. It can be argued that the "extreme particle size distribution" present in the WIPP dynamically-compacted seals will produce a favorable result in the consolidation process. The presence of fine particles mixed throughout the compacted mass is likely to result in rapid localized consolidation due to the higher surface area attributable to these particles. As this process continues, the connected porosity, and hence, permeability of the composite mass will reduce at rates greater than those predicted by WIPP experiments. This hypothesis is further substantiated by Stuhrenberg and Zhang's result that compaction of specimens having smaller grain sizes have lower permeabilities than specimens composed of larger particles. Therefore, the permeability measurements made on dynamically compacted crushed salt specimens having densities in the range of 0.90 to 0.95 do not represent expected in situ conditions.

An additional argument for the conservatism inherent in the PDF development can be derived by examining the testing method. Testing of the dynamically-compacted specimens utilized nitrogen gas as the permeant fluid. In general, gas permeability measurements are performed at different fluid pressure gradients so that the measured permeability values can be corrected for Klinkenberg effects. However, flow rates through the dynamically-compacted specimens were quite high, requiring the use of rotameter flow meters to measure gas flow rates. These meters are calibrated for a single fluid pressure; hence flow measurements were made using a single fluid pressure gradient and the Klinkenberg correction could not be applied to these test results. This correction would reduce the permeability calculated from the gas flow rates measured during test conduct. Therefore, results presented for dynamically compacted specimens can be considered maximum estimates of the compacted salt permeability. Also additional analysis of the data has led to the conclusion that brine saturation of the dynamically-compacted specimens was sufficiently low, such that relative permeability effects were inactive. These relative permeability effects would provide estimates of permeability that are lower than intrinsic values. It can be concluded that the permeability estimates derived for the dynamically-compacted specimens are maximum values.

In conclusion, it is the DOE's position that the PDF given in Form 464 for the permeability of crushed salt is a good approximation. The permeability versus density function given in Figure 9-27, and used in the development of the PDF for the permeability of crushed salt represent the best possible interpretation of existing data. The development of this function incorporates both engineering judgement and test results, and is considered defensible in light of the arguments presented in the preceding paragraphs. The DOE recognizes that uncertainty exists, and that uncertainty was incorporated into the development of the PDF. In addition, the DOE continues to pursue experimental work to reduce uncertainty.

Finally, the salt column is not expected to fulfill a sealing function until it has achieved a relatively low permeability. The seal system design recognizes this, and includes multiple, redundant components which will be functional during and after the consolidation period. The redundancy in the design alleviates concerns regarding the time span required to complete the consolidation process.

<u>Peer Reviewer Consideration of Issue</u>

The DOE understood the issue and provided a reasonable response. Therefore, the data included in this package are qualified per 40 CFR § 194.22(b).

9.3.4.3 <u>Peer Review Panel Concern - Permeability of Consolidated Waste</u>

> *Based on a review of the data and discussions with Sandia, Sandia has calculated a new value of* 2.4×10^{-13} m^2.

<u>Statement of Issue</u>

A change in the value of the average waste porosity from 1.7×10^{-13} m^2 to 2.4×10^{-13} m^2 based on a recalculation by the DOE is recommended. This change represents a factor of 1.4 increase in permeability.

<u>Response to Issue</u>

The DOE's calculation is based on a reasonable but highly conservative interpretation of the experimental data in terms of the ranges of permeabilities for the respective waste components. Slight modifications of these assumptions are also considered to be equally defensible, however, and are expected to increase or decrease the permeability value by similar factors. In addition, the data and assumptions are far too limited to discriminate between changes of this magnitude. The 2.4×10^{-13} square meter value is therefore as reasonable as the 1.7×10^{-13} square meter value.

The principal effect on performance assessment of this recommended change is to increase brine releases during a human intrusion in direct proportion to the increase in permeability. Such an increase would not significantly affect the final CCDFs, assuming that radionuclide solubility values remain unchanged.

It is concluded that the work involved in a sensitivity study to determine changes in assuming the new waste permeability value is not warranted because the change does not have any effect on the final performance outcome.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response. Therefore, the data included in this package are qualified in accordance with 40 CFR § 194.22(b).

9.3.4.4 Peer Review Panel Concern - Strength of Waste for "Blowout" (Spalling)

> *There is little data to support any value for this parameter, and the panel's opinion is that further analysis be undertaken by Sandia.*

Statement of Issue

There is no established scientific school of experience nor any database available to draw from for determining the mechanisms that this parameter (1.0 pound per square inch of waste strength) supports. Furthermore, because of the uncertainty of waste conditions at the time of intrusion, it requires an assumption that the standard waste composition and condition will be a granular material of a density approximating unconsolidated lightly cemented sand of unknown porosity and low moisture. The only data in the literature is for clays (and it is sparse) which approximates these conditions for strength properties (Lenke et al. 1996). Therefore, at this stage of process development and lack of defining conditions, it is not possible to ascertain if the value of 1.0 pound per square inch is adequate as a tensile strength.

Response to Issue

A value of 1.0 pound per square inch (6,895 pascals) was chosen to represent the tensile strength of decomposed waste for the purpose of computing blowout spall releases resulting from a drillbit intrusion into a pressurized waste panel. Such spall releases occur only if the gas pressure exceeds the hydrostatic drilling mud pressure of approximately 8 megapascals. A chemical reaction between the waste and brine from the surroundings is necessary to generate the gas to raise the waste pore pressure to these levels. Without brine inflow, little gas will be generated and waste decomposition will be negligible. Thus the phenomenon of blowout spall requires both brine inflow and waste decomposition.

The future state of decomposed waste is both time dependent and unknowable. Therefore a decomposed state consisting of graded granular materials is assumed. This is consistent with the granular nature of decomposed geologic materials and corresponds to an end state of the decomposition process. Such materials lack significant composite strength from the interleaving of components and is the salt found to be most troublesome in oil production where sand is produced form poorly consolidated sand layers. The value of 1 pound per square inch was chosen for cementation strength for the decomposed waste can be reasonably expected to be conservative, that is, lower than those data values found for many weak materials that are naturally occurring or that have been manufactured. Data to support this value can be found in the literature for the strengths of soils, laboratory produced mixtures of salt and clay, and mixtures of various materials with MgO; the latter added as backfill material to the waste. A discussion of these data sources follows.

Soil Data. Tensile strengths for several compacted, cohesive soils, for example, Vicksburg buckshot clay (CH), Vicksburg lean clay (CL), and a sandy clay (SC) mixture from De Gray dam were measured using hollow cylinder tests and indirect tensile tests in Al-Hussaini (1981). The samples were prepared to optimum water content, compacted, and then tested. Results for the hollow cylinder tests are shown in Table 9-5. All exceed 1 psi by factors of approximately 3 to 8 times. Similar results were obtained from the indirect tensile tests.

Table 9-5. Hollow Cylinder Tests

Material Type	Tensile Strength (pounds per square inch)
CL-1	2.95
CL-2	3.90
CL-3	3.93
CH-1	7.93
CH-2	7.41
CH-3	7.99
SC-1	5.90
SC-2	5.38
SC-3	4.49
CH-4	6.46
CH-5	6.12
CH-6	6.52

Direct tensile tests on simulated waste materials were also conducted by Berglund and Lenke (1995, 13-14). Various mixtures of partially saturated silica sand and kaolin clay were used to represent the waste. The clay represented a natural material that was chosen to be a close surrogate to partially decomposed cellulosics and plastics. The sand represented the particulate structure expected of magnetite or other products of the iron corrosion reaction. The mixture was 85 percent sand and 15 percent clay, a ratio similar to the ratio of decomposition products anticipated for some waste conditions. The tensile strength measured in these experiments was 2.9 ± 1.4 pounds per square inch. A second indirect method of measuring tensile strength in the Berglund and Lenke study implied an even higher tensile strength value of 4.3 ± 1 pounds per square inch.

The tensile strength of the above materials (Al-Hussaini 1981, Berglund and Lenke 1995) occurred in the absence of any additional cementation process which would tend to increase these measured tensile strengths.

Salt Mixture Data. Some brine is expected to exist within the waste panels after closure of the facility. The most likely source is brine of Permian age that was trapped in the Salado at the time of evaporite deposition. Limited brine occurrences in the WIPP underground have been extensively sampled and analyzed, and the composition of Salado brine is well understood. These brines contain approximately pounds (374 grams) of dissolved constituents per (liter) and are in chemical equilibrium with halite (NaCl), anhydrite ($CaSO_4$), and magnesite ($MgCO_3$).

The removal of even a small amount of water from this brine by evaporation or chemical reaction will result in the precipitation of salts which will act as a cementation agent. One such chemical reaction that is anticipated to occur is the anoxic corrosion of iron and ferrous alloys, which constitute a significant percentage of the waste inventory in the form of steel drums and boxes, contaminated tools and sheet metal, etc.

The reaction of brine with metal will consume H_2O and generate hydrogen and some corrosion product. A typical anoxic reaction might be

$$Fe + 2\,H_2O \Rightarrow Fe(OH)_2 + H_2$$

Consumption of H_2O by corrosion reactions will cause the mass of dissolved solids in the brine to precipitate as a series of evaporite minerals in close proximity to the surface of the corroding metals, forming encrustations which will tend to cement the waste. Simulation of the removal of H_2O from one kg of Salado brine using the EQ6 code (Wolery and Daveler 1992) yielded (534 grams) of precipitates (anhydrite, bischofite, carnallite, halite, kieserite, and magnesite). The mass is greater than the mass of dissolved solids because of the hydrous nature of some of the precipitates.

Evidence for this process in the WIPP underground was seen at the close of heated brine inflow experiments performed by the DOE a number of years ago. In these experiments, a metal canister containing an electrical heater was placed in a vertical hole excavated in the floor of a room in the northern experimental area. The top of the hole was sealed, and anhydrous nitrogen was circulated within the annulus between the canister and the hole. Small amounts of brine flowed toward the hole in response to the pressure and temperature gradients surrounding the heated hole, and evaporated as it approached the canister. The nitrogen acted as a carrier gas for water vapor and was allowed to exit the hole where it flowed into an apparatus where the water vapor was extracted and quantified.

It was found at the close of the experiment that the canister has become firmly cemented in the hole by the precipitation of salts from the evaporating brine within the annulus. A work-over rig had to be employed to extract the canister from the hole. The removal of water from brine by any process, be it evaporation or corrosion reactions, will produce the same cementation effect by the precipitation of minerals at the site of water removal. This cementation will act to increase the strength of the waste.

A number of strength tests were done for consolidated crushed WIPP salt and mixtures of WIPP salt and bentonite (70 and 30 percent, respectively) (Finley 1996). Finley's memorandum presents estimates of tensile strengths of clay/salt mixtures based on experimental observations of unconfined compressive strengths and the extended Griffith criterion for tensile failure (Jaeger and Cook 1976). These estimates are for 30/70 percent bentonite/salt mixtures at fractional densities of 0.83 to 0.88. Finley estimates tensile strengths between 10 and 100 pounds per square inch.

An average container of waste in a WIPP waste panel, upon creep closure and subsequent brine saturation, will consist of approximately 1,350 kilograms of waste solids (assumed average solid density of the waste was taken as 2,700 kilograms per cubic meter and 188 kilograms of precipitated salt (based on dissolved salt solids of 374 gram per liter cited above) per cubic meter of repository. These numbers are based on a typical closure porosity of 0.5 (final room height of 1.2 meters). The gravimetric ratio of salt precipitate to solid waste for these conditions is 0.14. This is a factor of 5 less than the ratio cited by Finley. Using this factor, it is not unreasonable to expect tensile strengths between 2 and 20 pounds per square inch.

Effects of MgO on Strength. An additional process affecting the strength of the waste/backfill composite material is the chemical interactions that will occur between Salado brine and the MgO backfill. This interaction is simulated using the EQ3/6 code (Wolery 1992; and Wolery and Daveler 1992) with the Pitzer activity coefficient option and Harvie-Moller-Weare database. Five moles of MgO were reacted with one kilogram of Salado brine in a series of small steps. The dissolution of the five moles (202 grams) of MgO into the brine resulted in the precipitation of a total of 507 grams of minerals and the incorporation of 20 percent of the original kg of brine as water of hydration within the precipitates. These precipitates include Mg-oxychloride (63 percent by mass) and brucite (31 percent by mass), with minor amounts of anhydrite, halite, and magnesite. Similar results were found by Wang (1996a).

The two dominant precipitates (Mg-oxychloride and brucite) are the key phases in Sorel cement. In fact, Sorel cement is commercially prepared by mixing a magnesium-chloride brine (quite similar to Salado brine) with MgO. Sorel cement is known to have uniaxial compressive strengths in the range of 7,000 to 10,000 pounds per square inch (Sax and Lewis 1987). This range is equivalent to tensile strengths of from 490 to 700 pounds per square inch (Dunham 1966). Thus, the use of an MgO backfill will result in the cementation and strengthening of the waste and backfill composite material as long as sufficient brine is available for the chemical reactions to occur.

Conclusions. While tests to actually measure the binding forces between particles of simulated waste have not been performed, there are data available from several independent sources that suggest that the selection of 1 psi is well below the actual value of tensile strength that can be reasonably expected for decomposed waste. The tensile data presented for several soils without chemically generated salt precipitates exceed 1 pound per square inch by factors generally greater than 3. Estimated tensile strengths of consolidated halite-bentonite mixtures exceed 1 pound per square inch by factors of ten or more. The role of precipitated salts from anoxic reactions of brine with waste metals is expected to be similar though perhaps not as intense. MgO is added to the waste as a backfill material in large volumes. The reaction of MgO plus brine are the principal components of Sorel cement which attains high compressive strengths and predicted tensile strengths of 490 to 700 pounds per square inch.

Peer Reviewer Consideration of Response

The DOE understood the issue and provided a reasonable response. Therefore, the data included in this package are qualified per 40 CFR § 194.22(b).

9.3.5 Natural Barriers Data Qualification Peer Review

The DOE used an IRT to carefully review the existing data that was necessary to support the performance assessment. Much of the existing data was qualified because the IRT determined that the quality assurance program in place at the time of its collection was equivalent to ASME NQA requirements. It was determined however, that some data used to describe natural barrier subsystems could not be qualified in that manner.

40 CFR § 194.22(b) states that

"Any compliance application shall include information which demonstrates that data and information collected prior to the implementation of the quality assurance program required pursuant to paragraph (a)(1) of this section have been qualified in accordance with an alternate methodology, approved by the administrator or the administrator's authorized representative, that employs one or more of the following methods: peer review, conducted in a manner that is compatible with NUREG-1297...."

A Natural Barriers Peer Review (NBPR) Plan (see Appendix PEER) was developed and approved in accordance with the requirements of TP 10.5. The purpose of the plan was to describe the NBPR process. The NBPR panel evaluated existing data and information that form the basis of the parameter values used in the mathematical expression of conceptual models for the natural barriers subsystems in the WIPP. The parameters selected for evaluation were those that had not previously been fully qualified for use in performance assessment.

The conceptual models used in the performance assessment of the natural barriers subsystem include components of: (1) Disposal System Geometry; (2) Culebra Model Geometry; (3)

Repository Fluid Flow; (4) Salado; (5) Impure Halite; (6) Salado Interbeds; (7) DRZ; (8) Actinide Transport (Salado); (9) Units Above the Salado; (10) Dissolved Actinides (Culebra); (11) Colloidal Actinides (Culebra); (12) Exploration Boreholes; (13) Cuttings and Cavings; (14) Spallings; (15) Direct Brine Release; (16) Castile and Brine Reservoir; (17) Multiple Intrusions; and, (18) Climate Changes.

A peer review panel, consisting of the following six members, was convened to undertake the work:

Darrel E. Dunn (Chairman), Independent Consultant
Florie Caporuscio, LANL
Paul L. Cloke, Independent Consultant
David A. Sommers, Independent Consultant
Charles Wilson, Independent Consultant
Chuan-Mian Zhang, Woodward-Clyde Federal Services

Dr. Dunn is an independent consultant with 38 years of experience in hydrogeology. He has a Ph.D. in geology and is a registered geologist in Wyoming. Dr. Dunn has taught advanced hydrogeology courses at Montana State University and the University of Toledo. He has been involved in finite-difference modeling of groundwater and vadose zones since 1967 and has been heavily involved in nuclear waste disposal since 1988.

Dr. Caporuscio has a M.S. in geology/chemistry and a Ph.D. in geology. He is a geochemist with 12 years of experience in high-level and TRU radioactive waste disposal. His primary work has involved the characterization of ash flow tuffs and their alteration products, and the technical analysis of bedded salt deposits. He has also worked in the fields of low-level radioactive and mixed-waste contamination, remediation, and disposal.

Dr. Cloke has 42 years of post-Ph.D. experience in geological science. Much of his experience has dealt with geochemistry and economic geology, but for the past eleven years has focused on problems in the disposal of nuclear wastes. He worked in the performance assessment departments for the former DOE Salt Repository Project and the Yucca Mountain Site Characterization Project. During the past two to three years, he has had significant interaction with the European nuclear waste programs in Germany, Switzerland, Sweden Spain, and Great Britain, as well as the Canadian and Japanese programs.

Dr. Sommers has a Ph.D. in geology and over 30 years of experience as a professional hydrogeologist, with registration in several states and certification by the European Federation of Geologists. He served on the NRC/National Academy of Sciences (NAS) Committee on Ground Water Resources and Coal Mining and is frequently retained as a technical expert to support litigation and provide expert testimony. Dr. Sommers has been involved in nuclear-related projects since 1971. Since 1995, Dr. Sommers has been an independent reviewer for the WIPP IRT.

Dr. Wilson has a Ph.D. in hydrology and is an independent consultant. He has acted as manager for a broad range of projects involving hydrogeology and geotechnical engineering, water resources planning, and environmental contamination. These projects have involved such topics as designing and conducting large-scale hydrologic tests in very low permeability, fractured rock; development of a national water resources planning agency for the Republic of the Philippines; and design of a sitewide groundwater monitoring system for DOE's INEL.

Dr. Zhang has a Ph.D. in civil engineering and has more than 10 years experience in surface water and groundwater hydrology, including contaminant transport, groundwater and watershed modeling, water resources management, statistical applications in hydrology and soil and water quality assessment and geochemical analysis. Recent work has been heavily involved in Rocky Flats.

The panel members all have well established credentials and were independent of the WIPP performance assessment activities. Additional information concerning the technical qualifications of the panel members is presented in the peer review panel report (see Appendix PEER). Documentation of the independence of the panel members is also provided in Appendix PEER.

Upon completion of the orientation and training required by TP 10.5, the panel was provided 32 parameter packages for their review. In addition, technical reports and documents were obtained by the panel from the SNL waste management library and records center to supplement the information in the parameter packages. Both formal and informal technical discussions were held with SNL principal investigators to assist the panel members to more fully understand the concepts and parameter derivation and application in the performance assessment.

The NBPR panel evaluated 142 parameters against the eight review criteria cited in NUREG-1297 (NRC 1988). The parameters were organized into 32 parameter packages, some of which contained more than one parameter. The parameter packages were grouped into three subsystems, Salado, Castile, and Units Above the Salado, to facilitate the review process.

In some subsystems, individual parameter values were evaluated and a determination made of their adequacy as used in the WIPP performance assessment program. In others, sets of parameters were evaluated to determine their collective contribution to a combined parameter value. The panel performed an in-depth critique of assumptions, alternate interpretations, methodology and acceptance criteria employed, and of the conclusions drawn in the original work. In evaluating the existing unqualified data, the peer review panel members considered the following:

- The source of the parameters and data (for example, professional judgment, published source material, field tests, laboratory experiments, etc.);

- The appropriateness of the parameters and data for their intended use; and,

- The assumptions, calculations, extrapolations, interpretations, methods, appropriateness, validity, sensitivities, and conclusions pertinent to the parameters and data used as input to the WIPP performance assessment.

At the conclusion of its review, the panel developed a final report (August 1996). A copy of the NBPR Report is provided in Appendix PEER.

Table 9-6 provides a listing of the 32 parameter packages, the appropriate subsystem, the number of parameters in the specific packages, and the qualification status of each as determined by the peer review panel. The panel concluded that 31 of the parameter packages were fully qualified. Therefore, the data supporting those parameters are qualified per 40 CFR § 194.22(b). As discussed below, the panel had a concern about one of the 21 data packages for the Culebra transmissivity parameter.

The NBPR panel's concern (in italics), the DOE's interpretation of the panel's concern ("Statement of Issue"), and the DOE response ("Response to Issue") are provided below. The panel then reviewed the response to determine whether the DOE understood the issue and provided a reasonable response ("Peer Reviewer Consideration of Response"). The justification for the DOE's continued use of the Well P-18 transmissivity value is also provided ("DOE Technical Position versus Panel Issue").

The DOE response was provided to the panel as an individual memorandum. For incorporation into this application, the response has been edited to remove the memorandum format, consolidate references, replace first-person text, insert cross-references where appropriate, and correct typographical errors. Substantive technical content of the responses has not been changed.

<u>Peer Review Panel Concern: Well P-18 Transmissivity Value</u>

The panel concluded in the NBPR Report that it was in general agreement with the parameter values chosen for the performance assessment models, except that

> *"The interpretation of the data from well P-18 is inadequate for its intended use as input to GRASP-INV for the development of transmissivity fields."*

Additional detail regarding the above issue is provided in the NBPR Report, which states

> *"<u>Well P-18</u> - the transmissivity value of 7.0 x 10^{-5} ft^2/day for well P-18, as reported in the Draft Culebra Transmissivity Database (July 1, 1996), represents a value obtained from interpretation of late time match parameters (after 600 hours since test inception) rather than early time data using semi-log slug test type curves on the semi-log plot of H/H_0 vs elapsed time (SAND87-0039, p.99). Use of the late time semi-log*

Table 9-6. Summary of Parameters Reviewed and Qualification Status

Parameter Package	Subsystem	Number of Parameters	Qualification of Parameter
DRZ Compressibility	Salado	2	Adequate
Undisturbed Halite Pore Pressure		1	Adequate
Undisturbed Halite Compressibility		1	Adequate
Effective Halite Porosity		1	Adequate
Undisturbed Halite Permeability		3	Adequate
Undisturbed Anhydrite Pressure		2	Adequate
Undisturbed Anhydrite Rock Compressibility		3	Adequate
Brine Salt Mass Fraction		1	Adequate
Brine Viscosity		1	Adequate
Brine Density		1	Adequate
Brine Compressibility		1	Adequate
Castile Brine Reservoir Rock Compressibility	Castile	1	Adequate
Castile Brine Reservoir Porosity		1	Adequate
Castile Brine Reservoir Pressure		1	Adequate
Castile Brine Reservoir Permeability		3	Adequate
Castile Brine Reservoir Volume		1	Adequate
Non-Salado Effective Porosity	Units Above the Salado	6	Adequate
Non-Salado Pressure		4	Adequate
Non-Salado Permeability		6	Adequate
Culebra Permeability		3	Adequate
Climate Index		1	Adequate
Culebra Transmissivity Data		100 Values	Adequate[1]
Culebra Thickness		1	Adequate
Culebra Storativity		1	Adequate
Culebra Fluid Density		32 Values	Adequate
Culebra Steady-State Freshwater Heads		31 Values	Adequate
Culebra Dolomite Grain Density		1	Adequate
Effective Culebra Thickness		1	Adequate
Advective Porosity		1	Adequate
Half Matrix Block Length		1	Adequate
Diffusive (Matrix) Porosity		1	Adequate
Diffusive (Matrix) Tortuosity		1	Adequate

[1] One of the 21 data packages for the Culebra Transmissivity parameter was deemed inadequate.

curve match for the transmissivity value seems questionable in this case, as the late time data do not represent the aquifer characteristics in the vicinity of the well, before boundary effects. Use of the late time data, after boundary effects, appear inappropriate since the theory presented by Cooper, et al. (1967) does not include boundary affects. Further, the early time (first 600 hours) interpreted transmissivity value of 4.3×10^{-3} ft^2/day (SAND87-0039, p.99) is in fairly close agreement with the 1.0×10^{-3} ft^2/day value provided by the interpretation of a preceding bailing test by the USGS (Mercer 1983)."

Statement of Issue

The DOE believes that the issue can be considered in two steps: a) is the choice of a P-18 transmissivity based on short-term data (less than 600 hours) or on the basis of long-term data (more than 600 hours) most appropriate?; and b) given the implementation of point transmissivity values into the regional T-field, is the difference between the two interpreted values (essentially two orders of magnitude) likely to be significant to WIPP regulatory compliance? These two lines of questioning are considered separately below.

Response to Issue

1. Concerning Specific Interpretation of the Culebra Transmissivity at P-18:

By way of introduction, it should be noted that the Culebra becomes progressively less transmissive from the west, where it is near land surface in Nash Draw, to the east, where its depth of burial increases. P-18 is the easternmost well in the Culebra in the immediate vicinity of the repository area. It was originally drilled to log the underlying Salado Formation, and was later perforated at the Culebra Dolomite. Other wells constructed in a similar fashion (for example, DOE-2, P-14) initially showed poor connection with the Culebra prior to acidization.

Specifically concerning P-18, the DOE agrees with the panel's comments to the effect that: a) the DOE specifically chose to use the long-term data from the rising-head slug test at H-19; b) that in doing so, the DOE specifically chose to use the interpretation from the time frame *after* boundary effects became evident; c) therefore, the theoretical basis for the interpretation used, that is, assumption of a homogeneous aquifer, no longer strictly applies; and d) the cause for the relatively sharp change (decrease) in recovery rate at approximately 600 hours remains unclear.

As summarized on page 100 of Beauheim (1987b), the DOE's preferred interpretation of this test is that: a) early-time data (less than 600 hours) reflect both a local or near-well zone of *relatively* high-permeability (perhaps generated by drilling activities) and the presence of a positive skin (poor connection between well and country rock) *immediately* adjacent to the well; and b) the long-term data (greater than 600 hours) most closely represent country-rock values outside the induced zone of increased permeability near the well. In summary, the transmissivity estimate from the early-time data, 4.3×10^{-3} square feet per day, is probably unrealistically high, but is reliably a maximum value. The estimate from the late-time data, 7×10^{-5} square feet per day, is probably more representative of the Culebra in the vicinity of P-18, but cannot be interpreted as a minimum value.

It is recognized however, that in the absence of additional data in the vicinity of hole P-18 (for example, a new well), it cannot be demonstrated objectively that the submitted transmissivity value is, in fact, representative of the rock mass in the vicinity. The question remains: Is the difference between the two transmissivity values (4.3×10^{-3} square feet per day versus

7×10^{-5} square feet per day) significant for purposes of WIPP regulatory compliance? The DOE's position is that the appropriate transmissivity value was selected, but that the P-18 data point does not substantially influence the critical potential migration pathways through the Culebra.

2. Concerning Issues of Implementation and Regulatory Impact

Ultimately it is not the transmissivity of a specific well *per se* that is important, but its impact on potential migration times from the Culebra overlying the repository to the WIPP boundary. There are several potential consequences resulting from mis-specification of a point value for Culebra transmissivity, such as that at well P-18, including:

a. Misidentification of the correlation structure used in geostatistical treatment of point data to generate the overall Culebra transmissivity field would result in a somewhat different overall pattern of simulated heterogeneity.

b. Changes in simulated transmissivity fields in areas that would affect potential radionuclide migration from the repository would be the most important ramification.

With regard to a), general estimates of overall heterogeneity are not extremely sensitive to the correlation structure, even though the semivariogram can be sensitive to outlying data points, such as the specific transmissivity assigned at well P-18. With regard to b), assuming that the higher transmissivity (4.3×10^{-3} square feet per day) is actually correct for well P-18, the impact of having used a lower value (7×10^{-5} square feet per day) on travel times near the repository is judged to be minimal. This consideration must, however, be made under two settings, that is, both in the absence of potash mining and assuming that such mining takes place.

Consider first the case without potash mining. Several data points (DOE-1, H-3, H-11, and H-19) define a finger of high transmissivity in the Culebra that extends up to the area near the repository. Transmissivities at these wells range from 2 to 3 square feet per day (H-3 and H-19) to approximately 80 square feet per day (H-11). This zone is bounded on the east and west by wells with distinctly lower transmissivity, including P-18. In the absence of potash mining, flow within the Culebra is mainly through the high transmissivity zone.

A salient feature of conditional geostatistical simulation is that local data values are incorporated (with consideration of measurement uncertainty) in the field. Thus, even if transmissivity at P-18 were increased to 4.3×10^{-3} square feet per day, the value based on short-term data, the high-transmissivity feature defined by wells such as DOE-1, H-3, H-11, and H-19 would still exist and be clearly defined. Since local data are honored in geostatistical simulations, the flow rates and directions in the high transmissivity zone, and hence, radionuclide travel time to the accessible environment, would still be more or less the same as estimated with the lower transmissivity value.

In the case of potash mining, Culebra transmissivities in the affected areas are assumed to increase by *up to* three orders of magnitude. The general impact on Culebra fluid flow is to deflect flow from a southerly direction, where it is focused in and near the high-transmissivity zone, toward and through the relatively low transmissivity district lying to the *west*. The transmissivity at well P-18, which lies east of *both* the high transmissivity zone and the zone which must be assumed to be impacted by potash mining, should have even less impact in simulations including potash mining than on those in which mining is not included.

Finally, the simulated transmissivity value for the grid block nearest P-18 was examined for the 100 transmissivity fields generated using GRASP-INV. The simulated value ranged from 10^{-8} to 10^{-4} square meters per second. Because the semivariogram had a nugget effect (implying small-scale noise), and because of upscaling effects, the block-average transmissivity need not and generally will not be the same as the P-18 data point. Over half the time, the transmissivity was between -5.5 and -6.5 log (square meters per second), versus the input value of -10.124 (7.5×10^{-11} square meters per second). Thus, if the higher value suggested by the Panel (about -8 log [square meters per second]) were used and honored exactly, the value used in the modeling analysis would still be higher. Also, note that the span of values for the grid block nearest P-18 in the generated transmissivity-fields is 2 orders of magnitude larger than that considered for the test. Thus, it is the DOE's belief that the probabilistic approach adequately deals with the uncertainty in this area.

Peer Reviewer Consideration of Response

The DOE understood the issue; however, the panel gave a "qualified yes" to the reasonableness of the response. A "qualified yes" indicates that the panel was split over the reasonableness of the response; however, the panel was in agreement that the data value in question had no effect on the qualification of the parameter value (see the discussion below).

DOE Technical Position versus Panel Issue

The DOE's technical position is that the appropriate transmissivity value was selected; however, which ever transmissivity value is used (4.3×10^{-3} square feet per day or 7×10^{-5} square feet per day), the well P-18 data point does not substantially influence the critical migration pathways through the Culebra. This interpretation is supported by the panel in Table 1.1 of its report (Appendix PEER) where the Culebra Transmissivity Data were determined to be adequate.

9.3.6 Waste Form and Disposal Room Data Qualification Peer Review

A Waste Form and Disposal Room (WFDR) Peer Review Plan (see Appendix PEER) was developed and approved in accordance with the requirements of TP 10.5. The plan describes the process used to plan and perform the review. The purpose of the peer review was to ensure that the scientific data used in the models describing the waste form and the disposal room closure and chemistry are qualified for use in the WIPP performance assessment.

The DOE used IRTs to carefully review the existing data necessary to support the performance assessment. Many of the existing data were qualified because the quality assurance program in place at the time of its collection was determined to be equivalent in effect to ASME NQA requirements. However, some of the data needed to support the waste form and disposal room models were not qualified by the IRTs.

As stated previously, 40 CFR § 194.22(b) states that

> *"Any compliance application shall include information which demonstrates that data and information collected prior to the implementation of the quality assurance program required pursuant to paragraph (a)(1) of this section have been qualified in accordance with an alternate methodology, approved by the administrator or the administrator's authorized representative, that employs one or more of the following methods: peer review, conducted in a manner that is compatible with NUREG-1297...."*

A panel consisting of the following two members was selected to perform the review of the above data that had not been qualified by the IRTs:

Duane C. Hrncir (Chairman), University of Texas at Dallas
Robert D. Knecht, Colorado School of Mines

Dr. Hrncir is an associate professor of chemistry and former head of the chemistry programs at the University of Texas at Dallas. He has 24 years of experience in research involving the interactions of metals with organic molecules.

Dr. Knecht is a research professor at the Colorado School of Mines and holds a Ph.D. in chemical-petroleum refining engineering and a Ph.D. in metallurgical engineering. He has provided management and technical assistance to a variety of energy, minerals and waste industries and to government.

The panel members were both highly qualified to conduct this review and were independent of the WIPP performance assessment program. Additional information concerning the qualifications of the panel members is provided in the peer review panel report (see Appendix PEER). Documentation regarding the independence of the panel members is also provided in Appendix PEER.

The panel received administrative orientation and training on the peer review plan, 40 CFR Parts 191 and 194, NUREG-1297, the QAPD and TP 10.5. During the course of its work, the panel reviewed information packages provided by SNL for each parameter. In addition, technical reports, published literature, and internal documents were used to supplement the information in the parameter packages. Discussions were held with SNL staff in order to more fully understand the concepts and parameter derivation.

The panel members evaluated existing data and information that form the basis of the parameter values used in the mathematical expression of conceptual models for the waste form and disposal room subsystem. As discussed above, the parameters evaluated had not previously been fully qualified for use in performance assessment. The conceptual models used in the performance assessment of the waste form and disposal room subsystem include components of:

- Gas Generation;
- Chemical Conditions;
- Dissolved Actinide Source Term; and,
- Colloidal Actinide Source Term.

The WFDR peer review panel evaluated 26 parameters against the eight NUREG-1297 review criteria. The parameters were solubilities of the actinides from the repository wastes in brines from the Salado and Castile.

The panel compared each calculated solubility parameter to those published in the peer-reviewed literature, when such data were available. To make this comparison, the panel considered compatibility of solvents, solution pH, and the absence of potentially ligating carbonate. The latter criterion is an imposed condition controlling the disposal room chemistry. When literature values were not available, the panel considered experimental data obtained from several different laboratories. In using these data, the panel evaluated the experimental approach to ascertain that the methods used for data acquisition and interpretation were consistent with recognized standards.

When experimental data were not available for particular parameters, the panel examined the method of calculation used to derive the value. The experimental data used as input to the calculation were evaluated and the validity of the calculation result was critiqued relative to similar calculated values where experimental data were available.

The panel members carefully reviewed each of the 26 parameters submitted for peer review. Based on their review, the panel prepared a final report in July 1996. A copy of the final report is provided in Appendix PEER.

Table 9-7 provides a listing and status of the reviewed parameters. As shown in Table 9-7, the panel concluded that all 26 of the values were qualified for use in the WIPP Performance Assessment for actinide solubility under repository conditions. Therefore, the data supporting these parameters are qualified per 40 CFR § 194.22(b).

Table 9-7 Listing and Status of Reviewed Parameters

ID number	Species	Brine	Status
	A. Inorganic Chemistry Controlled by $Mg(OH)_2/MgCO_3$		
WP037105	Am(III)	Salado	Qualified
WP037106	Am(III)	Castile	Qualified
WP037109	Pu(III)	Salado	Qualified
WP037108	Pu(III)	Castile	Qualified
WP037129	General An(III)	Salado	Qualified
WP037125	General An(III)	Castile	Qualified
WP037110	Pu(IV)	Salado	Qualified
WP037111	Pu(IV)	Castile	Qualified
WP037115	Th(IV)	Salado	Qualified
WP037112	U(IV)	Salado	Qualified
WP037130	General An(IV)	Salado	Qualified
WP037126	General An(IV)	Castile	Qualified
WP037131	General An(V)	Salado	Qualified
WP037127	General An(V)	Castile	Qualified
WP037113	U(VI)	Salado	Qualified
WP037114	U(VI)	Castile	Qualified
WP037132	General An(VI)	Salado	Qualified
WP037128	General An(VI)	Castile	Qualified
	B. Organic Chemistry Controlled by $Mg(OH)_2/MgCO_3$		
WP037116	General An(III)	Salado	Qualified
WP037121	General An(III)	Castile	Qualified
WP037117	General An(IV)	Salado	Qualified
WP037122	General An(IV)	Castile	Qualified
WP037118	General An(V)	Salado	Qualified
WP037123	General An(V)	Castile	Qualified
WP037120	General An(VI)	Salado	Qualified
WP037124	General An(VI)	Castile	Qualified

9.3.7 Passive Institutional Controls Peer Review

40 CFR § 194.43 states that

> *"Any compliance application shall include detailed descriptions of the measure that will be employed to preserve knowledge about the location, design, and contents of the disposal system."*

A Passive Institutional Controls Peer Review Plan (see Appendix PEER) was developed and approved in accordance with the requirements of TP 10.5. The plan describes the peer review process used to ensure that the passive institutional controls proposed by the DOE at the WIPP will reasonably preserve the knowledge about the location, design, and contents of the WIPP disposal system and reduce the likelihood of inadvertent intrusion.

A three-member panel of experts was convened in May 1996 to conduct an independent peer review of the system of passive institutional controls designed by the DOE. The panel reviewed the findings of the Passive Institutional Controls Task Force (PTF), evaluating detailed descriptions of the measures that the DOE intends to employ to preserve knowledge about the location, design, and contents of the WIPP disposal system. The primary focus of the evaluation was to determine whether the passive institutional controls designed by the DOE are adequate and have a reasonable expectation of meeting their intended purpose of reducing the likelihood of inadvertent intrusion.

The panel members were:

Jessica Glicken (Chairman), Ecological Planning and Toxicology, Inc.
Elizabeth K. Hocking, Argonne National Laboratory
Paul R. La Pointe, Golder Associates

Dr. Glicken is a senior anthropologist with over 14 years of experience in communications, strategic and organizational development and management, and policy analysis. She develops communications strategies for both public and private sector clients.

Dr. Hocking is a legislative analyst and section manager with Argonne National Laboratory. She provides technical, legal, and programmatic analyses of current statutes, regulations, and judicial decisions affecting the DOE and the energy industry.

Dr. La Pointe is a mathematical geologist and senior project manager with a Ph.D. in mining engineering. He has more than 16 years of experience in the oil and gas industry and is currently responsible for management and technical direction of reservoir engineering and characterization projects for domestic and international petroleum companies.

The panel members were well qualified for this review and were independent of the WIPP performance assessment program. Additional information concerning the qualifications of the panel members is presented in the panel report (see in Appendix PEER). Documentation of the panel member's independence from the WIPP project is also provided in Appendix PEER.

After administrative orientation and training, the panel members familiarized themselves with regulations impacting radioactive waste disposal at the WIPP (40 CFR Parts 191 and 194) and requirements for the conduct of peer reviews (NUREG-1297 and TP 10.5). Following briefings by members of the PTF and other WIPP project staff, panel members were provided two documents that formed the basis of their peer review:

Effectiveness of Passive Institutional Controls in Reducing Inadvertent Human Intrusion into the Waste Isolation Pilot Plant for Use in Performance Assessments (referred to as the Passive Institutional Controls Efficacy Report, see Appendix EPIC); and,

Passive Institutional Controls Conceptual Design Report (referred to as the Conceptual Design Report (CDR), see Appendix PIC).

Supplemental information requested by the panel was also used in the evaluation.

The peer review panel evaluated the assumptions and results presented in the Passive Institutional Controls Efficacy Report. The panel's findings, as presented in their final report, dated July 1996, are provided below. A complete copy of the panel's report is provided in Appendix PEER.

The panel identified several concerns during their review. The panel's concerns ("Peer Review Panel Concerns" - presented in italics below), the DOE's interpretation of the panel's concerns ("Statement of Issue"), the DOE's response to the panel's concerns ("Response to Issue"), and the panel's reaction to the interpretation and responses ("Peer Reviewer Consideration of Response") are provided below. In those instances where the panel determined the response did not reasonably address their concerns, the DOE's justification for its position ("DOE Technical Position versus Panel Issue") is provided. In some instances, a response addresses more than one concern; in those situations, the "Panel Concerns" will not necessarily be presented in the same order as they appeared in the passive institutional controls peer review report. The issues/concerns are from the Executive Summary and Conclusions sections of the report.

The DOE responses were provided to the panel in a memorandum format. For incorporation into this application, the responses have been edited to remove the memorandum format, consolidate references, replace first-person text (for example, where appropriate "PTF" was replaced with "DOE"), insert cross-references where appropriate, and correct typographical errors. Substantive technical content of the responses has not been changed.

9.3.7.1 Peer Review Panel Concerns - Adequacy and Completeness of Assumptions

In general, the panel found that the PTF's interpretation of the regulations regarding passive institutional controls was adequate and reasonable given the indeterminate quality of some of the regulations. However, the panel expressed concern about the way in which the PTF's interpretations were applied. In many cases, the panel found the PTF's assumptions to be reasonable but unsupported and/or incomplete. In other *cases, the panel determined that the PTF failed to discuss assumptions that were: 1) implicit in, and necessary to, the assumptions they presented, or 2) made by expert panels and incorporated into the overall design of the passive institutional controls (e.g., validity of archetypes as a communications vehicle).*

Another area of concern dealt with the PTF's failure to develop and/or discuss the communications and activities process models that underlie the conceptual design of the controls. Such models would: 1) look at passive institutional controls as communications vehicles, and 2) assume a general pattern of activity that will lead to an inadvertent intrusion event.

The panel's assessment of the individual assumptions presented in the PICs Efficacy Report resulted in a general consensus by panel members as to the adequacy and reasonableness of the information contained in the document. However, panel members noted their concern about areas within the PICs Efficacy Report that may be in need of clarification or modification. These areas include:

Basic human attributes. Several assumptions regarding human characteristics are poorly supported or in need of other modifications. For example, explicit assumptions should be provided relating to human evolution and associated biological and sociocultural capabilities.

Government. The PTF does not adequately define "government" and offers poor support for the assertions made in the PICs Efficacy Report. Also, some of the assumptions made by the PTF are actually conclusions or second order assumptions.

Language. Assumptions made by the PTF should be supported by references. Also, assumptions regarding other aspects of communication are not captured.

Natural resources. The panel found these assumptions to be generally reasonable and consistent with the requirements.

Estimating the effectiveness of passive institutional controls. Four assumptions are made that require additional support. Furthermore, the panel believes that social institutions other than government should be considered as potential facilitators of passive institutional controls since there are strong and effective mechanisms of social control other than government.

Statement of Issues

a. General: Regulatory interpretations were generally adequate and reasonable.

b. General: The panel believes that some assumptions were reasonable but were unsupported or incomplete.

c. Basic Human Attributes: The panel believes that the DOE failed to discuss certain assumptions that were implicit in other assumptions that were presented.

d. Government: The panel believes that the DOE failed to discuss assumptions from the Markers Panel that were used in the Passive Institutional Controls Efficacy Report.

e. Language: The panel believes that the validity of archetypes as a communications vehicle was an assumption used in the passive institutional controls work.

f. Natural Resources: The panel believes that a general communications model must be described. The model discussed by the panel includes: (1) develop intention; (2) identify audience; (3) encode in language; (4) capture in media; (5) transmit; (6) receive; (7) decode; (8) understand; and (9) respond and is shown as Figure 3.2.2-1 of the panel report (see Appendix PEER).

g. Passive Institutional Controls Effectiveness: In the absence of a documented communications model for the operation of the passive institutional controls, the panel created a model that they believe represents how the DOE expects that the passive institutional controls would be encountered by a site investigator/potential intruder (the "general pattern of activity"). The DOE believes that the panel interpretation of the operation of the passive institutional controls system is that if the markers at the WIPP were not encountered prior to a potential intrusion, then the passive institutional controls system would fail to communicate and deter inadvertent intrusion. The DOE believes that the panel proposed the horizontal drilling as a potential failure mechanism that could circumvent the markers.

<u>Response to Issues</u>

a. The DOE agrees with the panel report.

b. EPA's Compliance Application Guidance (CAG; EPA 1996c) was the basic source of guidance used by the DOE.

The EPA establishes Future State Assumptions in 40 CFR § 194.25 by stating that performance assessment and compliance assessment shall assume that characteristics of the future remain what they are at the time the application is prepared, except for geology, hydrology, and climate. Specific topical areas to which the future-state assumptions apply are listed in the Supplementary Information. This direction is consistent with the guidance provided on drilling technologies and plugging practices and technologies in 40 CFR § 194.33, which are integral parts of performance assessment. No specific guidance is provided on 40 CFR Part 194 as to the role of future-state assumptions in estimating credit for passive institutional controls in performance assessment (40 CFR § 194.43[c]), and assuming that the future-state assumptions apply to the passive institutional controls in the performance-assessment arena is not consistent with the guidance in the CAG (EPA 1996c). Separate guidance on how the DOE may obtain credit for passive institutional controls in performance assessment is provided in 40 CFR § 194.43 of the CAG, perhaps because the DOE is not required to propose a credit for passive institutional controls, and the EPA is not required to allow credit for the passive institutional controls. The DOE's approach, then, was to give equal weight to the CAG as to 40 CFR Part 194, as expressing the intent of the EPA.

In the CAG, the EPA states that credit for passive controls will be based on two aspects of the passive institutional controls: whether they are expected to endure for the time period proposed by the DOE (not to exceed 700 years after disposal) and whether they are expected to be understood by the potential intruder for the proposed time period. With respect to the first aspect, the EPA states that the period of time for which the markers (the EPA does not mention any of the other passive institutional controls in this discussion) are expected (but not required) to endure is likely to require a deterministic analysis tied into CAG 194.43(1)(a) (that is, markers designed, fabricated, and emplaced to be as permanent as practicable).

The second aspect will be evaluated with respect to "a prudent extrapolation of the future state assumptions established in 40 CFR § 194.25". In an example provided on what will and will not be accepted in the context of future-state assumptions, the EPA states that government regulations will remain in force but the exact form and content of the regulation cannot be identified with certainty. In continuing the guidance, the EPA does not require justification for the existence of government but does require justification why any assumptions made about the regulations are sound. The treatment of the existence of government in this example is consistent with the paragraph in the CAG following the example that discusses societal "common denominators".

Societal common denominators are described as "patterns of human behavior that may be detected throughout history and around the world." Nowhere in this paragraph are these common denominators described as "assumptions" nor is there any suggestion that the discussion of assumptions in the previous paragraph applies to common denominators. This approach by the EPA is consistent with the view that basic human characteristics (that is, societal common denominators) are facts and are not assumptions. In addition, nowhere in this paragraph does the EPA state nor imply that these common denominators need to be justified by the DOE. Based on the EPA's guidance, the DOE does not believe that providing a discussion or references to support the societal common denominators listed in the CAG is appropriate. It is important to emphasize that the period that is being considered for credit in performance assessment calculations ends 700 years after disposal.

In the Passive Institutional Controls Efficacy Report, the PTF listed the common denominators along with working assumptions derived both from the CAG and the DOE. This approach obviously caused confusion to the peer-review panel, especially with the expectation of justification of the societal common denominators.

In their review of the Passive Institutional Controls Efficacy Report, the panel approved of the DOE's approach in using the EPA's guidance with regard to the treatment of natural resources in performance assessment. Neither references nor additional discussion were requested to support EPA's guidance. The DOE used the same approach for the societal common denominators that the EPA had provided. The approach was to quote the EPA's language and accept it as part of the regulatory framework that had to be established in the context of performance assessment.

c. The EPA has identified societal common denominators as "facts" that the DOE is not required to justify. The DOE believes that the underlying human conditions upon which these common denominators are based also do not require justification or discussion.

d. The assumption that the DOE incorporated from the Markers Panel was that human beings will be essentially the same as they are today (not evolve into a different species). Because of the limitation to 700 years, the DOE believes it is so basic and reasonable that it was not discussed individually.

e. The conceptual design for the passive institutional controls does not incorporate the concept of archetypes due to the constraints of "practicable". Only Team A of the Markers Panel recommended the use of archetypes, and the use of Menacing Earthworks was the specific recommendation to the DOE for the large overall site design. That design was modified by the DOE to a "practicable" design that directly outlines the repository area and did not use archetypes. The stone monuments, by their very shape, are not consistent with archetypes because they are more honorific shapes.

f. Although no communications model was identified in the CDR for the passive institutional controls components, the DOE has identified the steps in Figure 3.2.2-1 of the panel report, and they are listed with PTF Interpretation 1.f. EPA regulations identified the intentions of the passive institutional controls, the Futures Panel identified the audience in the Assurance Requirement arena whereas the CAG identified the audience in the performance assessment arena, the Markers Panel identified the communications principles, and the DOE incorporated these principles into a conceptual design of the most permanent practicable. QA procedures that will assure that steps (3), (4), and (5) of the panel's general communications model take place: (3) the correct media are selected (for example, correct paper, correct quality of granite), (4) the correct messages are captured in the appropriate media (for example, the printer copies the correct messages on the correct paper, the engraver carves the correct messages at the correct locations in the granite monuments and walls), and (5) the completed passive institutional controls components will be transported to the correct locations (for example, the records get to the correct records centers and archives, the granite monuments are delivered and emplaced in the correct locations) are being developed by the DOE. The DOE dealt with the issues of how long the passive institutional controls would endure with their messages intact and whether the messages could be decoded (recognized) and understood in the 700 years of performance assessment concern. The response of future societies that have understood the messages was not a DOE concern.

The approach of the DOE as expressed in the Passive Institutional Controls Efficacy Report (Appendix EPIC) reviewed by the panel was to focus on EPA's two concerns of messages enduring and being understood (steps (5) through (8) of the panel's general communications model). Steps (3), (4), and (5) of the panel's general communications model were assumed to be completed because the DOE has committed to implementing the passive institutional controls as described in the CDR.

g. The process model developed by the panel (Figure 3.2.2-2 of their report) is incorrect when compared with the manner in which the DOE worked, because it does not recognize any deterrent components other than markers and does not indicate that any single deterrent component (for example, markers, records center, or archive) on its own could deter inadvertent human intrusion. As stated in the Passive Institutional Controls Efficacy Report, each of the deterrent components can convey sufficient information to deter a potential intruder, because a potential intruder would have the information to know that the Withdrawal needed to remain isolated and to understand the danger associated with intruding into the repository.

Section 4.3 of the Passive Institutional Controls Efficacy Report (Appendix EPIC) discusses a typical approach for resource site investigators to come upon knowledge of the WIPP (that is, starting with an initial investigation of the literature to identify potential resource areas). Such an investigation would reveal that there is an area within the Delaware Basin where drilling is prohibited. This typical approach is not the only one possible. A site investigator might examine the site first and be deterred by the messages on the markers. As such, the order of encounter does not matter, nor does it matter if more than one component is encountered by a potential intruder--each deterrent component contains sufficient information to deter inadvertent human intrusion.

Peer Reviewer Consideration of Response

The DOE understood all the issues except items "f" and "g," and provided a reasonable response for all of the items except item "b."

DOE Technical Position versus Panel Issues

b. The EPA developed the CAG (EPA 1996c) which provided the only guidance about how to treat passive institutional controls in performance assessment other than the limit on 700 years of credit. The DOE believes that the CAG (EPA 1996c) shows the EPA's intent and therefore the DOE must follow this guidance to develop credit for passive institutional controls in performance assessment.

9.3.7.2 Peer Review Panel Concerns - Systems Approach

> *Application of the systems approach. The panel found that the redundancy of the individual components was well-supported and explained, but that the sufficiency of the individual components to effectively deter inadvertent intrusion in the absence of any other component was unevenly supported. The panel noted the PTF's failure to discuss the "Gestaltic" nature of the system, in which the whole is more effective in deterring intrusion than the sum of its parts.*
>
> *Consequences for Performance Assessment. The panel concluded that:...4) the systems nature of passive institutional [sic] was not appropriately considered when calculating the probabilities that individual components and/or the system will fail.*
>
> *(Conclusion #2 from the report Conclusions Section) The effectiveness of the deterrence afforded by the passive institutional controls components is such that any component in isolation from all the other components effectively deters inadvertent intrusion. This conclusion ignores the systems nature of the passive institutional controls in that, despite all of the systems redundancy, some components do not have the same level of deterrent efficacy as others for every credible intrusion scenario.*

Statement of Issues

a. The panel believes that the DOE needs to support the sufficiency of individual passive institutional controls components to deter inadvertent human intrusion through year 700.

b. The panel believes that the DOE used a systems approach in estimating the effectiveness of passive institutional controls and needs to support it.

Response to Issues

a. The passive institutional controls components as a deterrent can be viewed in several ways:

(i). Each component is an independent deterrent whose effectiveness is uninfluenced by other components. The effectiveness of the passive institutional controls set or system is as effective as the most effective component that will be encountered by the potential intruder. Failure of one or more components could either reduce or leave unchanged the total effectiveness, depending on the differences in effectiveness of the components and the particular component(s) that fail. The message on each deterrent component conveys sufficient information so that comprehension of the message on any single component precludes inadvertent human intrusion.

(ii). The effectiveness of each of the components is dependent on the effectiveness of all of the other components. The effectiveness of the passive institutional controls system is the product of the effectiveness of each component in the system. Failure of any component to deter would mean that the entire passive institutional controls system fails.

(iii). The effectiveness of each component contributes to the effectiveness of the passive institutional controls system. The effectiveness of the passive institutional controls system is the sum of the component effectivenesses. Failure of one or more components would reduce the effectiveness of the passive institutional controls system.

(iv). The effectiveness of each component contributes to the effectiveness of the passive institutional controls system, but because of the Gestaltic nature of the system design, the effectiveness of the total passive institutional controls system is greater than the sum of the effectivenesses of the components. The effect of the failure of any component on the system effectiveness depends on the contribution of the component to the Gestalt.

The passive institutional controls for the WIPP are envisioned by the DOE to operate as alternative (i) for the purposes of performance assessment.

What has to be provided is a reasonable expectation that a component will survive and be able to be correctly interpreted.

> (A) Assumptions establish that because of the relatively short time period of concern here, the nature of drilling in going after resources of worth, and previous examples of reading 700 year-old English, that there is a reasonable expectation that any English text surviving (on paper, in stone, in other materials) for 700 years will be able to be read by the resource exploration/exploitation decision makers.
>
> (B) The other half of the rationale is whether there is a reasonable expectation that the physical form of the component (or a subset of the multiple copies of the component) will survive for 700 years.

All the components have (A) and if a component has (B), then a component is sufficient to correctly convey the correct information.

b. The passive institutional controls system for the WIPP consists of two types of components. Awareness triggers are one type of component and are intended to alert the potential intruder or site investigator that something anomalous is present at the WIPP site, and that more information should be obtained before proceeding with the intrusion activity. In the search for additional information, the potential intruder or site investigator will encounter one or more deterrent components, which are the other type of components. (No credit is claimed for awareness triggers in deterring inadvertent human intrusion for the performance assessment calculations.) Deterrent components are designed to convey a warning to the potential intruder or site investigator that the WIPP site contains hazardous materials and is not a suitable location for the intended intrusion activity. This distinction between the goals of awareness triggers and deterrent components is in a sense layering of the components by having separate goals for each category or components.

No hierarchy of deterrent components is intended. Each deterrent component contains enough information to deter the potential intruder or site investigator. Different levels of messages associated with different components may imply layering within the deterrent components, but these different message levels are targeted at different audiences to address the Assurance Requirement rather than to address the credit for passive institutional controls in performance assessment. Level II, and perhaps Level III messages, are targeted at people in societies that are not drastically different from our own involved in the natural-resource industries that might be interested in locating or exploiting natural resources at the WIPP site. Levels III, IV, and V messages are designed to reestablish basic scientific concepts within societies in which these concepts have been lost or the social/technological/language changes have been so great that the connection between the text messages and the concepts have to be reestablished. In addition, these higher-level messages provide basic information about the characteristics of the WIPP site, the repository, and TRU waste.

The concept of the passive institutional controls as an integrated system refers to design characteristics that develop a wide variety of passive institutional controls components encompassing a variety of message levels and using a variety of media for conveying the messages.

A Gestalt is a system in which the whole cannot be determined by simply summing the parts within the whole. The Gestaltic nature of the passive institutional controls system refers to the DOE's belief that the effectiveness of the system cannot be determined by summing the estimated effectivenesses of the passive institutional controls components. The physical presence of the passive institutional controls components, the repetition of the warning over and over on different media and in different ways, the size of the markers, and the level of effort required to construct the markers and distribute the records will reinforce to the potential intruder the importance of the location, and thereby reinforce the importance of the messages and warnings to an extent that simply reading a single message is unlikely to convey.

The concept of Gestalt for passive institutional controls addresses the requirements of the Assurance Requirements because of the potential for discontinuities in society and information. A future society might need to recreate all the information about the WIPP. For performance assessment purposes, and with the assumptions developed, redundancy and self sufficient passive institutional controls are used.

The DOE did not attempt to estimate the contribution of the Gestaltic nature of the passive institutional controls system when estimating the effectiveness of the passive institutional controls for performance assessment, and thus underestimated the effectiveness of the passive institutional controls system. Given the short time frame for which credit may be given for the passive institutional controls in performance assessment and the high levels of effectiveness of each component when considered independently in this time frame, the DOE decided not to include the concept of Gestalt and the likely accompanying controversies into the DOE estimates. For longer time frames in which substantially greater changes to society, technology, and language are likely to occur, the contribution of the Gestaltic nature of the passive institutional controls system is likely to be a larger contributor to estimates of passive institutional controls effectiveness in deterring inadvertent intrusions.

Peer Reviewer Consideration of Response

The DOE understood both issues and provided a reasonable response for item "b." The panel concluded that the DOE response for item "a" did not reasonably address their concern.

DOE Technical Position versus Panel Issue

(a) The DOE believes that any one of the components, in isolation, will be an effective deterrent. The panel's report indicates that all of the components need to be encountered for deterrence; this is at odds with the DOE's approach. The statement that "the system is only as strong as its weakest — not its strongest — component" is incorrect because if a potential intruder encounters more than one message, the most convincing message, that is, the stronger component, will be believed.

9.3.7.3 Peer Review Panel Concern - Uncertainty

> Assessment of the durability and comprehensibility of individual components of the system. *The panel examined descriptions of markers, archives, records centers, government control of land use, and other passive institutional controls. The panel concluded that the materials (e.g., granite) and plans for the storage and retention of records appear to be adequate, but that there is uncertainty attached to both the durability and comprehension of all passive institutional controls and that this uncertainty has not been taken into account by the PTF.*

> Consequences for performance assessment. *The panel concluded that:...1) uncertainties relating to the failure of various passive institutional controls components were not addressed properly.*

> Overall Conclusion from the Executive Summary. *The overall conclusions presented by the panel regarding the passive institutional controls described and supported in the PICs Efficacy Report and the Conceptual Design Report suggest that:...(2) the level of uncertainty as it applies to the passive institutional controls is higher than 0.0.*

> Concern #5 from the report Conclusions section. *The report concludes that the marker system is 100 percent reliable with no uncertainty, and that the*

records/archives/land-use controls are highly reliable with no uncertainty. The panel believes that there is uncertainty attached to comprehension of all the passive institutional controls and that the records centers and archives, as described in the documents under review, are highly likely to fail as communication events.

Statement of Issues

a. The panel believes that the DOE has not considered the uncertainty in durability and comprehension.

b. The panel believes that the DOE needs to calculate failure rates and uncertainty for each passive institutional controls component.

c. The panel believes that the DOE used a failure rate of 0.0 for the markers, records centers, archives, and land use controls at the WIPP.

d. The panel believes that the DOE considered no uncertainty in the response of the passive institutional controls to failure mechanisms.

e. The panel believes there is uncertainty in the response of the passive institutional controls to failure mechanisms.

f. The panel believes that there is a low probability and high uncertainty about the ability of records centers and archives to effectively communicate because of inadequate explanation in the Passive Institutional Controls Efficacy Report. As indicated in the text of the panel's report, this probability could be increased and the uncertainty decreased by developing additional arguments.

Response to Issues

a. The DOE assessment of durability and correct interpretation was that the effectiveness was very high, but not perfect. Explanations started out with the use of the term "virtually" to indicate high but not perfect performance. Later in the report the language slipped and the use of "virtually" was inadvertently left out, although the conclusions section does make use of the term. Any consideration of the passive institutional controls effectiveness being absolutely perfect would be counter to the EPA's instructions which the DOE quoted:

> "although passive institutional controls should not be assumed to completely rule out the possibility of intrusion" (EPA 1985, 50 FR 38089a) .

b. The assessment of a failure rate is in and of itself an uncertain quantity. The DOE used the approach of identifying a bounding value to address the factors that may affect this uncertainty. In addition, Budescu and Wallsten (1987) indicate that it does a disservice to decision makers to present material which suggests that there is more certainty about something than there really is:

> "It is argued that the decision-maker is poorly served when provided with forecasts that are more precise than is warranted by the available information."

Putting a number on a failure rate for each passive institutional controls component would be introducing speculation that does not add information for a decision maker to assess credit for passive institutional controls in performance assessment.

c. The initial treatment of the effectiveness of passive institutional controls based on design concepts from historical analogues was that they were highly effective, but not perfect (that is, not a failure rate of 0.0 as indicated by the panel), as indicated by the use of the term "virtually". The conclusions of the Passive Institutional Controls Efficacy Report state that:

> "Based on the above analyses, the passive institutional controls system will offer virtually complete effectiveness in deterring inadvertent human intrusions within the repository footprint for as long as the marker system components at this location are in place. The effectiveness of the passive institutional controls system in deterring inadvertent human intrusions within the Withdrawal outside the repository footprint will offer virtually complete effectiveness for the period from 100 years...after disposal to at least a couple of thousand years after disposal."

The term "virtually" has a meaning in common usage of "for all practicable purposes." In the context of the passive institutional controls performance for performance assessment for the 700 years when credit may be allowed, "virtually certain" indicates a high level of confidence while recognizing a possibility, no matter how remote, of an alternative conclusion.

d. The DOE realized the uncertainty in addressing the issue of failure mechanisms. The available information on the failure rate of the existing control system to prevent boreholes from being drilled where it is not lawful (analogous to an inadvertent human intrusion event where a borehole anywhere within the Withdrawal is not lawful) provided a failure rate for the land-use controls, without benefit of any markers, records centers, and archives, as will be the case for the WIPP. The failures observed in these cases were location errors within the correct claim.

The DOE believes it was appropriate to use information on recent failure rates because of EPA's own use of today's activities as a surrogate for future activities (for example, drilling activity), and because the EPA instructed the DOE to undertake a prudent extrapolation of current conditions for use in considering the effectiveness of passive institutional controls. A recent "failure rate" of 0.00001 for the Permian Basin, and a 0.0 recent "failure rate" for the Delaware Basin were thus calculated. Even with the added protection afforded by markers at the WIPP along with the deterrent components of records centers and archives, the DOE realized that the uncertainties inherent in addressing the impact of failure mechanisms and decided to recommend a bounding approach. As stated on 6-11 (see Appendix EPIC), "For the sake of addressing the needs of PA and to account for unidentified possible failure mechanisms and sources of human error that could result in reduced effectiveness of the passive institutional controls system, the DOE recommends that the failure rate for performance assessment calculations (100 to 700 years after disposal) be increased to a bounding value of 0.01." The DOE believes that the increase in the surrogate failure rate for use in performance assessment by three orders of magnitude is sufficient to capture the uncertainties associated with failure mechanisms. The DOE saw this as representing additional failure mechanism not considered and simple human error. As a result, the DOE increased the failure rate for performance assessment calculations by 1,000 times. Additional investigations into failures in several other states and several Canadian provinces supported the bounding failure rate developed previously.

e. The DOE agrees that there is uncertainty in the effectiveness of the passive institutional controls for certain failure mechanisms, and believes that it was appropriate to address it through the use of bounding estimates of effectiveness.

f. The DOE believes that the design solutions implemented for the records centers and archives for retaining WIPP material apply lessons learned from known failures and make retention of sufficient material to correctly communicate the necessary information a highly likely event and disagree with the panel on this point in the absence of any more specific failure-mechanism concerns. The design solutions implemented range from having both records centers (easier access to potential intruders) and archives (greater preservation potential) retain the information to having multiple locations for storage of the information under multiple jurisdictions to having a truthful representation of the risks of intruding upon the disposal system transmitted to future generations.

In order to ensure that these design solutions are implemented, the DOE is developing QA procedures addressing the three implementation steps (encode in language, capture in media, and transmit) from the panel's general communications model (Figure 3.2.2-1 of their report). The DOE believes that these QA procedures will provide the documentation that the panel felt was necessary to indicate how correct information will get into the records centers and archives. This documentation will support the DOE conclusions as to the effectiveness of records centers and archives.

<u>Peer Reviewer Consideration of Response</u>

The DOE understood all of the issues; however, the panel concluded that the responses to items "a," "d," and "f" did not reasonably address their concerns.

DOE Technical Position versus Panel Response

a) The definition of "virtually" that the DOE proposed in the Passive Institutional Controls Efficacy Report is consistent with the standard dictionary definition. The passive institutional control's components are over-designed for the relatively short time period for which credit may be given for passive institutional controls in performance assessment and based on the EPA's guidance on a prudent extrapolation from today's conditions. This over-design means that in fact the passive institutional controls are expected to be virtually (that is, for all practical purposes) certain to deter inadvertent human intrusion.

d) The DOE has committed to implementing the passive institutional controls as described in the CDR and the QA procedures being developed will assure that the correct documents will get to the correct records centers and archives with which arrangements have been made to receive and implement the prearranged storage and retrieval system. The list in the CDR of records centers and archives is based on those facilities that currently exist and that bear some relationship to, for example, nuclear waste, resource development, land use, document preservation, and health issues. When the DOE is ready to implement the passive institutional controls, the list will be finalized and the appropriate arrangements will be made. Because the WIPP information will be integrated into natural resource-based information centers, certain state and federal agencies dealing with land use and resource exploitation will be required by law to accept and maintain these records.

f) The DOE's responsibilities include developing estimates of the effectiveness of passive institutional controls for performance assessment based on the components in the CDR to which the DOE has committed. The DOE is responsible for ensuring that the components are designed, constructed, and implemented correctly.

9.3.7.4 Peer Review Panel Concerns - Failure Scenarios

> Assessment of Completeness of Failure Scenarios. *The panel found that at least two failure scenarios were not discussed by the PTF: collateral damage due to war and inadvertent intrusion due to horizontal drilling.*

> Consequences for performance assessment. *The panel concluded that:...2) certain credible failure scenarios were not considered;"*

> Concern #1 from the report Conclusion section. *This report concludes that the sole cause of failure is incorrect location of a drilling rig. The panel believes that there are other failure scenarios that have not been taken into account-- specifically, horizontal drilling, collateral damage due to war, and vandalism.*

> Concern #4 from the report Conclusion section. *The report concludes that vandalism and souvenir hunting will be effectively defeated by the passive institutional controls*

design. The panel believes that this conclusion has not considered the historical destruction of similar types of monuments, markers, and constructions during periods of war or loss of active governmental control.

Statement of Issues

a. The panel believes that horizontal drilling would constitute an inadvertent human intrusion (only inadvertent human intrusion is to be considered in performance assessments).

b. The panel believes that the probability of collateral war damage sufficient to make the markers at the WIPP unable to communicate is high enough to be screened in for performance assessment purposes and should be addressed in the report.

c. The panel believes that the markers as currently designed cannot completely address vandalism and souvenir hunting for a period of 600 years (from year 100 to year 700 after closure). It is not clear whether this failure was seen as a failure of some pieces of a component or the entire component.

d. The panel believes that the efficacy of certain markers components against potential horizontal drilling is lower than for vertical drilling, for instance, because of its more remote origination location.

e. The panel believes that the DOE used a failure rate of 0.0 for the effectiveness of the passive institutional controls against vandalism and souvenir hunting.

Response to Issues

a. Horizontal drilling would be subject to the same regulations as vertical drilling, and as a result would be subject to the same procedures. Consistent with these procedures (including examining maps ands other awareness triggers), horizontal drilling would require the obtaining of ownership or resource rights, both at the drill site and along the length of the drill string. There would be the same prohibitions on and legal disincentives to drilling into the disposal system from outside the Withdrawal as drilling vertically into the disposal system. As a result of being subject to the same procedures, the failure rate for horizontal drilling can be assumed to be the same as the failure rate for vertical drilling.

b. The collateral effects of war were not addressed and need not be addressed, because they would be such a low probability event. Collateral effects might take out some parts of a component or some parts of several components, but would be unlikely to take out all of the markers at the site. It would take a very large bomb to destroy all of the markers to the point that pieces of text on monuments did not remain in pieces larger enough to read. The trinitite produced from a nuclear device would itself be a marker. In discussing the impact of war damage, that is, bomb damage on a repository, the EPA has stated that "Similar to the question of sabotage is the question of damage to the repository through some act of war. The only credible act that could even fracture the rock down to about 500 meters would be the detonation of at least a ten-megaton or larger nuclear device. During a war, it is hardly likely that bombs would be aimed at a repository. Cities and strategic installations are far more attractive targets. In addition, the effects on the biosphere from a damaged repository would be insignificant compared with the other damage inflicted in such a conflict." The WIPP is not a strategic target and is many miles away from any strategic targets. The probability of a stray missile in the expanse of southeastern New Mexico away from strategic targets, of a capacity large enough to destroy all the markers, was below the regulatory cut-off for scenarios that had to be considered. In addition, to paraphrase the EPA, if a bomb that large did come, it would disturb the repository and that bomb would represent far greater impacts than the disruption of the repository itself. In addition, collateral effects of war at the WIPP would not destroy all of the records centers and archives containing WIPP information.

c. Vandalism was taken into account in the designs. The passive institutional controls components are not replicates of the historical analogues examined, but take the basic design concept from the historical analogue that enabled these structures to endure and enhances them to compensate for natural and human factors that will tend to destroy the components. Specific examples of design solutions incorporated to counteract the effects of vandalism include: (1) selection of granite for the monuments and other markers as a durable rock that will resist chipping away pieces and limit damage from bullets; (2) use of multiple copies of the individual monuments and markers so the system will continue to communicate even if one or more individual monuments or markers are damaged or removed; (3) use of right angles and relatively large, flat surfaces in the shape of the monuments to reduce the amount of material that can be chipped away by someone hammering on a monument, (4) use of the large size of the monuments and the berm to make these components difficult to destroy or remove, (5) inclusion of two copies of the Level IV messages on the granite walls in each of the buried rooms, (6) use of an irregular pattern of the spacing and depth of the small buried markers to make systematic collection of these markers difficult.

The DOE expects that the markers at the WIPP, with their multiplicity of copies will be able to withstand casual vandalism and souvenir hunting (for example, spray paint, bullet holes, chipping of edges) for the period for 100 to 700 years after closure so that a sufficient number of components or pieces of components will remain to communicate their intended messages.

The DOE believes that systematic vandalism (for example, the monuments and markers at the WIPP being caught in the middle of a tank fight, the target of a scorched earth policy of a retreating army, the target of rampaging renegade troops, the target of deliberate destruction by cults, or the development of new highly destructive technologies that can be owned by the general public) will be a low probability event at the WIPP during the years from 100 to 700 after closure. In addition, vandalism of this type is beyond the realm of a prudent extrapolation of today's societal conditions.

The DOE disagrees with the panel on the possible impacts of vandalism on the effectiveness of passive institutional controls in deterring inadvertent human intrusion. The DOE believes that the passive institutional controls to be implemented for the WIPP will be highly effective in the context of performance assessments because of all the design solutions incorporated to address potential vandalism and other potential failure mechanisms and the relatively short time frame of interest (from year 100 to year 700 after closure of the WIPP).

d. Horizontal drilling is required to go through the same site-evaluation procedures and permitting processes as vertical drilling. As a result, the passive institutional controls will be as effective in deterring inadvertent horizontal drilling into the Withdrawal as they will be in deterring inadvertent vertical drilling.

e. See Section 9.3.7.3, DOE Response c.

Peer Reviewer Consideration of Response

The DOE understood the issues and provided reasonable responses.

9.3.7.5 Peer Review Panel Concerns - Calculations

> Evaluation of credit calculations. *The panel's analysis suggested that the PTF's credit calculations may be incorrect or incomplete. For example, failure rates and the uncertainty surrounding failure rates should be calculated for each component.*
>
> Consequences for performance assessment. *The panel concluded that:...3) adequate evidence for calculating failure probabilities of various components was not provided,...*
>
> Overall conclusions from the Executive Summary. *The overall conclusions presented by the panel regarding the passive institutional controls described and supported in the PICs Efficacy Report and the Conceptual Design Report suggest that: (1) the evidence provided in the reports does not adequately demonstrate that passive institutional controls will have a failure probability of 0.01 or less....*
>
> Concern #3 from the Conclusions section of the report. *The report describes historical analogs for the passive institutional controls in order to justify a 0.0 failure rate for durability. However, failure rates ascribed on the basis of historical analogs do not account for the fact that similar monuments or constructions have not survived.*

Statement of Issues

a. The panel believes that it is appropriate and necessary to calculate failure probabilities for each component.

b. The panel believes that the DOE needs to provide additional evidence/calculations to support the assessed failure rate.

c. The panel believes that there is uncertainty associated with the passive institutional controls.

d. The panel believes the DOE used a failure rate of 0.0 for durability of the markers at the WIPP in the estimate of the effectiveness of passive institutional controls in deterring inadvertent human intrusion.

e. The panel believes that monuments similar to those designed for the WIPP have failed.

f. The panel believes that the failure of historical analogues means that the durability failure rate for the markers at the WIPP must be less than 0.0.

Response to Issues

a. The approach taken by the DOE was that there is so much redundancy in the passive institutional controls components that the probability that all elements of each component, and all components failing within the 700 year time frame of interest was so low, that the most productive course of action was to focus on the human errors within the process of resource development. The probability of passive institutional controls failure calculated incorporates not only the probability of mislocating a drill rig within a lease, but also the probability of someone trying to drill without proper authorization and the probability of setting up on the wrong lease (these were both zero for the knowledge base of the DOE's sources at the time of the DOE's first estimate). Realizing that there may be some additional failures that were not known by the DOE's sources, and realizing the uncertainties in the operation of failure mechanisms, the calculated failure rate was increased by orders of magnitude. The DOE does not believe that developing individual probabilities for each component would add information that would be of use to the EPA as the decision maker/regulator.

It is important to highlight at this point that the EPA guidance indicates that the effectiveness of the passive institutional controls in deterring inadvertent drilling can also apply to mining for the same time period. Because the societal common denominators, regulatory assumptions, and the DOE assumptions apply equally well to mining as to drilling, the DOE believes that the effectiveness of the passive institutional controls determined for drilling also applies to mining.

b. The DOE has contacted several additional government agencies to try to determine the historical rates at which oil and gas wells have been drilled on or into the wrong leases. These contacts resulted in the following information: (1) in Montana, over 1,200 wells have been drilled during the past six years with no instances of drilling on or into the wrong leases, (2) in Michigan, over 40,000 wells have been drilled since the current drilling regulations went into effect in 1927 with no instances of drilling on or into the wrong leases, (3) in Wyoming, over 60,000 wells have been drilled with perhaps two or three instances of drilling on or into the wrong leases, (4) in Manitoba, a total of 4,500 wells have been drilled for oil or gas with no instances of drilling on or into the wrong leases, and (5) in Alberta, the number of wells is in the range from 30,000 to 50,000 with perhaps 10 or 12 instances of drilling on or into the wrong leases. This new information supports the conclusions from earlier investigations of the Delaware and Permian Basins that drilling on or into the wrong leases is an extremely rare event.

Regulatory control over resource exploration and exploitation is just one of the deterrent components that the DOE will use to protect the WIPP from future human intrusion. The historical effectiveness of this one component in deterring drilling into the wrong leases has been extremely high, supporting the DOE's contention that the incorporation of additional deterrents will provide additional support to maintaining the effectiveness at extremely high levels. The DOE believes that the historical drilling information supports the conclusion that the proposed failure rate of the passive institutional controls for use in performance assessments of 0.01 is a bounding value that substantially underestimates by orders of magnitude the effectiveness of the deterrent components.

c. See Section 9.3.7.5, DOE Response a.

d. See Section 9.3.7.3, DOE Response c.

e. The DOE agrees that historical analogues have failed. The markers to be implemented for the WIPP are not merely replicates of historical analogues. Design solutions have incorporated elements shown to have endured, and the marker designs were modified to address possible failure mechanisms.

f. The DOE does believe that the failure rate is very close to 0.0, but is not 0.0. With the incorporation of design solutions, the markers should have greater durability than historical analogues, and thus the DOE disagrees with the panel.

Peer Reviewer Consideration of Response

The DOE understood all of the issues except item "f" and provided reasonable responses for all of the issues except items "a," "b," and "f."

DOE Technical Position versus Panel Issues

(a) As stated above, the passive institutional controls are over-designed. This over-design means that, in fact, the passive institutional controls are expected to be virtually (that is, for all practical purposes) certain to deter inadvertent human intrusion, and the only failure mechanism that could really impact effectiveness is human error. Oil field "failure rates" are a surrogate for human error in the resource development industry (this use of surrogates is consistent with the EPA's use of historical drilling rates as a surrogate for future drilling rates for other possible resources). Again, because of the over-design of the passive institutional controls in the performance assessment context, they are all highly effective. The DOE's approach was to assign a bounding value to the effectiveness of the passive institutional controls system in relation to human errors. In a practical sense, this bounding value can be considered to be a bounding value for each of the components.

(b) The DOE, or a successor agency, need only endure long enough to implement the passive institutional controls, not for the entire compliance period, nor even for the entire 700 years for which credit may be claimed for passive institutional controls in performance assessment. The controls are designed to be passive and need no maintenance by the DOE or a successor agency. Even if agencies are reorganized, the national interest is served by reassigning responsibility for nuclear waste management.

(f) The DOE addressed residual uncertainty by using a bounding value for the failure rate. Consultations with individuals involved in natural resource development in the regulatory arena confirmed that the 0.01 bounding failure rate to be used in performance assessment calculations grossly over-estimated the failure rate that would be expected under conditions similar to today. Note, this conclusion was for a single deterrent component, rather than the suite of components that the DOE has committed to implementing.

9.4 Peer Reviews Conducted Prior to Promulgation of 40 CFR Part 194

40 CFR Part 194 states that

> *"Additionally, this section requires compliance applications to include documentation of any peer review activities that DOE may have conducted apart from those required by this rule, including those activities which are similar to peer review, such as the reviews conducted by the WIPP Panel of the National Academy of Sciences."* (61 FR 5228)

and that

> *"Peer review which has been conducted prior to today's action must be documented in compliance applications."*

Over the course of the WIPP endeavor, the project has undergone extensive review. These historical reviews were conducted prior to the implementation of 40 CFR Part 194. They provide additional information to the peer reviews specifically stated in 40 CFR § 194.27(a). These reviews were evaluated against criteria developed from 40 CFR Parts 191 and 194 and NUREG-1297 to determine which ones were appropriate for incorporation in this application. The following criteria were used to screen the historical reviews:

1. Was the "peer review" relevant to this application?

   The purpose of this application is to demonstrate the WIPP's compliance with the disposal regulations found in 40 CFR Part 191. 40 CFR Part 194 provides significant detail concerning the necessary contents of the application. Reviews that cover subject matter pertinent to those contents are considered relevant to this application.

2. Was there a formal report by the reviewer?

   NUREG-1297 requires a peer review to be documented.

3. Was the review a "peer review" rather than a "technical review"?

   NUREG-1297 states that

   > *"A peer review is an in-depth critique of the assumptions, calculations, extrapolations, alternate interpretations, methodology, and acceptance criteria employed, and of conclusions drawn from the original work. Peer reviews confirm the adequacy of work. In contrast to peer review, the term "technical review," as used in this GTP, refers to a review to verify compliance to predetermined requirements; industry standards; or common scientific, engineering, and industry practice."*

4. Was the review a "peer review" rather than an "expert judgment"?

   As discussed above, a peer review confirms the adequacy of the work being reviewed. 40 CFR Part 194 states that

   > *"Typically, expert judgment is used to elicit two types of information: (1) Numerical values for parameters (variables) which are measurable only by experiments that cannot be conducted due to limitations of time, money and physical situation; and (2) essentially unknowable information, such as which features should be incorporated into passive institutional controls that will deter human intrusion into the repository."* (61 FR 5228)

5. Was the technical expertise of the reviewer at least that needed to perform the original work?

NUREG-1297 states that

"The technical qualifications of the peer reviewers, in their review area should be at least equivalent to that needed for the original work under review and should be the primary consideration in the selection of peer reviewers. Each peer reviewer should have recognized and verifiable technical credentials in the technical area he or she has been selected to cover. The technical qualifications of each peer, and hence of the peer review group as a whole, should relate to the importance of the subject matter to be reviewed."

6. Were the reviewers independent?

a. Were they involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed?

b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?

Regarding the reviewers independence, NUREG-1297 states:

"Members of the peer review group should be independent of the original work to be reviewed. Independence in this case means that the peer, a) was not involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed, and b) to the extent practical, has sufficient freedom from funding considerations to assure the work is impartially reviewed."

"Because of DOE's pervasive effort in the waste management area, the lack or unavailability of other technical expertise in certain areas, and the possibility of reducing the technical qualifications of the reviewers in order that total independence is maintained, it may not be possible to exclude all DOE or DOE contractor personnel from participating in a peer review. In those cases where total independence cannot be met, a documented rationale as to why someone of equivalent technical qualifications and greater independence was not selected should be placed in the peer review report."

"The pervasive nature of DOE's effort in the waste management area also makes it necessary that both the work under review as well as the peer review of this work be allowed to be funded by DOE."

"The independence criteria is not meant to exclude eminent scientists or engineer upon whose earlier work certain of the work under review is based so long as a general scientific consensus has been reached regarding the validity of their earlier work."

7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review" for incorporation into the historical review section of this application?

Interviews with former and current WIPP project personnel were conducted to identify past reviews that should be considered for inclusion in this application. Records of the historical reviews were obtained and evaluated against the above screening criteria to select the specific reviews to be documented in the application. The selected reviews are discussed below and copies of the reports are provided in Appendix PEER.

A "historical review" may provide an evaluation of completed work by the WIPP project, for example, the Engineered Alternatives Task Force Report (DOE 1991a) review. In most cases however, the reviews were sought by the project to seek guidance and an outside perspective as to appropriate "next steps." It should be remembered that most of these reviews were actually evaluating "work-in-progress." They focus on the status of ongoing work at a specific point in time to guide future emphasis and direction of the work and, by their very nature, tend to accentuate aspects of the work that need improvement. They have been very important to the WIPP project because they have consistently provided an understanding of deficiencies and contributed heavily in guiding the project's future direction and needs. The historical peer reviews provide an overall perspective of the evolution and growth of the project.

9.4.1 NAS WIPP Panel Reviews

The NRC (National Research Council) was established by the NAS in 1916. The Council operates in accordance with Academy general policies under the authority of the NAS congressional charter of 1863. The NRC has become a principal NAS operating agency for providing services to the government, the public, and the scientific and engineering communities.

In March 1978, the DOE requested the NRC:

"to review the scientific and technical criteria and guidelines for designing, constructing and operating a Waste Isolation Pilot Plant for isolating radioactive wastes from the biosphere."

The NRC assigned the study to the Committee on Radioactive Waste Management under the Commission on Natural Resources. The Committee organized the Panel on the WIPP to:

"review the scientific and technical adequacy of the site-suitability criteria; the guidelines for the site confirmation studies; the design criteria for the repository, including the waste acceptance criteria, the design philosophy, and the operational philosophy; the criteria for determining the environmental safety of future planned operations, viewed from the perspective of the environmental conditions of the repository site; and the design criteria for the experimental testing program of the behavior of the waste-geologic medium interaction."

Panel members are independent of the WIPP project and are nationally recognized experts in their respective disciplines. The panel was selected so as to provide an appropriate balance of relevant technical disciplines. The scope of the panel's expertise is very broad and includes environmental engineering, geology, geochemistry, nuclear science & technology, nuclear engineering, materials science and mining engineering. The panel regularly makes use of other members of the NRC Board of Radioactive Waste Management and/or consultants as necessary to provide additional expertise. The members of the initial panel were:

Frank L. Parker (Chairman), Vanderbilt University
Konrad B. Krauskopf (Vice Chairman), Stanford University
Merril Eisenbud, New York University Medical Center
Fred M. Ernsberger, PPG Industries, Inc.
Peter T. Flawn, University of Texas, Austin
Roger Kasperson, Clark University
Richard R. Parizek, Pennsylvania State University
Thomas H. Pigford, University of California, Berkeley
D'Arcy A. Shock, Consultant
Roger W. Staehle, University of Minnesota
John W. Winchester, Florida State University
John T. Holloway, NRC Senior Staff Officer

Changes to the membership of this panel have occurred over time. However, a continuity of WIPP knowledge has been maintained because of a significant overlap of members. The current panel members are:

Charles Fairhurst (Chairman), University of Minnesota
Howard Adler, Oxyrase, Incorporated
John O. Blomeke, Consultant
Sue B. Clark, University of Georgia
Rodney C. Ewing, University of New Mexico
Fred Ernsberger, Consultant
B. John Garrick, PLG, Incorporated
Leonard F. Konikow, U.S. Geological Survey
Konrad B. Krauskopf, Stanford University

Della Roy, Pennsylvania State University
David A. Waite, CH_2M Hill
Chris G. Whipple, ICF Kaiser Engineers, Inc.
Thomas A. Zordan, ICF Kaiser Engineers, Inc.
Darleane C. Hoffman, Lawrence Berkeley Laboratory (BRWM Liason)
Thomas Kiess, National Research Council Staff Officer
Angela Taylor, National Research Council Project Assistant

Since 1978, the WIPP Panel has produced several reports reflecting their ongoing review effort. An evaluation of the NAS reviews against the previously described screening criteria is provided in Table 9-8. Summaries of the review reports are provided in the following sections.

9.4.1.1 Letter Report of May 1, 1979

The panel reviewed the WIPP Draft Site Characterization Report (DSCR) (Powers et al. 1978) which was subsequently published as the Geological Characterization Report (GCR) (Appendix GCR). The DSCR is a compilation of the known geotechnical information about the proposed site and the surrounding region.

A copy of the NAS Letter Report is provided in Appendix PEER. The panel summarized its review findings in their report as follows:

> *"In summary, the Panel views the DSCR as a progress report on a continuing program of geotechnical data collection and analysis, conducted under the constraint of no perturbation of the potential site. The Panel considers the report to be useful as a compendium of the information available to the authors on the character of the unperturbed geological formation at the Los Medanos site and the dynamics of the geochemical/hydrological system. On the basis of this available information, further investigation of the site is warranted. However, final decisions regarding repository site selection must take into account more information than is contained in this report. Most importantly, they must take into account the effect of the emplacement of the waste and the waste itself on the repository and its surroundings. These decisions must be based also on supplementary data acquisition and analyses such as those suggested above; the additional studies delineated in the document itself; crucial in-situ studies conducted throughout the construction phase; and additional definition of design objective, criteria for safe operation, and waste forms to be accommodated."*

In response to the NAS report, a considerable amount of additional geotechnical information regarding the WIPP site has been developed. In particular, the geology and hydrology of the area have undergone continuing study since the inception of the project. Numerous evaluations and tests have expanded the project's knowledge of the site and the waste, and their potential interaction.

Table 9-8. NAS WIPP Panel Reviews

1. *Is the "peer review" relevant to the CCA?*	Yes - *The Panel has dealt with many* WIPP issues and most are directly relevant to the CCA.
2. Was there a formal report prepared by the reviewer?	Yes - There have been a series of formal reports.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A *technical review verifies compliance to* predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - Most of the reviews have addressed the adequacy of PA, site selection, etc. activities at WIPP.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The reviews have all evaluated the adequacy of work prepared by the WIPP project or others.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - Panel members are nationally recognized experts in their respective fields.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from *funding considerations to assure the work was* impartially reviewed?	Yes - The Panel was established by the National Research Council in the 1970's.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A - However, 40 CFR 194 (Supplementary Information re: §194.27) specifically indicates the NAS Panel reviews are appropriate for the CCA.

9.4.1.2 Letter Report of September 10, 1979

This report (see Appendix PEER) was prepared after the panel reviewed the findings of geological explorations through the following: briefings by SNL and the U.S. Geological Survey, study of both published and unpublished technical literature, site visits, examination of actual borehole cores and discussions with other experts in selected geotechnical areas. The panel recommended that *"an exploratory shaft be sunk at the site of one of the proposed access shafts to the depth of the proposed repository horizon"* and that *"drilling be done and tunnels developed in the salt as necessary to conduct the measurements and observations needed to resolve remaining site-specific geotechnical uncertainties and to ascertain the degree to which the site is suitable for the excavation of a repository."*

An exploratory shaft and tunnels were developed subsequent to this report. The information gained from this additional work was sufficient to allow the DOE to proceed with development of the WIPP repository and construction of supporting facilities.

9.4.1.3 Continuing Evaluation of the Carlsbad Site

This July 28, 1980 report (see Appendix PEER) reviewed the Carlsbad site in light of the President's decision to cancel the WIPP project. Two panel members, Drs. Cohen and Winchester, did not participate in the deliberations or the drafting of this report. The panel analyzed geological characterization efforts regarding the Carlsbad site, the WIPP Draft Environmental Impact Statement (DOE 1979), and defense waste characteristics. In its report, the panel concluded that:

> *"it is technically feasible to reorient the work on the Carlsbad site to fulfill the President's requirements for evaluation of this site, as one of several candidate sites, for later decisions regarding development of a licensed facility for defense and commercial high-level and transuranic wastes. If so reoriented, the project could contribute by:*
>
> - *providing prototype experience in site qualification;*
> - *testing, in situ, performance assumptions about the geologic medium; and*
> - *developing techniques and information which will be required in the licensing process.*
>
> *If given this new mission, work should proceed on constructing the exploratory shaft, acquiring hands-on repository mining experience, conducting in-situ tests and measurements at various depths, verifying engineering design assumptions, and developing analyses for licensing review."*

As indicated above, the DOE proceeded with site characterization and qualification, construction of an exploratory shaft and underground workings, and with in-situ testing.

Subsequently, development of the repository and construction of the above-ground facilities was initiated. Thermal tests to simulate defense high level waste were performed, but extensive evaluation for a spent fuel and high level waste repository were not conducted because the Congressional Authorization in 1980 restricted the WIPP to defense TRU wastes. Specific responses to the panel's concerns were provided in an August 18, 1989 letter from Mr. Leo Duffy to Dr. Peter Myers (Duffy 1989; Appendix PEER, Section PEER.10).

9.4.1.4 Review of the Criteria for the Site Suitability, Design, Construction, and Operation of the Proposed Waste Isolation Pilot Plant (WIPP); Progress Report: July 1, 1978, to December 31, 1979

This September 1981 report (see Appendix PEER) recounts the panel's findings through the end of 1979. Several major program documents had been issued and examined by the panel, including the GCR (Powers et al. 1978), the Title I Design Report (Bechtel 1979, 1980) and the Draft Environmental Impact Statement (DEIS) (DOE 1979). The report is based on analysis of these and other documents, numerous technical briefings, extensive discussions with representatives of DOE and its contractors, and several field visits.

The panel specifically addressed several topics during its review, including site selection criteria, design of underground facilities, acceptance criteria for TRU waste, environmental effects, in-situ tests and experiments, and natural resources at the WIPP site.

Regarding the issue of site selection criteria, the panel stated in its report:

> *"In summary, study of the WIPP site and its environs has shown that the criteria for site selection were in considerable measure satisfied; the Panel thinks probable site suitability has been demonstrated sufficiently to justify the sinking of an exploratory shaft without delay . . . ."*

Concerning the design of the underground facilities, the report recommends that a study be made to *"determine whether it is necessary to seal the excavations in such a way that their void space and permeability are very much less than is currently envisaged. Such a study is needed to show that the intrinsic properties of salt can be taken advantage of to effect safe isolation of radioactive waste by deep geologic disposal."*

Regarding waste acceptance criteria, the report discusses fire, gas generation, complexation, immobilization, package structure and solution rates. Specifically, the panel notes that the criteria primarily deal with operational aspects of the WIPP and that the only long term concern addressed is that of gas generation. The report stated that the inclusion of organic materials in WIPP wastes raises questions about fire in the short term and about gas generation and formation of organic complexes with radioactive materials in the long term.

The panel determined that a sequence of confirmatory underground in-situ tests and experiments would be needed after completion of extensive laboratory and field investigations and analyses. This testing would help resolve geotechnical uncertainties, evaluate the physical characteristics of the host media, corroborate the design of the repository, demonstrate the viability and effectiveness of underground techniques such as backfilling, and obtain measurements of initial rock response to excavation and waste emplacement. The panel noted concerns with regard to existing test plans.

Finally, the report discusses the impact of natural resources at the WIPP site. The panel concluded that the DEIS value provided for hydrocarbon resources were "greatly underestimated" and recommended updating the estimates. The panel determined that for potash resources however, the DEIS analysis appears "to provide adequate baseline information." The panel also concluded that the DEIS scenarios regarding the threat to the repository due to future exploration and exploitation of natural resources may fail to bound the maximum credible event. The panel states that *"(e)ither solution mining for table salt 100 years after closure of a high-level waste repository or mining of radioactive materials themselves, whether purposeful or not, could produce consequences greater than those indicated in the worst-case analysis"* of the DEIS and concluded that the significance of these factors should be carefully evaluated.

As noted in the report's preface, the WIPP project experienced major changes in direction and scope following the period covered by this report. The report notes that *"(m)any of the technical deficiencies that were perceived to exist at the end of 1979 have since been remedied by additional investigations and design changes."* The effects of these changes were considered by the panel as it continued its review of the criteria for site suitability, design, construction and operation of the WIPP. An interim report of the continuing review was developed in 1983 (see Section 9.4.1.5 below). The panel subsequently completed the review and provided its conclusions in 1984 (see Section 9.4.1.6 below).

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9.4.1.5 <u>Review of the Criteria for the Site Suitability, Design, Construction, and Operation of the Proposed Waste Isolation Pilot Plant (WIPP); Interim Report: July 1, 1978 to July 31, 1982</u>

This 1983 report (see Appendix PEER) updates the panel's review of WIPP and recounts the panel's findings through the end of July 1982. During this period several major project documents had been issued by the DOE, including the GCR (Powers et al. 1978), the Title I Design Report (Bechtel 1979, 1980), the FEIS (DOE 1980a) and the Safety Analysis Report (DOE 1980b). The panel report is based on analysis of the contents of these and other documents, numerous technical briefings, extensive discussions with representatives of DOE and its contractors, comments by interested members of the public, and several WIPP visits. The panel composition was the same as noted above, except that Drs. Eisenbud, Flawn, James, Kasperson, Pigford, and Staehle did not participate.

The recommendations from the report that are relevant to this application were as follows:

- Evaluate the practical effects of resource extraction in Zone IV to assess whether such extraction poses significant threat to the safety and integrity of the repository.

- Implement plans for further field and analytical work to test the extent of deep strata-bound dissolution.

- Locate one or both of the remaining hydrologic test holes planned to be drilled in 1983 in lineaments or fracture traces if such features are revealed on satellite images or high altitude areal photographs. Test holes so located will help determine fracture concentrations.

- Keep the WIPP R&D program flexible to accommodate changes suggested by early WIPP results or other waste disposal technologies by other organizations.

- Supplement the tests on waste form, package, overpack, and backfill with above-ground laboratory tests.

- Measure the humidity of still air in equilibrium with the salt and the pH of the salt at the storage horizon (significant for evaluation of biological and chemical degradation processes).

- If relative humidity of the sealed enclosure at the repository is 60 percent or less, drop restrictions on permissible mass of organic materials per unit volume of waste from the gas generation criteria.

- If the humidity of the air is higher than 60 percent, evaluate the metabolic prospects for particular classes of microorganisms that might contribute to gas generation in the expected repository environment.

- Provide state-of-the-art equipment at the WIPP facility for nondestructive verification of compliance of the waste acceptance criteria.

- Define the waste acceptance criteria for the defense high-level waste to be used in the experimental program.

- Establish explicit mechanisms for the transfer of information from experiments and information gathered during construction and development to final design.

- Determine if displacement of salt in the far field occurring as a result of long-term closure of excavations significantly increases the permeability of the bulk of the salt.

- Determine if sealing the repository is sufficient to preclude unacceptable increases in hydrologic conductivity across the repository horizon.

- Continue hydrologic investigations and monitoring programs to resolve interpretations of potentiometric maps and to determine the rates and directions of groundwater flow within Rustler aquifers above and immediately adjacent to the site.

- Delineate the karst-type flow in the Rustler aquifer near Nash Draw.

Consequences of natural resources in Zone IV and the decision to relinquish Zone IV as a buffer zone are detailed in the Natural Resources Study (Brausch et al. 1982). Additional hydrologic exploration holes were drilled in the site area to evaluate issues such as deep-seated evaporite dissolution. Transmissivity within the Culebra has since been evaluated through multipad interference testing. The DOE has continued to resist verification of waste acceptance criteria compliance at the WIPP site because of increased risk to workers. Laboratory testing continued to address proposed backfill material properties and effectiveness. The relative humidity at the WIPP was determined to be greater than 60 percent. Additional WIPP evaluations concluded that karstic flow exists within Nash Draw but that it does not affect the Rustler dolomites that dominate flow in the site area. Defense high-level waste experimentation was deleted from the project in 1988.

A considerable amount of further testing and evaluation occurred at the WIPP after this report was written. The DOE provided formal responses on August 18, 1989 to the NAS recommendations. The panel subsequently completed this review and provided its conclusions in 1984 (see Section 9.4.1.6 below).

9.4.1.6 Review of the Scientific and Technical Criteria for the Waste Isolation Pilot Plant (WIPP)

This 1984 report (see Appendix PEER, Section PEER.9.6) updates the panel's review of the WIPP and recounts the panel's findings through December 31, 1983. The report is based on analysis of the contents of documents issued to that date, technical briefings, discussions with representatives of the DOE and its contractors, comments by interested members of the public, and a number of field visits. The panel members involved in this review were the same as those noted in Section 9.4.1.5 above.

Several recommendations, in addition to those provided in 1983 (see Section 9.4.1.5), were provided by the panel. The new recommendations from the report, which are relevant to this application, are presented below.

- Redesign certification procedures to simulate those used commercially in the purchasing of commodities.

- Consider relaxing the waste acceptance criterion relating to gas generation due to bacterial action.

- Use models to assess whether closure of the excavations and consequent encapsulation of the waste in salt are likely to occur, and to determine the period of time within which they may occur.

- The FSEIS (DOE 1990a) should be reissued to correspond with the present design.

- Calculate all dosages on the same basis (that is, if recommendations of ICRP-26 and ICRP-30 were used, rather than those of ICRP-2).

A considerable amount of additional laboratory and in-situ testing and analysis have occurred. An FSEIS (DOE 1990 in the Bibliography) was issued in January 1990 to update the information in the FEIS and an additional resource evaluation was conducted by the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) in 1995 (NMBMMR 1995 in the Bibliography). Waste acceptance criteria continued to evolve based on further testing and analysis. The FSEIS (DOE 1990), a RCRA permit application, and formal performance assessment documents (Bertram-Howery et al. 1990 in the Bibliography, and subsequent reports) have provided significant additional analyses of potential accidents, environmental effects, and long-term performance of the repository. A disposal phase SEIS (SEIS-II) is currently being developed.

9.4.1.7 Letter Report of April 1987 on Planned Sorbing-Tracer Field Tests

The WIPP panel considered the sorbing-tracer field test planned at WIPP and provided their comments in April 1987 (see Appendix PEER). The purpose of the planned test was to develop data regarding the K_d (distribution coefficient) values for predicting retardation of radionuclide movement in the Culebra aquifer. The test plans were described to the panel at its February 1986 and September 1986 meetings.

The panel was divided in its opinion as to whether the tests would yield useful results but agreed that the tests should be carried out because of WIPP commitments to the state of New Mexico and the desirability of obtaining *in-situ* K_d values. The panel's Letter Report provided the following six recommendations regarding the tests:

1. Calculate the probable rate of release to the accessible environment of the important radionuclides in TRU waste on the assumption of no retardation due to sorption.

2. Select drillholes for injection and recovery for which the history since drilling is well known, particularly with respect to the composition of the drilling fluid and any other fluid that has been subsequently added.

3. Recommend additional research in the study of Culebra hydrology in different parts of the WIPP site and autoradiographic study of Culebra specimens to determine what phases are active sorbents for TRU elements.

4. The panel strongly urges the use of radionuclides rather than analog elements as sorbing-tracers.

5. Conduct tests at more than one hydropad to obtain a statistically significant result and to give some sense of the possible variability of the geochemistry and characteristics of groundwater flow in the Culebra aquifer.

6. Conduct laboratory tests for determination of K_d, using chunks of dolomite from drill cores with their surfaces and fractures kept in a state as close as possible to natural conditions.

The DOE provided a formal response to the panel's recommendations on August 18, 1989 (see Appendix PEER). The recommended calculations were performed and documented in SAND87-7105 (Reeves et al. 1987) and estimates of additional properties were provided in SAND89-0462 (Lappin et al. 1989). The sorbing-tracer test itself was canceled because it was concluded that mechanistic understanding could be better gained by a combination of laboratory experiments and additional hydrologic work. Agreements were reached with the state of New Mexico to conduct laboratory and hydrological studies, including a multipad interference test. The DOE position on a sorbing-tracer test is that it would be conducted only if the above studies and performance assessment calculations indicated it was necessary to reduce uncertainties. To date, the DOE believes this test is not necessary.

9.4.1.8 Report of March 3, 1988 on Brine Accumulation in the WIPP Facility

The following discussion of the issue is summarized and/or excerpted from the subject report (see Appendix PEER).

When the underground WIPP repository has been sealed, the surrounding salt is expected to move by plastic flow into repository openings and ultimately to lock the waste in a solid mass of crystalline salt. In addition, brine is expected to accumulate slowly in these openings. The amount of brine accumulation is uncertain and different estimates of the amount have been proposed.

A group of local scientists, primarily composed of staff from the University of New Mexico, suggested that the amount of brine accumulation in the repository:

> *"may be large enough to entrain both backfill and waste in a mobile radioactive "slurry." Such a fluid would prevent consolidation of the salt and might move to the surface to release radioactive material in quantities exceeding EPA standards."*

Scientists at the SNL believed that the amount of brine accumulation will be small, and calculations indicated that it will be absorbed by the backfill material to be placed in the rooms and tunnels. Therefore, SNL staff concluded that:

> *"no interference is expected on the basis of preliminary observations with the plastic flow of salt into disposal rooms and around the waste packages."*

The NAS was asked to express an opinion as to how well existing data resolve these conflicting viewpoints. In response to the request, a review panel composed of members of the NAS Board on Radioactive Waste Management and the WIPP panel, supplemented by outside experts was established. The panel consisted of Drs. Parker, Krauskopf, Cohen, Ernsberger, and Shock from the WIPP panel in addition to the following individuals:

Samuel Basham, Battelle Memorial Institute
John O. Blomeke, Oak Ridge National Laboratory
John D. Bredehoeft, U.S. Geological Survey
E. William Colglazier, University of Tennessee
Rodney C. Ewing, University of New Mexico
Charles Fairhurst, University of Minnesota
John W. Healy, Consultant
George M. Hornberger, University of Virginia
Leonard Konikow, U.S. Geological Survey
William R. Muehlberger, University of Texas, Austin
Irwin Remson, Stanford University
Christopher G. Whipple, Electric Power Research Institute

These members provided additional expertise in engineering, civilian waste program, chemical engineering, hydrology, risk analysis, local and regional geology, rock mechanics, health physics, geochemistry, and energy economics. Dr. Krauskopf chaired the augmented panel during this review. The panel reviewed pertinent documents and convened a special meeting at which local scientists and representatives of SNL and the Environmental Evaluation Group (EEG) presented their views. The panel was assisted in its review by several members of the three invited consultants. The panel's report was presented to, and discussed with, the New Mexico Congressional delegation on March 3, 1988.

The panel concluded in its report that

> *"from its study of currently available evidence that the formation of an abundant mobile fluid in a repository at the WIPP site, as postulated by [the group of scientists], is very improbable."*

However, the panel recommended the following actions:

- Establish a comprehensive, systematic experimental program to reduce remaining uncertainties and to support a conservative performance assessment.

- Better define the planned experimental program for a 5-year period.

- Only when the experimental work has substantially reduced the uncertainties about brine accumulation should additional waste containers, other than those required by the experiments, be emplaced.

- Experiments should be designed to lessen uncertainties, not to verify preconceived ideas about probable results.

- Continually refine performance assessment calculations as experimental results are obtained to test the confidence of achieving compliance with EPA standards.

- Develop multiphase models (gas + liquid + solid) to describe the behavior of complex fluids that may form as brine enters the repository and gas is generated from the waste.

- Investigate the feasibility of possible technical "fixes" if the problem of fluids in the repository is determined by the recommended experiments to be serious.

The DOE provided specific responses to the foregoing recommendations on August 18, 1989 (see Appendix PEER). The performance assessment process is iterative and as new experimental results were acquired, the impacts on compliance with the EPA standards were reassessed. For example, as estimates were made of the impacts of brine inflow, additional in-situ permeability measurements were made and models of brine inflow were improved. The WIPP Performance Assessment efforts refocussed the experimental program to supply the needs of the performance assessment program. A management plan (Bertram-Howery and Hunter 1989) describing the performance assessment program was provided to the NAS in 1989.

9.4.1.9 Letter Report of December 1988 on Experiments of Room Closure Rates

The DOE requested the panel to review the data collected on room closure rates from laboratory tests and in-situ experiments. Measurements in underground test rooms at the WIPP site indicated room closure rates three to six times greater than the rate predicted by numerical computational codes used to model the deformational behavior of the rooms and associated pillars. The codes incorporate mechanical properties for the salt around the rooms identical to the properties derived from deformation behavior observed in laboratory creep tests on small core samples taken from the WIPP site.

The December 1988 report (see Appendix PEER) provides the panel's suggested design for an intermediate-scale experiment to better define the sources of the discrepancy between the predicted and observed salt creep rates. The panel recommended that a few (two to five) in-situ tests be conducted to observe closure rates around horizontal, circular excavations intermediate in scale (that is, 1 meter or so in diameter) between the above mentioned field and laboratory tests.

The Intermediate Scale Borehole Test was conducted to address the possible "scale-effect" between laboratory and large underground tests. The Intermediate Scale Borehole Test consisted of a 0.91-meter-diameter hole core-drilled completely through an existing 18-meter-thick pillar between two large rooms (which had been constructed about 6.7 years earlier). The hole was situated so that the pillar was essentially composed of pure salt. Closure gauges were used to provide hole deformation and creep rate data.

The Brine Inflow Test (Room Q), a 107-meter-long room with a 2.9-meter-diameter, also provided creep data on a different (cylindrical) room scale geometry. A multimechanism constitutive model of salt deformation was developed which incorporated both steady state and transient creep. Results indicated the model is scale- and shape-independent and behavior can be predicted accurately from first principles within the current model.

9.4.1.10 Review Comments on DOE Document DOE/WIPP 89-011: Draft Plan for the Waste Isolation Pilot Plant Test Phase: Performance Assessment and Operations Demonstration

This July 19, 1989 report (see Appendix PEER) documents the WIPP panel's review of the subject document. A panel meeting was convened on June 6-8 at which DOE staff and its contractors made presentations and answered questions.

The panel members attending the meeting included Drs. Fairhurst, Blomeke, Bredehoeft, Cohen, Ernsberger, Ewing, Shock, Hornberger, and Whipple as noted above, plus the following consultants with expertise in risk assessment and transportation:

B. John Garrick, Garrick, Pickard and Lowe

Sherwood Chu, MRS Commission

Dr. Fairhurst served as chairman for the panel meeting. The recommendations and conclusions made by the panel in its report were as follows:

- Develop and publish within the next six months a short, integrated, overall systematic assessment of long-term safety of the WIPP repository.

- Define the combined effects of gas generation, room closure and sealing, brine inflow, and other effects on the potential for long-term build-up of gases in the repository to lithostatic pressure, with respect to the long-term isolation capability of the WIPP repository.

- Examine options for modifications to the waste as part of the resolution of the gas generation issue.

- The panel agrees that the bin-scale and room-scale experiments, involving approximately 0.5 percent by volume of the capacity of the WIPP, are warranted and should begin without delay.

- Collect and study data from laboratory tests (including tests at high ambient pressures), information from studies on gas generation from waste packages now stored at various sites, information on experience abroad, and engineering modifications to address the gas generation issue.

- The test plan should discuss the risks associated with transportation of TRU waste to the WIPP, relative to the transportation of other hazardous materials.

- Delay the demonstration of operational readiness until several important issues concerning underground emplacement of waste for permanent isolation at the WIPP have been resolved.

This report was updated by a subsequent letter report, dated April 1991, which is discussed below (see Section 9.4.1.11). The April 1991 report also summarizes the DOE responses to the recommendations in this 1989 report and the NAS reaction to those responses.

9.4.1.11 Letter Report of April 1991, Summary of Recommendations

This April 1991 report (see Appendix PEER) summarizes the views of the WIPP panel on the status of the DOE program to assess the WIPP's ability to isolate TRU waste and to demonstrate compliance with relevant regulations. This report reviewed the progress made in the WIPP program since the 1989 report, summarized the responses made by the DOE to the earlier recommendations, provided an overview of the panel's views on the overall safety of the WIPP facility, and presented some new recommendations to address unresolved issues. The panel members included Drs. Fairhurst, Blomeke, Bredehoeft, Ernsberger, Ewing, Garrick, Konikow, and Whipple. Dr. Fairhurst served as chairman for the panel during this review. Two additional experts served on the panel during this review:

Howard Adler, ORAU Medical Sciences Division
Jeremiah O'Driscoll, Jody Incorporated

The specific recommendations made by the WIPP panel in its report were as follows:

- Continue detailed study of the effects of human intrusion on repository performance.

- Apply performance assessment procedures to the alternatives identified by the Engineered Alternatives Task Force to assess the merits of engineered modification of the waste form and/or the repository to address the issues of gas generation and human intrusion.

- Use performance assessment analysis for the long-term extrapolation of the repository behavior.

- Assess the various engineered alternatives in terms of total system risk; including worker exposure, transportation and other risks, to evaluate the impacts on the entire TRU waste management system.

- Develop a well-designed experimental program and schedule that are sufficiently flexible to permit performance assessment analysis of important scientific and technical issues.

- Determine whether reliable conservative estimates of field retardation coefficients can be developed for use in performance assessment. If retardation is essential for adequate isolation of untreated TRU waste under the human intrusion scenario, such studies could be crucial before a decision is made on the required level of waste treatment.

- Continue the full-scale Room Q experiments with minimal interruption, together with intermediate-scale (900-mm-diameter) borehole inflow tests, since these experiments may provide conclusive evidence concerning the permeability of the repository salt to resolve the brine inflow question. DOE should consider constructing another full-scale room for additional brine inflow studies, using the improved instrumentation, seals, and excavation equipment now available at the WIPP site.

- The panel is concerned that the bin experiments, which are designed to provide information about gas generation, are of such large scale and complexity that they might not yield significant gas generation data within an acceptable time frame. The DOE should ensure that the effort and the resources devoted to the bin experiments do not impede other important experiments that may help to reduce significantly uncertainties in the assessment of repository performance.

- The DOE should actively support vigorous international discussion of scientific and technical issues affecting repository safety, including gas generation. In addition, the DOE should encourage critical review of the WIPP program through broader publication of its research findings in referred scientific journals.

As indicated above, the underground bin and alcove tests have been canceled. Smaller scale tests, replacing the bin experiments, are being conducted at LANL and INEL using actual TRU waste. Other recommendations have been incorporated into the WIPP project. In particular, see Section 9.5 for a discussion of ongoing international review and cooperation.

9.4.1.12 Letter Report of June 1992

This June 1992 report (see Appendix PEER) addressed the experimental plan for the WIPP and was based principally on a review of various documents submitted to the panel and presentations by the DOE and its contractors before the panel over the preceding three years.

In addition to Drs. Fairhurst, Adler, Blomeke, Bredehoeft, Ernsberger, Ewing, Garrick, Konikow, O'Driscoll, and Whipple, the panel was composed of:

Ina B. Alterman, National Research Council Staff Officer
Ricky A. Payne, National Research Council Project Assistant

Dr. Fairhurst served as chairman for the panel. The panel reaffirmed its position that performance assessment is the appropriate basis for setting priorities in the research and testing program for the WIPP. The report states that it believed DOE is "making excellent progress with its ongoing performance assessment efforts." Several proposed studies are specifically considered by the panel and comments are provided. The "Major Conclusions" section of the panel report is provided below.

Current performance assessment (PA) studies by the Department of Energy (DOE) indicate a high probability that the Waste Isolation Pilot Plant (WIPP) would perform successfully as a transuranic (TRU) waste repository. For some time, however, the panel has been concerned that questions identified as most critical by PA, particularly solubility and retardation, were not being given adequate or timely attention. The highest priority should now be given to conducting those tests that can determine the validity of the critical

> *assumptions used in the PA calculations, especially the recently initiated solubility and dual porosity flow studies, and the proposed investigations on retardation in the Culebra.*
>
> *The February 1992 DOE/WIPP report is a clear statement of the 15 critical information needs and associated experiments necessary to assess the long-term performance of the repository. However, the report fails to indicate how the results of the experimental program at all scales (laboratory, bin, alcove, and field tests) will be integrated to assess the long-term performance of the repository. DOE needs to articulate a convincing scientific rationale for the proposed test program in terms of the performance of WIPP as a TRU repository.*
>
> *The panel has not been convinced by the scientific rationale, as presented, for the underground gas generation tests. In particular, the plan to conduct a large number of expensive bin tests and to terminate the experiments after five years has no discernible scientific basis. The possibility that the underground bin tests, as currently planned without brine sampling, will contribute to advances in the understanding of the overall long-term performance of a repository at WIPP is small.*

As previously indicated, the bin and alcove tests have been deleted from the project. However, the necessary input to WIPP performance is based on determination of required process parameters and their use in a disposal room model. Real waste tests supplement this information and are used to verify model predictions.

An additional report is expected from the NAS WIPP panel during October 1996.

9.4.2 Performance Assessment Peer Review Panel

The Performance Assessment Peer Review Panel (PAPRP) was established in 1987 as a standing group under contract to the WIPP Performance Assessment Department at SNL. The PAPRP charter states that the purpose for establishment of the panel was as follows:

> *"An external Peer Review Panel has been established for significant PA documentation so that the DOE can be assured that the performance evaluation is well-conceived and being carried out with professional competence, and so that scientists and state officials can be assured that the DOE's conclusions as to the suitability of the WIPP as a repository are credible."*

An evaluation of the PAPRP reviews against the screening criteria is provided in Table 9-9. Panel members were selected on the basis of their professional stature within the university, scientific and/or engineering communities. The PAPRP membership provides expertise in environmental research, geology, nuclear engineering, hydrogeology and public policy

Table 9-9. Performance Assessment Peer Review Panel

1. Is the "peer review" relevant to the CCA?	Yes - The PAPRP evaluates SNL PA efforts.
2. Was there a formal report prepared by the reviewer?	Yes - Formal reports are developed.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The PAPRP reviews the adequacy of the SNL performance assessment activities.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The PAPRP performs documented, in-depth, critical evaluations of PA reports and other documentation, addressing validity of basic assumptions, alternative approaches, methodology, uncertainty, supportability of conclusions, and consequences of incorrect assumptions or conclusions.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - All members of the PAPRP are recognized experts in their fields.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - The PAPRP operates as a independent group under contract to the SNL PA Department. Uncensored comments by the panel are maintained in the SWCF.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

development. Members were chosen explicitly for their independence from performance assessment work undertaken by SNL. Panel members are

G. Ross Heath (Chairman), University of Washington
Robert J. Budnitz, Future Resources Associates, Inc., Berkeley, California
Thomas A. Cotton, JK Research Associates, Inc., Washington, D.C.
Peter A. Domenico, Texas A&M University (Until 1990)
C. John Mann, University of Illinois, Urbana
Thomas H. Pigford, University of California, Berkeley
Frank W. Schwartz, Ohio State University (Since 1990)

The PAPRP chairman is responsible for ensuring that members do not have a conflict of interest. If an apparent or potential conflict of interest exists, the chairman and the SNL Performance Assessment program manager will determine if a conflict does exist and how to resolve it.

Panel members are requested to address the following areas, as applicable, for each review:

1. Validity of basic assumptions and extrapolations,
2. Alternative interpretations or approaches,
3. Appropriateness, logic and limitations of methodology,
4. Uncertainty of results,
5. Supportability of the conclusions drawn,
6. Consequences of incorrect assumptions or conclusions, and
7. Other issues appropriate to the review subject.

Whenever possible, following its review of a particular issue, the PAPRP meets with the SNL staff member who is the task leader for the work being reviewed, the author(s) of the material under review, and other performance assessment participants for a workshop to discuss the comments. The PAPRP chairman leads the discussion of comments. Conclusions regarding each issue discussed are recorded in the workshop proceedings. Uncensored comments by the panel are maintained in the SWCF. The performance assessment task leader for the document being reviewed is responsible for obtaining responses from the document authors for all comments identified by the PAPRP as mandatory.

The panel chairman and the peer panel task leader (the SNL staff member assigned to work with the PAPRP) prepare a review report. The report contains all panel review comments and recommendations, including the panel member's rationale and references. Each comment is identified as mandatory or non-mandatory by the PAPRP member. A statement of potential impact is also presented if the results of the review are considered to have a significant impact on schedules. The final report also includes the panel announcement memorandum, the workshop minutes, and a cover page identifying the panel and approval signatures of panel members. The panel meets as needed (more than 20 times since inception) to discuss issues and review performance assessment documentation. The major issues (and their resolution) raised by the PAPRP during its review of performance assessment documentation since 1987 are provided below as summarized in (Trauth 1995; see Appendix PEER, Section PEER.11).

"Issue 1: Need to display confidence bounds around the mean CCDF.

Resolution: Beginning in 1990, the WIPP PA has used a methodology that allows for construction of a family of CCDFs from which both a mean curve and selected percentile curves can be derived. This methodology is first discussed in detail in the 1990 PA, and is further discussed in Volumes 1 and 2 of the 1991 PA and Volume 2 of the 1992 PA. References for additional publications can be found in Volume 2 of the 1992 PA. Note that all CCDFs presented in WIPP PAs are conditional on the modeling and data assumptions used in the analyses.

Issue 2: Question on how best to construct scenarios from the events and processes that remain following the screening process.

Resolution: Since 1988, the WIPP PA has used a "logic diagram" procedure to construct all possible combinations of events. This procedure differs from the "event tree" approach used in reactor safety assessments and in earlier WIPP PAs in that order of occurrence is not considered, and a smaller number of scenarios can be considered while maintaining comprehensiveness. Documentation of this technique is available in the 1990 PA, in Volume 1 of the 1991 PA, in SAND89-7149, and in SAND90-1429.

Issue 3: Need to provide automated data flow between subsystem level computational models within the PA. This issue was raised internally and by the PAPRP in 1988 and 1989 as being the most computationally efficient approach as well as essential for QA.

Resolution: The PA Department began development of software in 1988 to automate linkages between major codes. See Appendix CODELINK for a discussion of the current implementation.

Issue 4: Need to provide a means to estimate the probability of human intrusion and to quantify the effectiveness of potential passive marker systems, other than by ad-hoc estimates of fixed probabilities. This issue is based on interpretations of regulatory guidance, and was raised internally by the PAPRP in 1990.

Resolution: Beginning in the 1990 PA, a Poisson model for intrusion probability (intrusions are random in time, with a maximum expected value equal to the EPA guidance of 30/km/10,000 yr), was substituted for previous ad hoc estimates of probability. Expert panels were convened to consider future societies and the degree to which passive markers would be effective in communicating with them. Results of the expert judgment were used in the 1992

PA. Documentation of the Poisson model is available in Volume 2 of the 1991 and 1992 PAs, and in references provided therein. The algorithm for deriving drilling rates from the expert judgment is described in a memorandum by Hora in Appendix A of Volume 3 of the 1992 PA.

Issue 5: Need to include effects of gas generation and 2-phase flow in PA modeling.

Resolution: PA developed the capability to model 2-phase flow in human intrusion scenarios in the fall of 1990, using the BRAGFLO code developed in-house. Gas generation reactions and their dependency on reactant (i.e., brine, iron, and cellulosic waste) availability were included in the code. Technical complexities related to the short time steps required to model rapid pressure drops during intrusion precluded the use of other 2-phase flow codes prior to the development of BRAGFLO. The use of BRAGFLO is first documented in the 1990 PA, and subsequently described in Volume 2 of the 1991 and 1992 PAs, as well as in Volume 4 of the 1992 PA and in SAND92-1933.

Issue 6: Need to display uncertainty in performance estimates resulting from alternative conceptual models for waste form properties and radionuclide transport in the Culebra.

Resolution: Beginning in 1990, the PA Department examined conceptual model uncertainty by performing ceteris paribus Monte Carlo analyses, in which vectors of input values were the same for each conceptual model except for the parameters used to describe the specific model change. This technique allows direct comparison of probabilistic outcomes from system-level models using alternative conceptual models for those cases in which the alternative models can be described by parameter variations within the existing conceptual models. For example, potential effects of waste-form modification were examined by repeating the Monte Carlo analyses using various fixed values for radionuclide solubility and waste-form porosity and hydraulic conductivity. Dual- and single-porosity transport models for the Culebra were compared by repeating dual-porosity simulations with matrix porosity set to zero.

Issue 7: Need to couple creep closure process with gas generation and 2-phase flow.

Resolution: The 1992 PA included the effects of creep closure for the first time. Computational complexity prevented a full coupling of the mechanistic creep model SANCHO with the 2-phase flow code BRAGFLO, and instead SANCHO output, in the form of waste/backfill porosity as a function of moles of gas generated, was used to define time and pressure-dependent waste/backfill porosity in BRAGFLO calculations. See Volume 4 of the 1992 PA for additional information.

Issue 8: Need to include effects of pressure-dependent fracturing of anhydrite interbeds in the Salado Formation.

Resolution: Beginning in the fall of 1993, PA calculations have used an approximation of pressure-dependent fracturing in which porosity and permeability of the anhydrite interbeds are varied as a function of pressure at pressures close to lithostatic. Additional data are needed to evaluate the adequacy of this approximation (or to develop another) and to justify the parameter distributions used.

Issue 9: Need to reexamine the event and process screening procedure used in scenario construction. The PAPRP and other reviewers have noted since 1991 that some of the evidence used in screening is out of date, some is incomplete, and some events have never been adequately analyzed.

Resolution: The PA Department has undertaken a major effort in reviewing the screening of features, events, and processes (FEPs) for inclusion in scenarios, some of which involves sample calculations. Supporting documentation for those FEPs screened from consideration on regulatory grounds (specifically excluded from consideration by 40 CFR Part 191 or its supporting documentation, or excluded because of low probability or low consequence as per 40 CFR Part 191) and technical ground are being developed, and will be maintained in the Sandia WIPP Central Files.

Issue 10: Need to confirm adequacy of two-dimensional modeling in the repository environment (BRAGFLO) and the Culebra (SECO) with three-dimensional modeling.

Resolution: The PA Department is addressing these two questions through the FEPs effort. FEP S1 "Verification of 2D-radial flaring using 3D geometry [room to room processes]" is being addressed by comparing 2D BRAGFLO calculations against 3D TOUGH28W and 3D BRAGFLO calculations, based on the same physical representation (i.e., model) of the WIPP site. TOUGH28W is a version of TOUGH2 with WIPP-specific features such as creep closure and pressure-induced anhydrite fracturing.

FEP NS9 "Justification of SECO 2D approximations" addresses the SECO issue and the current rationale and justification are documented in a Summary Memo of Record written by T. Corbet. This memo summarizes the use of three-dimensional simulations to evaluate the amount of flow across the upper and lower surfaces of the Culebra.

Issue 11: After reviewing the 1990 and 1991 PAs, the PAPRP requested a more complete and accessible presentation of the data used in the PA calculations.

Resolution: Volume 3 of the 1991 PA contains a first attempt at providing data tables. Further improvements were made for Volume 3 of the 1992 PA which contains data tables that include the new categories of "correlation," usage" (in mathematical and computational models) and "ranking in past sensitivity analyses."

9.4.3 Shaft Seal Design Independent Review

A review plan, titled Shaft Seal System Design for the Waste Isolation Pilot Plant (WIPP), was developed and approved on January 12, 1996 (Hansen 1996). The review plan governed the preliminary and final reviews of the WIPP shaft seal system.

Members of the review panel were selected on the basis of their respective knowledge, experience and independence from the WIPP shaft seal design effort. The group had expertise in computational geomechanics, rock mechanics, mining engineering, civil engineering, and the design and construction of underground seals and bulkheads. The panel for both the preliminary and final reviews consisted of a review team chairman and three reviewers:

R.E. Stinebaugh (Chairman), SNL
Dr. Malcolm Gray, Atomic Energy of Canada Limited Whiteshell Laboratories
Stephen Phillips, Phillips Mining
Dr. John Tinucci, Itasca Consulting Group

A evaluation of the shaft seal design reviews against the screening criteria used to determine whether this review should be addressed in this application is presented in Table 9-10. While it might appear that the independence of the review could be questioned because of Mr. Stinebaugh's affiliation with SNL, Mr. Stinebaugh's organizational independence from the WIPP project, and his actual role in the review process, established and preserved the independence of the review. Mr. Stinebaugh is a member of Organization 2165, which has no responsibility for the WIPP program. In his role as chairman, Mr. Stinebaugh served as a manager and facilitator for the review and coordinated the preparation of the final report. He was not a reviewer and did not prepare formal comments or a summary statement regarding the design of the shaft seal system as did the three reviewers, Drs. Gray and Tinucci and Mr. Phillips.

Shaft seal design activities were conducted under an approved quality assurance program. The review was conducted in accordance with the requirements of SNL QAP 3-2, entitled Verification of Design Adequacy, approved 7/31/95 (Quality Assurance Department 1995), and the provisions of the review plan. Panel members were trained in accordance with the provisions of QAP 3-2 prior to beginning the design review. A member of the SNL quality assurance staff (Organization 6860) briefed the panel at the onset of the review, monitored the review as it progressed, and inspected record-keeping activities. Records of panel training and other QA records concerning this review were maintained in accordance with SNL QA program requirements.

Table 9-10. Shaft Seal System Design Review

1. Is the "peer review" relevant to the CCA?	Yes - The seal system is directly relevant to PA.
2. Was there a formal report prepared by the reviewer?	Yes - The title of the report is "Final WIPP Shaft Seal System Design Review."
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The review focussed on the adequacy of the shaft seal system that was developed by SNL National Laboratories.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The review evaluated the adequacy of the work of others (the design of the shaft seal system).
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - The reviewers were specifically chosen because of their expertise in seal design and related disciplines.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - It may appear that the independence could be questioned because of the chairman's affiliation with SNL. However, his organizational independence from the WIPP project and his actual role in the review process (see text of Section 9.4.3 for additional discussion) preserved the independence of the review.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

In both reviews, the panel was asked to address the following questions:

1. Will the shaft seal system satisfy design guidance?

2. Are there elements of the design which will prevent the sealing system from meeting design requirements?

3. Can the design be successfully implemented?

A short summary of each of the reviews is provided below.

Review of the Preliminary Shaft Seal Design

The preliminary design review considered the adequacy of design concepts summarized in the report entitled Waste Isolation Pilot Plant Sealing System Design Report (DOE 1995d). The report includes descriptions of the WIPP setting, design guidance derived from the regulations, a description of the design, materials comprising the seal components, and preliminary evaluations of the shaft seal system.

The review of the Sealing System Design Report was initiated in January 1996 and completed in March 1996. Following their review of the Sealing System Design Report, Dr. Gray, Dr. Tinucci and Mr. Phillips prepared detailed comments. These comments were forwarded to the appropriate design staff and formal responses were prepared. The reviewers evaluated the responses and determined their responsiveness to the concern.

Subsequent to resolution of outstanding issues, the updated information was used to amend the documentation provided to the review panel for its final review (discussed below). At the conclusion of the final review, all of the reviewers, without exception, stated that the actions promised in the responses to the preliminary review comments had been completed.

Review of the Final Shaft Seal System Design

During April 1996, the panel was convened to review the Compliance Submittal Design package for the WIPP shaft sealing system (SNL WIPP Central File records package WPO: 36546). Panel input was subsequently incorporated into the final Compliance Submittal Design report (Repository Isolation Systems Department 1996). The review was based on documentation provided by SNL and briefings by the WIPP technical staff. The documentation included an enhanced annotated outline for the compliance shaft seal design report, detailed drawings, a material specifications framework, and topical summaries of structural and fluid flow calculations. Briefings provided the panel with additional information covering the design, laboratory and in-situ experimentation results, and analyses that were completed.

Following completion of the review, each panel member prepared specific comments regarding the design (see Appendix PEER). The WIPP staff prepared specific responses to the comments and met with the reviewers to resolve them. In some instances, the WIPP staff, in response to the reviewer comments, promised to make certain changes or additions to the design drawings, the documentation of the analyses, or the report test; in some of these cases, a reviewer conditionally accepted those responses but required a copy of the marked up document to remove the condition for full acceptance. The comments were formally tracked with comment resolution forms. In addition, conditionally accepted comments were formally closed by sending the text changes to the reviewer as evidence of the direct incorporation of his or her comments. Final comment closure was documented in the form of a letter from the reviewer stating full acceptance of the changes.

Each reviewer also prepared a summary statement (see Appendix PEER). The summary statements provided recognition or explanation of specific technical concerns in the final documentation, identified the need for future work prior to emplacement of the seals, provided suggestions for design and analysis enhancements or simplifications, and encouraged more detailed quantification of design guidance. Each of the reviewers provided "bottom-line" assessments. Excerpts from the summary statements are provided below:

Dr. Malcom Gray

> *"In summary and conclusion, I consider that when completed as stated immediately above, it is likely that the documents being developed will present a design that will meet the general requirement of shaft sealing systems that will mitigate against water and gas flows from the repository to the biosphere and that can be built using existing technologies or reasonable extrapolation therefrom."*

Mr. Stephen Phillips

> *"It is considered improbable that the seal design, as presented including the revisions recently discussed, can be significantly and practically improved within the limits of existing construction materials and technologies, except in some areas where optimization of materials and methods of emplacement can be achieved."*

Dr. John Tinucci

> *"The design that has been put forth presents one way of efficiently sealing shafts. Recognizing that other ways could also be made to work, the design presented here is similar to others suggested by the scientific community for sealing deep geologic nuclear waste repositories. The concepts presented have been developed from sound engineering judgment and sound analyses techniques. The anticipated performance of individual sealing components are within reasonable expectations based on currently available field and laboratory data, albeit limited. To address the wide scale of*

> *uncertainties, the design has been conservatively laid-out with redundant multiple-barrier components so that the overall seal system performance is not dependent on the functionality of an individual component. The design as it exists today is a conceptual design since it describes basic concepts and provides sufficient backup analyses to demonstrate that those concepts will reasonably satisfy the qualitative design guidelines."*

9.4.4 Engineered Alternatives Task Force Report Peer Review

The Engineered Alternatives Task Force (EATF) was established by the DOE in 1989. The EATF was tasked to evaluate the effectiveness, feasibility, and risk of implementing alternative facility designs, backfills, and/or waste forms in improving the long-term performance of the WIPP disposal system. The purpose, methodology, assumptions, and conclusions of the EATF are documented in a report, titled "Evaluation of the Effectiveness and Feasibility of the Waste Isolation Pilot Plant Engineered Alternatives: Final Report of the Engineered Alternatives Task Force" (DOE 1991a). The author of the report, IT Corporation, convened a peer review panel to review a final draft version of the report during 1991. An evaluation of the EATF review against the screening criteria is provided in Table 9-11. The panel consisted of experts in chemical and nuclear engineering and geology. The members of the panel and their affiliations were as follows:

Dr. H. Eric Nutall, University of New Mexico and Nutall & Associates, Inc.
Dr. Douglas Brookings, University of New Mexico
Dr. Robert J. Budnitz, Future Resources Associates, Inc.
Donald E. Shaw, P.E., Engineering and Management Consultant

A formal comment resolution process was employed to ensure that the reviewers' comments were incorporated into the final version of the report. The comments of the panel can be grouped into three general topics: (1) quality of technical work; (2) utility of a single figure-of-merit; and, (3) use of relative versus absolute risk.

The comments made by the peer review panel (see Appendix PEER) and the WIPP project responses are discussed below.

Quality of technical work

One reviewer commented that:

> *"The complex technical risk analysis work, aimed at determining risk-reduction factors of the many different risk endpoints and for 16 different alternative scenarios, is of high quality and deserves commendation. The technical information buried in the back of the Attachments to this report can provide an excellent basis for decision-makers to understand the various risk issues, and make decisions about them. The*

Table 9-11. Engineered Alternatives Task Force Report Review

1. Is the "peer review" relevant to the CCA?	Yes - The review was conducted on the 1991 EATF report which formed the basis for the subsequent Engineered Alternatives Cost/Benefit Study.
2. Was there a formal report prepared by the reviewer?	Yes - The "report" consists of review comment record forms that were used to formally document the comments, responses, and their dispositions.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The purpose of the review was to determine the adequacy of the EATF report.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The review evaluated the adequacy of the EATF report.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - The reviewers were nationally recognized experts in their respective fields.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - The reviewers were not involved in the preparation of the work and were free from funding considerations.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

choice of alternative scenarios, the assumptions made to limit the scope of the analysis, the risk endpoints identified, and the analysis methods used are all fully acceptable to me. I am particularly pleased with how the analysis of specific risk endpoints was accomplished in a way that focused on the key issues relevant to the alternative scenarios. This part of the report can be a gold mine for further study by experts, as well as of use to decision-makers if presented properly."

The future value of the work predicted by the reviewers was an accurate prediction because the methodology and models developed for the EATF formed the basis for the subsequent Engineered Alternatives Cost/Benefit Study (EACBS) (DOE 1995b; Appendix EBS) that was performed in 1995. The EACBS was recently the subject for another peer review panel (see Section 9.3.3)

Utility of a single figure-of-merit

The reviewers questioned the utility of a single figure-of-merit to express the aggregated risk elements. The EATF used a Multi-Attribute Utility Theory approach to combine the risk components for each alternative into a single value for alternative ranking purposes. These risk components included the routine and accidental risks from waste transportation and handling, exposure to radiation and hazardous constituents in the waste during treatment, cost, schedule, and benefits to future generations from a safer disposal system. One reviewer commented that:

"Although I admire the attempt to come up with a single figure-of-merit useful to decision-makers by which to judge the overall benefit/disbenefit of each of the various scenarios being studied, in my view the effort has not succeeded. The methodology did use established decision-theory methods to identify and calculate such a single figure-of-merit, and seems to break some new ground, but in my opinion, the single figure-of-merit identified is not sufficiently useful to decision-makers to justify the continuation of work along those lines. In fact, I believe that the use of a single figure-of-merit obscures rather than illuminates the situation. Decision-makers are in my opinion fully capable of dealing with multiple attributes presented separately, and of weighing them in their own ways for decision-making purposes--this goes on every day in the upper-management board rooms of large enterprises and agencies. But to make these judgements, decision-makers need the best available disaggregated information about the issues at hand, in this case, the best absolute numbers and uncertainties about the specific risk endpoints. I don't believe that high-level decision-makers generally use aggregated information very much or very well, and I don't believe that the aggregated information based on the single figure-of-merit developed in this report will be of much use."

The WIPP project believed that although dissaggregated information may be used by many decision makers in finance and industry, it was not sufficient for the EATF. A compromise was reached in final version of the EATF report. That compromise consisted of providing both the aggregate and individual risk components. This allows a decision-maker the option to develop an independent figure-of-merit based on personal weighting factors and preferences.

Use of relative versus absolute risk

The EATF methodology involved the calculation of relative risk reduction factors rather than absolute risks for each alternative. These relative risk reduction factors were based on a risk of unity for the baseline case (defined as: no waste treatment; a crushed salt backfill; and, the current repository design). Risks for each engineered alternative were ratioed against the risk for the baseline case, yielding the risk reduction factor. The main advantage of this relative risk approach is that many parameters that affect absolute risk will cancel when calculating relative risk. Uncertainties in those parameter values do not translate into uncertainties in the relative factors. Some reviewers felt that the calculation of absolute rather than relative risks would have been more useful to decision-makers. For instance, one reviewer commented that:

> *"In my view, the approach of identifying and working with risk-reduction factors (RRFs) is a very useful intermediate step toward what is actually needed. Indeed, calculating RRFs is often simpler than calculating absolute magnitudes of risks for reasons cited well in the report. However, I believe that for decision-makers these RRFs cannot adequately substitute for knowing the actual magnitudes of the risks involved, except in special cases, such as when almost no changes occur (RRF near unity) or when absolute risk magnitudes and minuscule small for both the base-case scenario and the alternative scenarios."*

The WIPP project concluded that although absolute risks convey a greater amount of information for decision-makers than relative risks, the calculation of absolute risks were outside the scope of the EATF study and would have entailed a considerably greater effort than was warranted. For instance, calculating absolute long-term risks to future generations for each alternative would require performing a complete performance assessment for each alternative.

9.4.5 Blue Ribbon Panel Peer Review

The Secretary of Energy established the WIPP Blue Ribbon Panel (BRP) in August 1989. The panel was composed of the following five members:

Dr. Thomas Bahr
Robert W. Bishop, esq.
Dr. Arthur S. Kubo
Leonard C. Slosky

Newal Squyres

Dr. Bahr, a water quality management expert and the Director of the New Mexico Water Resource Research Institute, was nominated to the BRP by the Governor of New Mexico. Mr. Bishop, General Counsel and Corporate Secretary for the Nuclear Management Resources Council, and Dr. Kubo, a nuclear and civil engineer and a vice president of the BDM Corporation, were appointed to the BRP by the Secretary of Energy. Mr. Slosky, an environmental consultant, and Mr. Squyres, an attorney, were nominated by the Governors of Colorado and Idaho, respectively.

The panel members were each requested to provide an independent technical review of WIPP issues and individually report on the following:

1. The concept and timing of DOE's proposed WIPP Operations Demonstration.

2. Whether or not the Operations Demonstrations should be conducted in parallel with the performance assessment.

3. An evaluation of DOE's validation plan for certification of TRU waste to meet the WIPP Waste Acceptance Criteria.

The panel conducted site visits at the WIPP facility and portions of INEL and the Rocky Flats Plant. The panel met with and/or were briefed by staff from the DOE and its contractors, the NAS Board of Radioactive Waste Management WIPP Panel, the Environmental Evaluation Group and the Environmental Protection Agency. The panel members were provided an extensive amount of documentation and were encouraged to address questions to the above groups. An evaluation of the BRP review against the screening criteria is provided in Table 9-12.

Following submission of its reports, the BRP was asked to continue its service by providing their observations and recommendations to the DOE in three areas: (1) continued review of DOE plans to characterize Rocky Flats Plant TRU and mixed waste; (2) assist DOE in developing a strategy for achieving compliance with RCRA and other environmental regulations at WIPP; and (3) evaluate the Final Test Plan and ancillary documents. Subsequently, the DOE expanded the BRP charge to include a management review of the WIPP project, review of the rationale and plans to characterize waste for the test phase and a review of plans for engineered alternatives relating to the waste form.

The BRP was also asked in late November 1989 to comment on questions submitted by members of the New Mexico Congressional Delegation. The questions were: (1) what is the rationale for conducting in-situ experiments at the WIPP rather than at existing waste generation and storage sites; (2) how much waste would need to be emplaced at the WIPP for the experiments; and, (3) what are the BRP's recommendations regarding DOE's proposed Operational Demonstration experiments?

Table 9-12. Blue Ribbon Panel Review

1. Is the "peer review" relevant to the CCA?	Yes - The reviews addressed waste certification and PA aspects.
2. Was there a formal report prepared by the reviewer?	Yes - Each panel member prepared an individual report.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The panel reviewed the adequacy of work being done primarily at WIPP, Rocky Flats Plant and INEL.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The panel reviewed DOE plans and processes.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - Panel members were specifically chosen by the governors and the Secretary of Energy because of their qualifications.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - The panel members were not otherwise associated with the WIPP project.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

The BRP provided individual responses to the congressional delegation and provided testimony to the Senate Committee on Energy and Natural Resources on April 26, 1990. The general observations of the panel were provided to the Senate by Dr. Bahr who stated the following:

> *"At this point Mr. Chairman, rather than going into my specific observations and recommendations and then having each of the panel members do the same, we decided in order to save time that I would very briefly summarize the general observations of the panel to date. The first and most significant observation in my opinion is that each member of the Blue Ribbon Panel has independently arrived at similar conclusions on each of the issues we were asked to evaluate. Also noteworthy is the high level of congruence of our findings with those of the Advisory Committee on Nuclear Facility Safety (Ahearne Committee). We have also participated in meeting with the WIPP Panel of the National Academy of Sciences and I can report that we also generally share the same views on those issues we have both looked into. Let me now highlight those items upon which members of the Blue Ribbon Panel seem to agree.*
>
> *1. The deep bedded salt repository at the WIPP appears to be a safe site for long term isolation of transuranic waste; certainly safer than where this waste is presently stored. Radioactive releases over the long term for an undisturbed WIPP site will probably meet EPA standards (40 CFR 191 Subpart B). Meeting this standard having to consider human intrusion scenarios will be more difficult. Treating the waste so as to change the waste form and thereby force the repository environment to known conditions will significantly reduce present uncertainties. The most controllable variable in the design of the repository environment is the waste form.*
>
> *2. In situ testing is important and necessary and should begin as soon as possible. Results of bin and alcove testing should significantly increase the confidence of long range predictions undertaken in the performance assessment. Individual members of the Blue Ribbon Panel agree that the quantity of waste emplaced for experimental purposes should not be limited such as to preclude justifiable experiments. A limit of approximately 1% of the WIPP waste capacity is reasonable. A limit of 0.5% may be too restrictive by precluding the opportunity to undertake important Phase III bin testing of different waste forms resulting from different engineered modifications.*
>
> *3. Members of the Blue Ribbon Panel agree conceptually that the EPA suggestion of adding two filled rooms for monitoring purposes is worthy of further consideration by DOE. This approach, however, should be evaluated in the context of verifying facility performance and not considered as part of the test phase itself. We have not, however, been asked to evaluate EPA's suggestion.*
>
> *4. On the subject of Operations Demonstration, our panel agrees that such an undertaking will provide valuable information because of the practical experience gained*

in system-wide operations. We are in general agreement, however, that a full "ramping up" of an Operations Demonstration should be postponed until such time as the final waste form and repository configuration are determined and that there is a high level of certainty that the Subpart B standard can be met.

5. We also have general agreement that DOE had underestimated the complexity and level of effort required to comply with RCRA in managing its transuranic-mixed wastes.

Mr. Chairman, I have touched the high points and obviously skipped over many details. Other panel members may wish to elaborate on these and other items. In closing, there is one last item of strong agreement expressed by all panel members. We are very impressed by the responsiveness of DOE to our suggestions. Some examples include 1) The significant improvements that have been made in the DOE organization toward overall systems integration, both vertically and horizontally among the varied elements of transuranic and mixed-transuranic waste management; 2) The significant increase in effort being placed on evaluation of engineered alternatives and waste treatment; 3) The accelerated activity and seriousness with which DOE is now placing on dealing with RCRA and in particular on waste characterization issues; and finally 4) The decision by the Secretary to postpone the start up of the Operations Demonstration program."

The full text of the panel's testimony to the Senate and of the independent reports prepared by the individual panel members are provided in Appendix PEER. There have been significant changes as a result of the recommendations of the BRP and other reviews of the project. These changes are especially dramatic with regard to the performance assessment activities and review. All of the findings and recommendations from the BRP were resolved by the WIPP project to the extent that they were formally closed by the individual Blue Ribbon Panel members.

9.4.6 Advisory Committee on Nuclear Facility Safety Review

The Advisory Committee on Nuclear Facility Safety (ACNFS) was established by the DOE on November 13, 1987, on the recommendation of the NAS. The Committee was appointed by the Secretary of Energy to provide advice and recommendations on the safety of the DOE's nuclear production and utilization facilities. The facilities reviewed by the ACNFS included the WIPP site and the waste generator sites. An evaluation of the ACNFS review with the screening criteria is provided in Table 9-13.

The Committee was composed largely of recognized experts (from outside the DOE) in the field of nuclear energy. Specific expertise of the committee members included environmental chemistry, risk assessment, radioactive waste management, medicine, geology, geochemistry, biophysics, health physics, and environmental regulatory compliance. The ACNFS panel was composed of the following members:

Table 9-13. Advisory Committee on Nuclear Facility Safety

1. Is the "peer review" relevant to the CCA?	Yes - The review addressed long term performance, gas generation and engineered alternatives issues.
2. Was there a formal report prepared by the reviewer?	Yes - There was a formal report.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - Although much of the Committee's scope could be characterized as technical review, there were other issues, such as the adequacy of the WIPP programs to address gas generation, long term performance and waste characterization that would be better characterized as peer review.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The Committee reviewed DOE operations, processes and documentation.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - Committee members were recognized experts in the field of nuclear energy.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - Committee members were from outside the DOE and were appointed by the Secretary of Energy under the Federal Advisory Committee Act.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

John Ahearne (Chairman), Sigma Xi
Jess Cleveland, U.S. Geological Survey
Floyd Culler, EPRI
Jacob Fabrikant, University of California, Berkeley
William Kastenberg, University of California, Los Angeles
Terry Lash, Consultant
Harold Lewis, University of California, Santa Barbara
James Martin, University of Michigan
Dana Powers, SNL
William Schull, University of Texas
Robert Seale, University of Arizona
C. Frederick Sears, Northeast Utilities
Gerald Tape, Associated Universities
Victoria Tschinkel, Landers and Parsons

The ACNFS visited WIPP in June 1989, at which time a subcommittee was formed to review safety issues in further detail. The WIPP subcommittee was chaired by Dr. Tape (Paul D. Rice, a consultant, chaired the subcommittee until October 1990). Members included Drs. Kastenberg, Lash, Martin and Seale. Special consultants to the subcommittee included

Konrad Krauskopf, Stanford University (until October 1990)
James Ling, Consultant (until October 1990)
Thomas Pestorius, Consultant
Thomas Pigford, University of California, Berkeley (until October 1990)
Bernard T. Resnick, Consultant
Frank Rowsome, Consultant (until October 1990)

The subcommittee subsequently revisited WIPP and other related facilities: SNL, INEL, and the Rocky Flats Plant. Areas of review included unresolved short-term technical and operational issues and long-term environmental performance. A report to the Secretary was issued by the ACNFS on December 11, 1989 (see Appendix PEER, Section PEER.15) and a final report was issued in November 1991 (see Appendix PEER for the WIPP chapter of the final report).

The 1989 report identified several recommendations to resolve issues related to both short-term operations and long-term performance of the repository. The final report, titled "Final Report on Department of Energy Nuclear Facilities" (Document PB92-119809), contained a section that dealt with its review of WIPP. This final report contained the following recommendations to *"increase the probability of successful compliance with EPA's proposed standards in a shorter period of time . . ."*:

- *Prepare a concise report in a timely manner comparing the expected performance of WIPP with the requirements in EPA's proposed standard (40 CFR 191). This report should specifically focus on those parameters that are currently significantly uncertain and set forth the actions including alternatives, necessary to reduce the uncertainties to acceptable levels for demonstrating regulatory compliance.*

- *Change current project priorities by putting more emphasis on the use of experts. At this time, panels of experts will provide more significant input to the demonstration of compliance with EPA standards than will the results of the Dry Bin Tests. The Bin Test Program should continue to be focused on reducing uncertainties in those parameters that are most important in determining compliance with EPA's proposed standards.*

- *Initially dispose only the contact handled TRU waste that will not pose a gas generation problem. Other TRU wastes can be safely stored above ground until it is determined whether they can be buried at WIPP in compliance with regulatory requirements or have to be treated so that disposal at WIPP is acceptable.*

- *Immediately begin development and implementation of engineered alternative, especially for newly generated waste. DOE should be a technological leader in waste management and this initiative should go forward even if it were not specifically required to demonstrate compliance with EPA's proposed standards.*

The WIPP project initiated and continued several activities to resolve the ACNFS concerns. Specific action plans were developed and these plans were implemented. In June 1990, the DOE prepared a concise report summarizing the current understanding of expected performance and the potential for demonstrating compliance with 40 CFR Part 191, Subpart B (Bertram-Howery and Swift 1990). Preliminary performance assessments in 1990, 1991, and 1992 identified significant uncertainties and provided guidance to the project. The experimental program was refocused to meet the needs of the compliance evaluation, and the underground bin and alcove tests were canceled. Chapter 4.0 and Appendices WCA and WCL address which wastes will be emplaced at WIPP. The subject of engineered alternatives was reviewed by two recent peer review panels (see Sections 9.3.3 and 9.4.4). The ACNFS recommendations were formally closed by the Advisory Committee.

9.4.7 Performance Assessment Review Team

The Performance Assessment Review Team (PART) was organized in 1992 by the Department of Energy's Director of Environmental Restoration and Waste Management WIPP Project Management Division (EM-342). The purpose of the PART review was *"to assess the adequacy of the WIPP PA program for meeting relevant regulatory standards for the disposal of radioactive and hazardous wastes, to identify any deficiencies in the program, and to make recommendations for improvements."* The team members were as follows:

Bryan Bower (Chairman), DOE/EM-342
Charles Voss (Deputy Chairman), Golder Associates, Inc.
James Russell, Texas A&M University
Neville Carter, Texas A&M University
Pamela Doctor, Pacific Northwest Laboratory
Charles Cole, Pacific Northwest Laboratory

The group was very knowledgeable of geologic repositories and included specific expertise in performance assessment methodology, brine migration, flow and transport modeling, creep and room closure, and site operations. The review team was not completely independent because the chairman of the review team was a staff member of DOE/EM-342, which had oversight responsibility for WIPP. Section 1.4.1 of the PART (the complete report is provided in Appendix PEER) report states that

"The Director of EM-342 and the PART chairperson selected the PART members on the basis of their knowledge of components and processes associated with salt repository and their independence from the WIPP Project. More specific criteria included (1) familiarity with geologic repositories; (2) PA expertise or knowledge of risk assessment techniques; (3) knowledge of RCRA and/or 40 CFR 191 requirements; and (4) no direct association with any of the PA activities for the WIPP."

It should be noted that the report findings *"reflect the consensus of team members"* and that the final report was signed by all team members. It was included in this application because of its insight into the performance assessment effort at a pivotal time in the direction of performance assessment for the WIPP project. An evaluation of the PART review against the screening criteria is provided in Table 9-14.

The review was primarily conducted during the first half of 1993 and a final report was issued in February 1994. All PART activities were conducted and documented in accordance with EM-342's NQA-1 based QA program. The PART reviewed the pertinent performance assessment documents and activities, toured the WIPP site, and interviewed members of the project staff. The team concluded that

"The review team finds that the work on the WIPP has generally been perceptive, incisive and fundamentally sound. However, for compliance with current standards and regulations, substantial progress and improvements will be necessary in certain areas where additional investigations and documentation may be required; the PA department is fully aware of most of them. These areas include PA documentation, parameter evaluation, conceptual model justification, time-dependent behavior of natural and engineered barriers to fluid migration from the coupled disposal system, and a total system model."

Table 9-14. Performance Assessment Review Team (PART) Independent Review of WIPP Performance Assessment

1. Is the "peer review" relevant to the CCA?	Yes - The review dealt directly with the PA.
2. Was there a formal report prepared by the reviewer?	Yes - The report is titled "Performance Assessment Team's Independent Review of WIPP Performance Assessment Activities (40 CFR 191 and 40 CFR 268.6) for EM-342. The report is dated February 1994.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The review focussed on the adequacy of then current PA and RCRA activities at WIPP.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The review evaluated the adequacy of the work of others.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - Section 1.4.1 states "The Director of EM-342 and the PART Chairperson selected the PART members on the basis of their knowledge of components and processes associated with salt repository and their independence from the WIPP Project. More specific criteria included (1) familiarity with geologic repositories, especially salt; (2) PA expertise or knowledge of risk assessment techniques; (3) knowledge of RCRA and/or 40 CFR 191 requirements; and (4) no direct association with any of the PA activities for the WIPP."

Table 9-14. Performance Assessment Review Team (PART) Independent Review of WIPP Performance Assessment (Continued)

6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	No - The team chairman was a DOE EM-342 employee. EM-342 has oversight responsibility for WIPP. The remaining members were university staff and a professional consultant.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	Yes - Report findings reflect the consensus of team members and the final report was signed by all team members.

Considerable effort has been made to resolve the concerns identified in this review. The performance assessment process has changed significantly since the PART report to address issues identified in this report as well as to document the conformance with the requirements of 40 CFR Part 191 and criteria of 40 CFR Part 194. Finally, it should be noted that the PART final report was provided to the recent conceptual models peer review panel (see Section 9.3.1) for its consideration. The issue of engineered alternatives, as they relate to performance assessment, was specifically reviewed by recent peer review panels (see Section 9.3.3).

9.4.8 INTRAVAL

The INTRAVAL project was initiated in 1987 in Stockholm as an international effort to validate geosphere models for transport of radionuclides. The project was initiated by the Swedish Nuclear Power Inspectorate and was first formed as an ad-hoc group with representatives from eight organizations. INTRAVAL has since grown to include 24 "Parties" from 14 countries. The project is governed by a coordinating group which has one representative from each member of the group. Project organization, the objectives of the study, and the rules for publication of results are defined by an agreement between the group members. The INTRAVAL philosophy is to use results from laboratory and field experiments as well as natural analog studies in a systematic study of the model validation process. The goal is to evaluate conceptual and mathematical models for groundwater flow and radionuclide transport in the context of performance assessment of repositories for radioactive waste, with particular focus on the validity of model concepts.

A number of "test cases" have been studied at various locations around the world. These test cases include field tests, mining operations, natural analogs, and laboratory experiments. In

1990, two test cases from the WIPP site were included as part of the INTRAVAL investigations, and were designated as WIPP1 and WIPP2. An evaluation of the INTRAVAL project reviews against the screening criteria is provided in Table 9-15. These two test cases are discussed in INTRAVAL Progress Reports (numbers 5 through 10) (see Appendix PEER) and are briefly described below.

WIPP1

The WIPP1 test case was based on experiments performed to determine the rate of brine flow through WIPP bedded evaporites. The experiments were designed to provide a variety of data with which to determine whether Darcy's Law for a porous, elastic medium correctly describes the flow of brine through evaporites, or whether a different model is more appropriate. The test case was also related to the ability of waste-generated gas to flow from the repository into the formation. Data from three types of experiments form the basis for the test case:

- small scale brine inflow experiments,
- pore pressure and permeability testing, and
- integrated, large scale experiment.

The following project teams analyzed the WIPP1 test case:

SNL, United States
Ecole Nationale Superieure des Mines de Paris (EdM), France
Commissariat a l'Energie Atomique/Institut de Protection et de Surete Nucleaire (CEA/IPSN), France
National Institute of Public Health and Environmental Hygiene (RIVM), The Netherlands

The general approach taken by the teams was to attempt to determine values of permeability and specific capacitance that would be consistent with other available data and would be able to provide reasonable simulations of all of the brine-inflow experiments performed in the Salado Formation. All of the teams concluded that the average permeability of the halite strata penetrated by the experimental boreholes was between approximately 10^{-22} and 10^{-21} m^2. Specific capacitance values ranging from about 10^{-10} to 10^{-12} were found to be consistent with the experimental data.

All of the project teams found that Darcy-flow models could replicate the experimental data in a consistent and reasonable manner. Discrepancies between the data and simulations were attributed to inadequate representation in the models of processes modifying the pore-pressure field and to physical processes, such as ongoing deformation of the rock around the excavations, occurring in the experiments themselves.

Table 9-15. INTRAVAL

1. Is the "peer review" relevant to the CCA?	Yes - Although not a review of the WIPP project specifically, INTRAVAL used WIPP site characterization data to validate models of groundwater flow.
2. Was there a formal report prepared by the reviewer?	Yes - Annual INTRAVAL reports and journal articles provide summaries of the findings.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The two cases discussed provide independent evaluation of the validity of the conceptual models used for Salado brine inflow and Culebra groundwater flow at WIPP.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The two cases evaluated the validity of conceptual models for the WIPP site.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - Reviewers were internationally recognized experts in their respective fields. Many had extensive experience in radioactive waste disposal projects in other countries.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - Reviewers were not involved in the WIPP project, were impartial, and were free from funding considerations.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

The conclusion from the test case is that Darcy-flow models could reliably predict brine flow to WIPP excavations, provided that the flow modeling is coupled with measurement and realistic modeling of the pore-pressure field around the excavations. Realistic modeling of the pore-pressure field would probably require coupling to a geomechanical model of the stress evolution around the repository.

WIPP2

The WIPP2 test case was based on flow and transport experiments in heterogeneous fractured sediments overlying the WIPP repository horizon. Geologic, hydrologic, geochemical, and isotope data had been collected to resolve several issues concerning the hydrology of the Culebra dolomite. A central issue involved the travel time within the Culebra from a location above the repository to the WIPP site boundary. Sixty wells into the Culebra dolomite at 41 locations had been completed to provide information on the hydraulic properties. Two pumping tests, each of two months' duration, and two convergent-flow tracer tests had been performed. Geochemical and isotope studies had also been conducted to obtain additional insight into the hydrologic behavior of the Culebra.

The test case was studied by the project teams from

U.K. Nirex Ltd. (AEA/NIREX), United Kingdom
Empresa Nacional de Residuos Radioactivos S. A. (UPV/ENRESA), Spain
Atomic Energy Control Board, Canada
Bundesanstalt fur Geowissenschaften und Rohstoffe (BGR), Germany
SNL, United States

The primary data used in the INTRAVAL studies were the hydrogeological properties of the Culebra dolomite. The Culebra dolomite is quite thin, approximately 8 meters thick, but extends for many kilometers and is highly fractured in some locations. A large number of hydraulic tests has been performed in the dolomite including transmissivity measurements, steady-state measurements of heads, and cross-hole tests. The modeling has mainly addressed the issues involved in treating the heterogeneity of the transmissivity of the Culebra dolomite. The effects of the varying salinity of the groundwater in the Culebra dolomite have also been analyzed. There are large variations in the transmissivities of the Culebra leading to uncertainties in quantities of importance in a repository performance assessment such as travel times. Therefore, there seems to be a generally agreed-upon approach to use stochastic models. The conceptual models include two- as well as three-dimensional descriptions of the Culebra dolomite. Continuum porous media as well as fracture network models have been studied.

The teams from AEA and UPV tackled this test case by using stochastic models. The AEA team applied the Turning Band algorithm for generation of realizations. The finite element groundwater and transport code NAMMU was used to solve the problem. The team examined the uncertainties in the path-lines, travel time, head and Darcy velocity that resulted from the uncertainties in the parameters. Furthermore, the statistical behavior of the variogram estimators was studied using Monte-Carlo simulations. The team considered four different stochastic models, all isotropic, and concluded that if the correlation length was comparable to, or greater than, the size of the domain investigated it was not possible to determine the correlation length from the measured data. However, this did not have a significant impact on the uncertainties in quantities such as the travel time, provided that the model was conditioned on a reasonable number of transmissivity measurements. The team applied three different approaches to condition the head data. None of these approaches were found to be entirely satisfactory. Furthermore, the performed work gave some evidence that conditioning on head data is not as strong a constraint as conditioning on transmissivity data.

The UPV team used a sequential Gaussian simulation for the generation of realizations. The finite difference codes MODFLOW and MODPATH were used to compute the flow and particle paths. An optimization method was used to condition the head data. The team found that the anisotropic variogram gave best fits. The conditioning on the heads provided significant improvement, but some discrepancies were still remaining. Gaussian models imply lack of connectivity of regions with higher (or lower) than average transmissivity. Therefore, they might not take into account fast flow paths from the repository, which are responsible for the main radiological consequences. Furthermore, the modeling performed by the team indicated that variable density has a large impact on the results and should therefore be included.

The Atomic Energy Control Board team studied the effects of salinity on the groundwater flow. This was done by comparing the groundwater flow and the head data using three different salinity distributions. The problem was solved using the finite difference code SWIFT. The results indicated that there was not any strong evidence for a trend, the variations were consistent with the correlated spatial process. The match to the heads was not good even with conditioning. The calculations with different salinities indicated that the flow paths in the Culebra from the center of the site are relatively insensitive to the uncertainties in the salinity distribution.

The BGR team addressed issues relating to the choice of conceptual model. The AEA, UPV and Atomic Energy Control Board teams all considered two-dimensional areal models of the Culebra dolomite and assumed that the permeabilities of the units above and below are sufficiently small so that vertical flow can be neglected. The BGR team used a two-dimensional cross-section model to evaluate vertical leakage between members of the Rustler Formation. The team concluded that flow between the Culebra and the overlying Tamarisk Member and underlying unnamed lower member affects the Culebra flow field. The team also concluded that the present-day salinity distributions within the Culebra and Magenta are consistent with diffusional transport of salt from halite-bearing members of the Rustler to the dolomite members.

The SNL team has applied different conceptual models to study the importance of vertical flow between the Culebra dolomite and the overlying units. Calculations using the preliminary conceptual model indicated that leakage into the Culebra may be of importance.

The test case provided a very valuable focus for the development and study of stochastic models for the treatment of heterogeneity in hydrogeological properties. The applied stochastic models have proven to be valuable tools in assessing the effect of uncertainty due to heterogeneity on the performance of a repository. The test case also provided impetus for 3-D basin-scale modeling to evaluate the conditions under which the Culebra could be conservatively modeled as a 2-D confined aquifer for performance assessment purposes.

9.4.9 WIPP Conceptual Model Uncertainty Group Review

The WIPP Conceptual Model Uncertainty Group (CMUG) was an advisory group that was formed and operated in 1993 to provide guidance to SNL's WIPP Performance Assessment effort. An evaluation of the CMUG activities against the screening criteria is provided in Table 9-16. A report of their evaluation of the WIPP Performance Assessment was prepared September 27, 1993 (see Appendix PEER) and is summarized below.

The CMUG included expertise in hydrology, geology, geochemistry, risk assessment, and environmental modeling. All committee members were consultants who, at that time, worked outside the SNL community. The panel members were as follows:

- Craig Bethke, University of Illinois
- Rafael Bras, Massachusetts Institute of Technology
- Jesus Carrera, Universidad Politechnica de Catluta
- Neil Chapman, Intera Information Technologies Ltd.
- Ghislain de Marsily, University Pierre et Marie Curie
- Daniel Galson, Galson Sciences Ltd.
- Steven Gorelick, Stanford University
- Jane Long, Lawrence Berkeley Laboratory
- Dennis McLaughlin (Chairman), Massachusetts Institute of Technology

The charter of the CMUG states

> *"The conceptual model uncertainty ... group is being formed to provide guidance to the WIPP PA program on how to account for uncertainty associated with conceptual models for the groundwater flow and radionuclide transport systems in the Rustler and other non-Salado formations."*

Table 9-16. Conceptual Model Uncertainty Group

1. Is the "peer review" relevant to the CCA?	Yes - The CMUG reviewed the 1992 conceptual models used for PA.
2. Was there a formal report prepared by the reviewer?	Yes - Meeting summaries were prepared.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - It was a review of the adequacy of the WIPP conceptual models.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Partially - Although the CMUG reviewed the existing PA models, its primary thrust was to recommend improvements in the models.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - Group members are internationally recognized experts in their respective fields.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - The recommendations were provided from an independent and impartial perspective.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	Yes - The review conducted a detailed review of the WIPP conceptual models and provided extensive comment on those models.

The group is also asked to

> *"... help ... on the development of alternative conceptual models and treatment of conceptual model uncertainty ..."*

During its first two meetings in March and October of 1993, the CMUG focused on gaps, ambiguities, questionable assumptions, and simplifications which should be resolved before a final performance assessment is submitted. The CMUG's initial reaction was that the WIPP Performance Assessment has concentrated too much on simulation exercises and too little on identifying potential pathways and processes. They recommended that the performance assessment should devote more effort to understanding the origins and evolution of the non-Salado environment, particularly its geology, geochemistry, and hydrology. Specific concerns were provided in four areas: (1) regional hydrology, recharge, and the effects of climate change; (2) geologic history, evolution, and structure over a range of scales; (3) geochemical evolution and composition of groundwater; and (4) alternative transport pathways. These concerns are documented in the CMUG report which is provided in Appendix PEER.

Most of the recommendations provided by the CMUG have been implemented. In direct response to the CMUG recommendations, an in-house working group was formed in the spring of 1993 to re-evaluate conceptual models for use in performance assessment. That group contained representatives of both performance assessment and experimental activities, and made significant progress during the remainder of 1993 in redefining performance assessment conceptual models. The DOE performed a complete rescreening of all FEPs as part of the preparation of this application: CMUG concerns were addressed as part of this activity. Also, the CMUG reports were provided to the recent CMPR panel (see Section 9.3.1) for consideration in its assessment of the WIPP Performance Assessment conceptual models.

9.4.10 Environmental Evaluation Group Reviews

The EEG was established in 1978 as an independent technical advisory group to assist in the State review of the WIPP project. The EEG continues to be funded by the DOE through the New Mexico Institute of Mining and Technology.

Current and former staff members of the EEG, and their technical disciplines, include the following:

Robert Neill (Director), Radiological Hygienist
Lokesh Chaturvedi (Deputy Director), Engineering Geologist
Sally Ballard, Laboratory Scientist
William Bartlett, Health Physicist
James Channell, Environmental Engineer (previous staff member)
Jenny Chapman, Hydrogeologist (previous staff member)

Thomas Clemo, Geohydrologist
Stuart Faith, Consulting Geochemist (previous staff member)
Donald Gray, Environmental Specialist
Jim Kenney, Environmental Scientist/Supervisor
Lanny King, Assistant Environmental Technician
Betsy Kraus, Technical Editor/Librarian
William Lee, Senior Scientist
Marshall Little, Health Physicist (previous staff member)
Kenneth Rehfeldt, Hydrologist (previous staff member)
Matthew Silva, Chemical Engineer
Peter Spiegler, Radiological Health Analyst (previous staff member)
Ben Walker, Quality Assurance Specialist
Ruth Weiner, Senior Scientist (previous staff member)
Carla Wofsy, Mathematician (previous staff member)

The EEG conducts independent technical analyses of numerous aspects of the WIPP project. These analyses include assessments of reports issued by the DOE and its contractors as they relate to the potential health, safety and environmental impacts from the WIPP. The EEG also performs independent environmental monitoring of background radioactivity in air, water and soil, both on- and off-site.

The EEG has published 60 reports relating to numerous aspects of the WIPP project since 1978. An evaluation of the EEG reviews against the screening criteria is provided in Table 9-17. When evaluated against the screening criteria, it was determined that most of the reports (and associated work) involve issues outside the scope of the this application and/or appear to represent expert judgment or technical review. However, 15 of the reports appear to qualify as peer reviews, per NUREG-1297, and address issues relevant to the compliance certification application. Each of these reports is discussed below.

The issues and concerns raised by EEG have been continually evaluated by the WIPP project. A considerable amount of additional testing and analysis have been undertaken because of EEG's involvement; substantial changes have occurred in the WIPP project as a result.

9.4.10.1 EEG-2 (1978): Review Comments on the GCR, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, SAND78-1596, Volumes I and II

The GCR (Powers et al. 1978) was a two volume summary of the geological background and studies of the geology through preliminary screening to site selection and initial characterization of the WIPP site. The EEG report was a

Table 9-17. EEG Reports

1. Is the "peer review" relevant to the CCA?	Some of the reports address site characterization and other CCA issues.
2. Was there a formal report prepared by the reviewer?	Yes - EEG prepares and publishes formal reports.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Some of the reports fit the NUREG-1297 definition of peer review.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Some of the reports review the adequacy of the work of others.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - The EEG is recognized as an expert group.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - EEG was created to provide an independent technical review of WIPP.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	Only those reports which pass the above criteria will be incorporated into the CCA.

synthesis of comments by Mr. Neill, Dr. Channell, Ms. Wofsy, Lynn Gelhar (a part-time staff hydrologist), and numerous consultants. The EEG report (see Appendix PEER) identified the following issues as the principal concerns relating to the review of the GCR:

- Concerns regarding high-pressure brine reservoirs encountered in the Castile formation in ERDA No. 6 and in other wells near the site.

- Concerns regarding 'breccia pipes' in the area. EEG proposed that the pipes may be localized deep dissolution features originating in the lower portion of the evaporites and migrating upward and that such features could now exist or develop later beneath the proposed repository.

- Concerns regarding processes and rates of deep dissolution of salt near the site that could result in preferential removal of the repository salt horizon.

- Inadequate hydrological information regarding the aquifers above and below the evaporites to assess possible releases from the repository.

Extensive study of the geology and hydrology of the area in and around the WIPP has been conducted. In particular, WIPP-12 was drilled and deepened to investigate the occurrence of brine in the Castile (when brine was encountered in deepening WIPP-12, the repository layout was reoriented to make emplaced waste further away from the brine occurrence). A breccia pipe study was also undertaken and completed by the United States Geological Survey (USGS) (USGS 1982). In addition, deep dissolution of salt near the repository was specifically addressed in at least two ways: a) by a SAND report (Lambert 1983); and, b) by drilling and hydrologic testing of hole DOE-2, sited on a structural "depression" in the Salado, believed initially to be the result of deep-seated dissolution (This was found not to be the case [Borns 1987]).

Information regarding the increased understanding of these features and processes have been documented in numerous technical reports and is summarized in the WIPP FEIS (DOE 1980a), the WIPP FSEIS (DOE 1990a), and the RCRA Part B application. The EEG raised the same issues in its EEG-3 report (see Section 9.4.10.2).

9.4.10.2 EEG-3 (1979): Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U.S. Department of Energy

The Draft Environmental Impact Statement (DEIS) (DOE 1979) was prepared to satisfy the requirements of the NEPA regarding the analysis and documentation of the impacts associated with major federal actions. EEG-3 (see Appendix PEER) is a compilation of the EEG's comments on the DEIS. Document editors were Mr. Neill, Dr. Channell, Ms. Wofsy, and Moses Greenfield (a consultant). Topics addressed by the comments included health effects, transportation, waste acceptance criteria, site characterization, site selection criteria, operational exposure, the experimental waste program, long-term radiation releases, retrievability and decommissioning. From the report summary, the comments and recommendations relevant to this application included the following:

- The WIPP should have to meet NRC license requirements.

- Estimate both health effects and potential radiation exposures.

- Develop waste acceptance criteria before a full evaluation of radiological consequences of operations and accidents can be completed.

- Include a more detailed analysis of the following geological and hydrological aspects of the area surrounding the WIPP site:

- Brine reservoirs (EEG noted that large high pressure reservoirs were encountered in seven wells within 9 miles of WIPP).

- Dissolution of lower and intermediate levels of the salt beds.

- Breccia pipes which EEG noted may be localized deep dissolution features.

- Uncertainties in groundwater flow rates and flow paths.

- Effect of impurities on the physical, hydrological, thermal, and strength characteristics of rock salt from the repository horizons.

- Formally request federal agencies and other experts to comment on the reasonableness and adequacy of the site selection criteria.

- Include the detailed sensitivity analysis being conducted by DOE.

- Waste retrieval should be examined in detail.

- Evaluate the feasibility of site control for more than 100 years.

As stated previously, the geology, hydrology, and geochemistry of the WIPP site have continued to be the focus of extensive experimentation by the DOE and the USGS and evaluation by the DOE and others such as the NAS. In particular, further studies on brine reservoirs, deep dissolution, and breccia pipes were conducted (see Section 9.4.10.8 for a listing of some of the relevant reports). Information regarding the increased understanding of the site has been summarized in the WIPP environmental impact statements, and the RCRA Part B application.

Chapter 15 of the FEIS (DOE 1980a) provided responses to the EEG comments received on the DEIS (DOE 1979). Section 7 of the FEIS was extensively revised to answer many of the geological/hydrological issues raised by the EEG. In addition, the FEIS discussions of waste retrieval and decommissioning were expanded (see Section 9.4.10.5 for the EEG's comments on the FEIS).

9.4.10.3 EEG-8 (1980): The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Doses from WIPP

This report (see Appendix PEER), written by Ms. Wofsy, evaluates the assumptions used for modeling radionuclide transport in the DEIS (DOE 1979) and the WIPP Safety Analysis Report (SAR) (DOE 1980b). The report summary states that

> *"The radionuclide transport modeling is used to predict worst possible consequences of a WIPP repository breach event in which waste enters groundwater. The aim of this report is to determine whether plausible changes in the parameters used by DOE to describe the flow of groundwater near the WIPP site could result in: a) significantly faster radionuclide movement in groundwater; and b) significantly higher concentrations of radionuclides in Pecos River water and correspondingly higher radiation doses than predicted by DOE.*
>
> *The conclusion reached is that while plausible changes in hydrologic conditions and waste-rock interactions might result in a significant reduction in the time it takes for radionuclides to reach the Pecos River, the shorter travel times do not result in significant increases in the estimated concentrations of radionuclides in the Pecos River, nor in the radiation doses associated with the use of such water."*

A number of reviews and analyses by the DOE and others have consistently concluded that catastrophic breaches of the repository, such as assumed above, are very unlikely. However, in the event of such an occurrence the DOE does not disagree with the EEG-8 report's basic conclusion that there would not be significant increases in radionuclide concentrations, or associated radiation doses, in the Pecos River.

9.4.10.4 EEG-9 (1981): An Approach to Calculating Upper Bounds on Maximum Individual Doses from the Use of Contaminated Well Water Following a WIPP Repository Breach

The EEG reviewed the approach used in the FEIS (DOE 1980a) and the SAR (DOE 1980b) to calculate the potential radiological consequences of releases from the WIPP repository. This report (see Appendix PEER) was written by Dr. Spiegler and evaluates the postclosure radiation dose commitments associated with a possible breach event (the hydrological event considered is described as communication event no. 2 in the FEIS). This postulated release involves dissolution of the radionuclides in the repository by groundwater and their subsequent transport through an aquifer to a well. The well is assumed to exist 3 miles downstream from the repository. The report states that

> *"The concentrations of uranium and plutonium isotopes at the well are based on the nuclear waste inventory presently proposed for WIPP and basic assumptions concerning the transport of waste as well as treatment to reduce the salinity of the water. The concentrations of U-233, Pu-239, and Pu-240......would exceed current EPA drinking water limits. The concentrations of U-234, U-235, and U-236.......would be well below current EPA drinking water limits. The 50-year dose commitments from one year of drinking treated water contaminated with U-233 or Pu-239 and Pu-240 were found to be comparable to a one year dose from natural background. The 50-year dose commitments from one year of drinking milk would be no more than about 1/5 the dose obtained from ingestion of treated water.*
>
> *These doses are considered upper bounds because of several very conservative assumptions....."*

As stated above, DOE and others have consistently concluded that catastrophic breaches of the repository, such as are presented above, are very unlikely. However, in the event of such an occurrence the DOE believes that the basic conclusion of the EEG-9 report, that resulting exposures would be small, even when using very conservative assumptions, is correct. Analyses of events similar to the one above were provided in the 1990 Final Supplement Environmental Impact Statement (FSEIS) (DOE 1990a).

9.4.10.5 EEG-10 (1981): Radiological Health Review of the Final Environmental Impact Statement, (DOE/EIS-0026), Waste Isolation Pilot Plant, U.S. Department of Energy

The FEIS provided a review of the potential impacts of the proposed WIPP project. The EEG reviewed the FEIS to determine (a) the changes made to the DEIS; (b) the adequacy of the evaluation; (c) the thoroughness of the DOE's response to EEG's comments on the DEIS; and (d) other issues which EEG believed should be addressed more fully before beginning construction of the WIPP.

The EEG concluded in its report (see Appendix PEER) that DOE had *"incorporated and addressed the majority of the concerns and recommendations that the EEG provided to them in our (EEG-3) August 1979 review of the Draft Environmental Impact Statement on WIPP and the FEIS provides a generally satisfactory evaluation of the potential radiological impact."* There were, however, areas that EEG believed that had not been adequately treated by DOE. The report made the following recommendations:

- Discuss how a zone of possible instability in the area north and southwest of ERDA-9 would be further investigated. The EEG also requested further information on brine reservoirs and dissolution processes near the site.

- Provide the criteria for the high-level experimental wastes and the procedures to assure that Waste Acceptance Criteria will be met.

- Provide more detailed information on the future control of the mineral and hydrocarbon resources at or near the site, and of the hazard analyses that led to the conclusion that resources at the site can be safely extracted.

- Consider the consequences of other potential release scenarios which have been recommended by the EEG.

Geophysical (Time Domain Electromagnetic) surveys were conducted in the immediate vicinity of ERDA-9 to examine the WIPP area for Castile brine reservoirs (Earth Technology Corporation 1988). Additional boreholes were drilled which showed deep dissolution was absent (see Section 9.4.10.1 for additional discussion of brine reservoir and dissolution process studies).

The high-level experiments were canceled. Additional evaluation of the mineral and hydrocarbon resources and their control has occurred since the FEIS was developed. A New Mexico Bureau of Mines and Mineral Resources report (titled, Evaluation of Mineral Resources at the Waste Isolation Pilot Plant [WIPP] Site) in March 1995 (NMBMMR 1995) was the most recent review and reevaluation of the potential for mineral resources and their development. Analysis of other potential release scenarios have been developed and provided in the 1990 FSEIS (DOE 1990a).

9.4.10.6 EEG-11 (1982): Calculated Radiation Doses from Radionuclides Brought to the Surface If Future Drilling Intercepts the WIPP Repository and Pressurized Brine

This report (see Appendix PEER) questions assumptions relating to potential brine reservoirs in the FEIS (DOE 1980a) and other documents and discusses the consequences if pressurized brine were encountered by future drilling at WIPP. The postulated scenario assumes that an exploratory borehole connects the repository and an undiscovered pressurized brine reservoir below the repository and results in saturation of the waste storage area. A subsequent borehole is assumed to bring portions of this contaminated brine to the surface. Based on the calculated radiation doses obtained from this study, the report recommends

- A more detailed evaluation of the probability of this scenario occurring, and

- Consideration of maintaining active institutional controls of WIPP for about 600 years after closure unless the probability of occurrence can be shown to be less than estimated.

Section 5.4 of the 1990 FSEIS (DOE 1990a) evaluated several postclosure repository release scenarios. The SEIS analyses considered a suite of breach scenarios, including some involving disturbed repository scenarios similar to that postulated in EEG-11. Title 40 CFR Part 191 requires that performance assessment not consider contributions from active institutional controls for more than 100 years after disposal.

9.4.10.7 EEG-12 (1982): Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP

The report (see Appendix PEER) evaluates release scenarios provided in the 1980 FEIS (DOE 1980a). The report was written by Mr. Little and evaluates the DOE's position regarding the likelihood and consequences of hydrocarbon and mineral exploration and development in the area of the WIPP site. An analysis of the potential radiological consequences of solution mining of halite is also provided. In the report summary, the EEG concluded that:

- The radiological consequences of the mining of potash or extraction of hydrocarbons (mostly natural gas) are probably bounded by the hydrologic breach scenarios and that the resultant doses would not constitute a significant threat to public health.

- The risk from the solution mining of salt was believed to be small and it is unlikely that the small doses resulting from such mining breach event would produce any detectable biological effects.

Potential radiological consequences of potash mining have been explicitly incorporated into the compliance certification application transport calculations by inclusion of an increase of up to three orders of magnitude increase in Culebra transmissivity/conductivity over mined areas, as a direct consequence of potash mining. The DOE continues to believe that solution mining of halite in the WIPP area is not a credible scenario. The shortage of water in the area, the amount of impurities in the Salado salt, and the enormous quantity of salt available in other parts of the country decrease the likelihood of this scenario.

9.4.10.8 EEG-22 (1983): EEG Review Comments on the Geotechnical Reports Provided by DOE to EEG Under the Stipulated Agreement Through March 1, 1983; and EEG-23 (1983): Evaluation of the Suitability of the WIPP Site

The DOE provided the EEG several reports documenting the status of evaluation and analysis of geotechnical issues regarding the WIPP site.

"Interim Report: Dissolution of Evaporites in and Around the Delaware Basin" (Lambert 1983)
"Evaluation of Breccia Pipe in Southeastern New Mexico and their Relation to the WIPP Site" (USGS 1982)
"Brine Reservoirs in the Castile Formation, Southeastern New Mexico" (Popielak et al. 1983)
"Delaware Mountain Group Hydrology - Salt Removal Potential" (DOE 1982)
"Fracture Flow in the Rustler Formation: WIPP, Southeast New Mexico (Draft Interim Report)" (Gonzalez 1983)
"Interim Policy Statement on Resource Recovery at the WIPP Site" (DOE 1981)
"Simulated Waste Experiments Planned for the Waste Isolation Pilot Plant (WIPP)" (Matalucci 1982)

EEG-22 (see Appendix PEER) is a compilation of the written comments by EEG on each of these reports. EEG-23 (see Appendix PEER) discusses each of the above documents and makes recommendations concerning additional work needed for further site characterization. These recommendations were

"The following is a list of certain investigations currently in progress or planned by DOE and additional work which EEG recommends that the State should demand if the construction is allowed to proceed."

<u>Continuing or Planned DOE Studies</u>

1. Field tests to identify possible occurrence of brine under the repository.

2. Analyze draw-down data in test holes H-1, H-2 and H-3 caused by WIPP shaft excavations.

3. Publish results of solute transport modeling in the Rustler aquifers.

4. Analyze Rustler aquifer for environmental isotopes (C-14, Cl-36, U-234, U-238) to aid in understanding groundwater flow direction and velocity.

5. Drill planned additional wells for hydrologic testing, viz. H-11 and H-12. Evaluate the cores to determine the extent of fracturing and solution residues in the Rustler formation.

6. Conduct a water balance study for the WIPP site.

7. Study mechanics of salt removal from the Rustler formation near WIPP.

8. Drill a shallow auger-hole in the depression in the SW corner of Sec. 30, T22S, R31E in Zone III to determine if this depression is a doline.

9. Study MB139 to determine its origin and its effect on the repository and confirm it does not violate Section 13.2 of the DOE's site criteria and qualification factors.

Studies Recommended by EEG

1. Investigate the depression of the MBs in the lower part of the Salado formation, centered two miles north of the WIPP shafts.

2. Perform computer modeling of groundwater flow in the Rustler aquifers.

3. Conduct the following hydrology tests:
   a) A long duration pumping test at well H-3.
   b) Measure anisotropy of hydraulic conductivity at test pads H-1, H-2 and H-3.
   c) Perform convergence tracer tests at wells H-1, H-3 and H-4.
   d) Perform convergence tracer tests at well H-6 using sorbing tracers."

The EEG recommendations for additional studies at the WIPP formed a large part of the basis for modification of the Agreement for Consultation and Cooperation between the DOE and the state of New Mexico. Several specific studies addressing issues raised by the EEG were performed between 1983 and 1988. The results of these studies are documented in SAND88-0157 (Lappin 1988), and in detailed references in that summary report. Specifically:

1. Brine occurrence under the repository - see (Earth Technology Corp. 1988).

2. Culebra draw-downs due to shaft excavation - see (Beauheim 1987a) and (Haug et al. 1987).

3. Publish solute-transport modeling in Rustler aquifers - see (Kelley and Pickens 1986), the 1990 FSEIS (DOE 1990a), and the annual performance assessment reports (Bertram-Howery et al. 1990, and subsequent reports).

4. Use of environmental isotopes - see (Lambert and Carter 1984, 1987), (Lambert 1987) and (Lambert and Harvey 1987).

5. Drilling additional wells for hydrologic testing - see (Beauheim 1989) and (Jones et al. 1992).

6. Water-balance study - see (Hunter 1985).

7. Mechanisms of salt removal from the Rustler - see (Holt and Powers 1984, 1987) and (EEG-34 1987).

8. Auger depression in SW corner of section 30 - see (Bachman 1985) and (Bachman 1987).

9. MB139 - see (Borns 1985).

Regarding studies recommended by the EEG:

1. Hole DOE-2 was redrilled and tested to study the noted depression in the Salado north of the WIPP site (see above references).

2. Computer modeling of groundwater flow has been performed - see (Haug et al. 1987) and (LaVenue et al. 1988) and reference the continuing use of Culebra T-field.

3. Non-sorbing tracer tests have now been conducted at H-2, H-3, H-4, H-6, H-11 and H-19. Convergent-flow tests were conducted at H-3, H-4, H-66, H-11 and H-19. Modern single-well tests were conducted at H-11 and H-19.

The DOE position is that the combination of field-scale testing with non-sorbing-tracers, batch sorption tests in the laboratory, and core/column tests in the laboratory using both sorbing and non-sorbing tracers is adequate; that is, that a field-scale sorbing-tracer test is not necessary for WIPP to demonstrate adequate regulatory compliance.

In summary, the DOE implemented tests and studies to address all of the above recommendations.

9.4.10.9 EEG-29 (1985): Evaluation of the Safety Analysis Report for the Waste Isolation Pilot Plant Project

The SAR defines the safety envelope for operation of the WIPP facility. The contents of Chapter 8 of the SAR (entitled "Long Term Waste Isolation Assessment") is relevant to this application. The EEG report (see Appendix PEER), prepared by Mr. Little, evaluated the WIPP SAR and its associated amendments and provided written comments and recommendations based on that review. EEG-29 provided two unresolved comments related to Chapter 8 of the SAR:

- Provide maximum TRU content for packages authorized for WIPP.

- Change the SAR to reflect the results of in progress hydrological studies.

The DOE revised the WIPP SAR and provided a draft to the EEG in 1989. The EEG comments on that draft were provided to the DOE in EEG-40 (see Section 9.4.10.10).

9.4.10.10 <u>EEG-40 (1989): Review of the Final Safety Analysis Report (FSAR) (Draft), DOE Waste Isolation Pilot Plant</u>

As stated above, the DOE revised the SAR and provided the EEG with a draft version for review and comment. The EEG review is documented in EEG-40 (see Appendix PEER) which identified the following issues, relevant to this application in its summary:

- Since the FSAR does not include the long-term risk assessment required by EPA in Part 191, a supplement to the FSAR must be developed prior to the disposal phase.

- The FSAR should specify in as much detail as possible the volumes, curies, and distribution within both CH-TRU and RH-TRU containers and the totals.

- The FSAR takes credit in Chapter 8 for a peer review panel providing assurance on suitability of WIPP as a repository. The panels do not provide credibility unless the EEG is involved.

- The FSAR should discuss when the decision on backfill will be made and the probable final backfill design during operation.

The purpose of the SAR is to document that a systematic analysis of the potential hazards associated with operating the WIPP has been performed, that potential consequences have been analyzed, and that reasonable measure have been taken to control or mitigate the hazards. The focus of the SAR is to address hazards for the design life of the WIPP. Performance Assessment is a probabilistic risk assessment tool designed to evaluate the long-term performance of the repository.

The WIPP SAR was again revised on November 30, 1995 (DOE 1995c). Section 5.4 of the SAR, "Long-Term Waste Isolation Assessment," discusses the performance assessment process and its role in demonstrating compliance with Parts 191 and 268. The SAR is updated annually and the 1996 update is scheduled to address the use of magnesium oxide as backfill. The results of performance assessment will be presented in this application rather than in the SAR.

Finally, the EEG did participate as an observer of the recent peer review panels that were organized to support development of this application.

9.4.10.11 EEG-41 (1989): Review of the Draft SEIS, DOE Waste Isolation Pilot Plant, April 1989

The DOE published and provided to the public the draft SEIS in 1989 (DOE 1989). The purpose of the SEIS was to update the environmental record established in the 1980 FEIS (DOE 1980a). The EEG reviewed the draft SEIS and provided their comments to the DOE as EEG-41 (see Appendix PEER). The report summary includes the following conclusions/recommendations regarding the SEIS:

- The draft does not adequately justify shipping up to 620,000 cubic feet of TRU waste to WIPP before demonstrating compliance with 40 CFR Part 191.

- Discuss the lack of progress in demonstrating compliance with 40 CFR Part 191.

- Preliminary performance assessment calculations indicate the repository may not meet the EPA standards under human intrusion scenarios. Address this issue and its impact on the proposed action.

- Quantify CH-TRU waste volumes associated with the various alternatives.

- Explain changes in the estimates of waste from the FEIS. EEG recommended (EEG-3) that estimates of the uncertainty of radionuclide inventories be included.

- The calculations of human exposure from the stock water well to beef pathway are incorrect. The correct doses will likely violate EPA standards.

- Address concerns expressed in this review of the SEIS. Issues identified by EEG in its review of the 1980 FEIS were rejected by DOE and have come to pass or have yet to be resolved. The unresolved issues include:

    - Evaluate high pressure gas generation from organic decomposition of the waste which could drive wastes to the surface or form explosive gas mixtures.

    - Estimate the total radioactivity expected to be emplaced at WIPP.

    - An effective control period of 400 years should be established.

    - Information was not adequate on large brine reservoirs.

    - Include estimates of the uncertainties of waste quantities.

- The Site and Preliminary Design Validation (SPDV) program is insufficient to determine the site's geological adequacy.

The DOE reviewed the public and agency comments, including those from the EEG, categorized them and prepared a comment-response document (Volume 3 of the FSEIS [DOE 1990a]) that presents synopses of the comments and the DOE's responses. The SEIS was revised extensively to accommodate the comments received on the draft.

As noted in the Volume 3 comment responses, the WIPP will demonstrate compliance with Part 191 prior to any decision to utilize the WIPP as a permanent waste repository (in fact, the purpose of this application is explicitly to demonstrate that compliance). Other sections of the SEIS, including Sections 3 and 5 and Appendix I were also extensively revised to clarify waste inventories, assess environmental consequences, and readdress release scenarios. It should also be noted that, as promised in the 1990 FSEIS, a disposal phase SEIS is currently in preparation.

9.4.10.12 EEG-50 (1992): Implications of Oil and Gas Leases at the WIPP on Compliance with EPA TRU Waste Disposal Standards

This report (see Appendix PEER) was prepared by Drs. Silva and Channell. The report contends that DOE documentation, including the FEIS (DOE 1980a), the SAR, the Secretary's Decision Plan, and the Implementation of the Resource Disincentives (DOE 1991b) document, is inconsistent and/or inaccurate regarding the presence of two active oil and gas leases and a gas well within the WIPP site boundary.

The report suggests that this situation indicates a need to reexamine the assumption that active institutional control will be completely effective for 100 years after disposal and how much credit should be taken for passive institutional controls between 100 and 10,000 years. The EEG recommends that the DOE be required to publish specific plans on how it intends to maintain active institutional control. Finally, the EEG states that the DOE needs to describe in detail its passive institutional control system and show how it will provide a deterrence to inadvertent human intrusion after 100 years.

The DOE provided specific responses to the issues raised by the EEG report in July and November of 1992 (see Appendix PEER). The DOE's position is that the significant conclusions of EEG-50 relative to institutional controls are incorrect and that none of the documents discussed by the EEG as being inconsistent or inaccurate are a part of the institutional control process at the WIPP. The issue of passive institutional controls was reexamined by a recent peer review panel (see Section 9.3.7).

9.4.10.13 EEG-57 (1994): An Appraisal of the 1992 Preliminary Performance Assessment for the Waste Isolation Pilot Plant

The report (see Appendix PEER) documents the EEG review of the WIPP 1992 performance assessment. The evaluation was prepared by Drs. Lee, Chaturvedi, Silva, and Weiner, and Mr. Neill. A summary of the recommendations from the report were as follows:

- Apply fully coupled codes regarding gas generation, brine flow, and room closure.

- Perform more field and laboratory work regarding transmissivity fields in the Culebra.

- Abandon claiming credit for matrix diffusion and corrensite sorption.

- Show the full uncertainty band of CCDFs.

- Use experimental solubility values, when available, in performance assessment.

- Use only demonstrable retardation coefficients in performance assessment.

- Discard subjective probabilities for human intrusion used in the 1992 Performance Assessment.

- Provide EEG with relevant computer code documentation and access.

- Accelerate experimentation to quantify matrix diffusion and sorption.

- Include the deleterious effect of gas generation in future analysis.

- Show results with physical correlations in performance assessment or explain their absence.

- Accurately reflect the status of resource development near WIPP in performance assessment.

- Use the latest data regarding oil and gas production near WIPP in performance assessment.

- Include methane and radiolytic hydrogen generation in gas calculations.

- Validate gas generation model before incorporation into BRAGFLO.

- Evaluate the criticality issue before concluding its effects are negligible.
- Evaluate and incorporate subsidence effects into human intrusion scenarios.
- Include contaminated brine flow to the surface in human intrusion scenarios.
- Analyze brine-slurry release regarding undisturbed performance and in E2 scenario.
- Do not assume perfect plugging of abandoned oil and gas wells. For the human intrusion borehole, the range of degraded permeabilities should span sand and gravel.
- Performance assessment should include erosion of waste by helical turbulent flow and the effect of sediment erosion. Analyze of other relevant scenarios, such as the E1/E2 with brine slurry discharge to the surface.
- Include ^{135}Cs, ^{129}I and ^{99}Tc and other fission products in PAs.
- Show the basis for inventories used.
- Limit the sampling range to the error bands in experimental data in performance assessments.
- Analyze two-phase transport of volatile organic compounds (VOCs) through gas-fractured interbeds.
- Do not claim credit for corrensite sorption, unless the extent of corrensite or other clay minerals can be quantified along postulated flow paths.
- Do not model movement of VOC vapors as ideal gas flow in showing Part 268 compliance without experimental corroboration.

Specific responses have been provided to the EEG regarding the above comments in a series of transmittals from the DOE. Also, detailed responses to the EEG comments on Volumes 1 through 3 of the 1992 WIPP performance assessment are provided in Appendix PEER (see Appendix PEER documentation supporting Section 9.4.14).

It should be noted that the 1992 performance assessment was not intended to demonstrate compliance with 40 CFR Part 191. The concerns identified by the EEG have been addressed through: (1) the continued development of modeling capability; (2) continued site characterization and experimental data collection activities; and, (3) documentation, review, and quality assurance activities completed to support the demonstration of compliance with applicable regulations. The concerns related to code coupling, gas generation modeling, brine flow to the surface, and waste erosion by helical flow were handled in the 1996 Performance Assessment through model capabilities developed since 1992. The concerns regarding radionuclide transport in the Culebra, solubility values, isotopes considered in transport, and gas-generation validation have been addressed in experimental and characterization programs. Finally, the concerns related to the use of transmissivity fields, CCDF reporting, human-intrusion probabilities, documentation of the values assigned to model parameters, development of scenarios, abandoned-borehole treatment, and inventory basis are addressed in quality-assurance procedures, IRT processes, documentation in the FEPs screening and scenario development process, and in the DOE's implementation of regulatory criteria in 40 CFR Part 191 and 40 CFR Part 194.

Several of the concerns stated by the EEG are not relevant to this application because they concern the transport of non-radioactive substances. The DOE has considered the comments provided by the EEG in preparing the compliance certification application and appropriate revisions were made. In addition, EEG-57 was provided to the recent conceptual models peer review panel for its consideration in evaluating the adequacy of the conceptual models used to describe the WIPP.

9.4.10.14 EEG-61 (1996): Review of the WIPP Draft Application to Show Compliance with EPA TRU Waste Disposal Standards

A draft compliance certification application (DCCA) was prepared by the DOE and provided to the EEG for review. The EEG report (see Appendix PEER) was prepared by Messrs. Neill, Kenney and Walker, and Drs. Chaturvedi, Lee, Clemo, Silva, and Bartlett. The following comments and recommendations were provided in the report:

- The DCCA cannot be considered to be an adequate draft document for demonstrating compliance with 40 CFR Part 191.

- The historical sections of the DCCA omit several significant details.

- Descriptions of alternative conceptual models for projected conditions and processes in the repository and along potential breach pathways, and the defense of the models selected are inadequate.

- Experiments to resolve the conceptual model for radionuclide retardation in the Culebra aquifer, suggested in 1979 by the EEG, should be conducted.

- A basic understanding of the hydrology of the site is yet to be attained.

- The DCCA does not improve on the 1992 WIPP Performance Assessment calculations regarding containment requirements. It does not adequately analyze several potentially disruptive scenarios, establish the probabilities for potential breach scenarios, or provide the basis for calculating consequences.

- Performance-based waste acceptance criteria are mentioned, but not listed.

- There is a lack of commitment to demonstrate compliance with the assurance requirements and none of the 40 CFR § 191.14 elements are adequately addressed: plans for institutional controls have not been prepared; engineered barriers are not addressed appropriately; issues regarding presence of natural resources are not resolved; and, plans for waste retrieval have not been developed.

- Compliance with the individual and groundwater requirements is not adequately demonstrated.

- An analysis of compliance with the DOE orders, and reviews and approvals by the Office of Environment Safety and Health and the Defense Nuclear Facilities Safety Board should be included in the Biennial Environmental Compliance Report (Appendix BECR).

The EEG raises several concerns in its critique of the DCCA. These concerns are considered, generally, as requesting that thorough documentation be provided to support the modeling and assessment conducted. The EEG statement that the DCCA does not demonstrate compliance is accurate, and this document was not intended nor is it purported to be a compliance demonstration; rather, it provided a vehicle for the DOE to begin the process of assembling a complete compliance certification document. This application follows a structure similar to the DCCA, but it contains a through description of the methodology used in performance assessment, utilizes expanded modeling capabilities, expanded historical references, and a discussion of alternative conceptual and mathematical codes. Also, this application either contains or references a much larger body of information related to site characterization, repository design, waste characterization, scenario screening, and performance assessment conceptual and mathematical models and techniques. The EEG concerns regarding assurance requirements criteria in 40 CFR § 191.14 have been addressed in the context of 40 CFR Part 194; concerns regarding the criteria in 40 CFR § 191.15 and 40 CFR § 191.16 are addressed.

In summary, this application has been extensively revised. The DOE has carefully considered the comments provided by the EEG in preparing the application and appropriate revisions were made. In addition, EEG-61 was provided to the recent conceptual models peer review panel for its consideration in evaluating the adequacy of the conceptual models used to describe the WIPP.

9.4.11 Fracture Expert Group Review

SNL convened the Fracture Expert Group (FxG) during the spring of 1993. A summary report of the FxG meeting (see Appendix PEER) was prepared in March 1993.

As discussed in the meeting report, the charter of the group was to:

"*1. Review the current (as of 1993) BRAGFLO model assumptions for permeability and porosity as a function of pressure for their adequacy as first-order representations of the changes in the anhydrite beds adjacent to the waste disposal horizons due to pressurization of the formation.*

2. Recommend improvements in the characterization of changes in permeability and porosity in the anhydrite beds adjacent to the waste disposal horizons due to pressurization of the formation."

An evaluation of the FxG review against the screening criteria is provided in Table 9-18. Since the 19-member FxG contained SNL staff, SNL contractors, and external experts, it was not a truly independent review group. However, the group, and especially the 11 external experts, provided a valuable review of the issues and made several valuable recommendations which were, to a large extent, independent. The group included nationally and internationally recognized expertise in experimental mechanics, materials science, fracture and fluid mechanics, and computational fluid dynamics. The group members were as follows:

Pierre Bérest, Ecole Polytechnique, Palaiseau, France
Barry Butcher, SNL
Peter Davies, SNL
Chandrakant Desai, University of Arizona
Dick Ewing, Texas A&M University
Mert Fewell, SNL
Mel Friedman, Texas A&M University
Bezalel Haimson, University of Wisconsin
Samuel W. Key, RE/SPEC Inc.
Jane Long, Lawrence Berkeley Laboratory
Darrell Munson, SNL
Sia Nemat-Nasser, University of California-San Diego
Karsten Pruess, Lawrence Berkeley Laboratory
Thomas Russel, University of Colorado at Denver
Chin-Fu Tsang, Lawrence Berkeley Laboratory
Palmer Vaughn, Applied Physics Inc.
Wolfgang Wawersik, SNL

Table 9-18. Fracture Expert Group

1. Is the "peer review" relevant to the CCA?	Partially - Although the FxG reviewed the BRAGFLO conceptual model, its focus was primarily related to compliance with Part 268, rather than Part 191, requirements.
2. Was there a formal report prepared by the reviewer?	Yes - Meeting summaries were prepared.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The FxG reviewed the adequacy of 1993 BRAGFLO model assumptions as they relate to repository pressurization.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Partially - The FxG's purpose was as much to recommend improvements in BRAGFLO as to evaluate its adequacy.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - Group members are recognized experts in their respective fields.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Partially - The 19-member FxG contained SNL staff, SNL contractors, and external experts so it was not a truly independent review group. However, the eleven external experts provided valuable review and recommendations from an independent and impartial perspective.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	Yes - The FxG provided valuable review of one of the conceptual models used in PA.

Stephen Webb, SNL
Teng-Fong Wong, State University of New York-Stonybrook

The meeting summary report concluded that "The proposed first-order model in BRAGFLO for representing changes in permeability and porosity due to pressure-induced changes in the anhydrite is an acceptable first approximation." The FxG report also made recommendations for additional studies to support an extended and improved second-order model in BRAGFLO for simulating the two-phase flow occurring in the altered anhydrite MBs (MB138 and MB139). These recommendations are summarized in the FxG report (Appendix PEER).

Recommendations by the FxG for additional studies of fracturing were driven by concerns regarding the gas-phase transport of VOCs away from the repository via pressure-induced fractures. Gas-phase transport is not a mechanism that could contribute to actinide releases from the disposal system. The DOE therefore concludes that the current performance assessment model used to approximate the effects of pressure-induced fracturing, which is a refinement of the model presented to the FxG, is adequate for use in estimating actinide releases from liquid-phase transport. The FxG meeting summaries were provided to the recent conceptual models peer review panel for consideration during its evaluation of the WIPP conceptual models.

9.4.12 Fanghänel Review - WIPP Thermodynamic Model for Trivalent Actinides

Dr. Thomas Fanghänel of the Institut für Nukleare Entsorgungstechnik, Forschungszentrum Karlsruhe, Germany, was contracted to perform an independent review of the thermodynamic models WIPP has developed to predict potential dissolved concentrations of actinides in WIPP brines. An evaluation of his review against the screening criteria is provided in Table 9-19.

He was tasked to provide an independent assessment of the methods used to estimate the dissolved concentrations of III, IV, and VI actinides. For the V actinides, he performed an independent assessment of the WIPP augmentation of his Np(V) thermodynamic model, as well as its use for estimating dissolved concentrations of V actinides in WIPP brines. He performed the review and submitted his final report, dated May 7, 1996. A copy of the full report is provided in Appendix PEER.

Dr. Fanghänel is an internationally recognized expert regarding the thermodynamic modeling of actinides and is completely independent of the WIPP project. His qualifications include extensive experience with the development and evaluation of thermodynamic models for actinides. He is first author of a journal publication documenting the Np(V) dissolved concentration model that serves as the basis for the WIPP +V actinide dissolved concentration model.

Table 9-19. Fanghänel Review of the WIPP Thermodynamic Model for Trivalent Actinides

1. Is the "peer review" relevant to the CCA?	Yes - The reviewer evaluated one of the models used in the WIPP PA.
2. Was there a formal report prepared by the reviewer?	Yes - A report was prepared.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The work was a review of the WIPP thermodynamic model for predicting dissolved concentrations of trivalent actinides in WIPP brines.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The review evaluated the adequacy of the WIPP thermodynamic model for trivalent actinides.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - Dr. Fanghanel is an internationally recognized expert.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - The reviewer is independent of the WIPP project.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

The following paragraphs are quoted from Dr. Fanghänel's report:

"*For the WIPP thermodynamic model the ion interaction approach (Pitzer equations)* was chosen for modeling the excess properties of the aqueous solution (activity coefficient model). At present, the Pitzer approach is the most sophisticated semiempirical approach for the Gibbs excess energy of a concentrated electrolyte solution. It is widely used and a database with ion interaction parameters covering a large variety of different solution species is available.....

The WIPP model treats the interaction of AN(III) with Cl^- and SO_4^- as strong ion-ion interaction without invoking the formation of complex species. Within the composition range of the WIPP brines, this is a reasonable approach, which was demonstrated in several comparisons between model calculations and data...

The applied assumptions for the development of the WIPP thermodynamic model are conservative and simplify the overall model. This is a prerequisite for calculating dissolved actinide concentrations in the very complex repository system.

In general, the model represents the present state of the knowledge of aqueous solution thermodynamics. The chosen activity coefficient model and the applied data base are, with a few exceptions, suitable for calculating maximum trivalent actinide concentrations in WIPP brines.

The model needs to be improved in some parts. This concerns in particular the hydrolysis equilibria of trivalent actinides which have to be introduced into the model. Moreover, the reviewer recommends that the model regarding the interaction of carbonate complexes in concentrated electrolyte solutions be refined."

In accordance with Dr. Fanghanel's suggested improvement in the model concerning the hydrolysis equilibria of trivalent actinides, the recommended data have been incorporated into the CHEMDAT database. Regarding the second suggestion, carbonates are no longer considered to be significant to repository performance due to the implementation of magnesium oxide backfill.

9.4.13 Independent Technical Review of the Bin and Alcove Test Programs

The objective of this Independent Technical Review (ITR) team assessment of proposed TRU waste experiments at WIPP, as specified in the charter, was to:

"Review the need for, and technical validity of, the Bin and Alcove test programs, as defined in the Test Phase Plan, the Technical Needs Assessment Document, and individual test plans."

The team consisted of nine technical personnel from the DOE, LANL, Lawrence Livermore National Laboratory (LLNL), and private consultants. The team members had a large amount of expertise and experience in mechanical, chemical and civil engineering, earth and environmental science, and geology. The team was composed of the following members:

- Stephan Brocoum (Team Leader), DOE, Office of Geologic Disposal
- Philip Thullen (ITR Team Leader), LANL
- Deborah Bennett (ITR Team Leader), LANL
- Richard Beddoes, Golder Associates
- Corale Brierley, Private Consultant
- Jan Docka, Roy F. Weston, Inc.
- Joseph Farmer, LLNL
- Ron Guimond, Ogden Environmental and Energy Services
- Stan Kosiewicz, LANL
- Abraham Lerman, Northwestern University
- John Shaler, Private Consultant
- Terry Steinborn, Applied Research Associates, Inc.
- Dave Swale, British Nuclear Fuels Limited

Although the independence of the ITR could be questioned because of the presence of a DOE staff member as Team Leader, Dr. Brocoum, as a Director in the Office of Geologic Disposal, had no responsibility or authority as regards the WIPP project. Further assurance of the independence of the team was provided by the credentials and professional stature of the team members and the direct oversight of the ITR review by the Technical Oversight Board (TOB). The independence and technical qualifications of the ITR members were verified by several parties prior to commencement of work. A summary evaluation of the ITR team against the screening criteria for peer reviews is shown in Table 9-20.

The team began it's review in July, 1993, and completed a final report (see Appendix PEER) in December of that year. The review process consisted of document review, formal presentations by the DOE and its contractors and other groups, and interviews with personnel. The team met several times to develop consensus on issues and recommendations and to prepare its report.

A TOB was chartered to review all aspects of the ITR team's activities. The TOB was composed of senior level individuals who have extensive experience in the development, execution, management and evaluation of large and technically involved projects. The TOB members included

- Dr. Colin Heath (Chairman), GC Management Associates
- Mr. Richard Baxter, Independent Consultant

Table 9-20. Independent Technical Review of the Bin and Alcove Test Programs at the WIPP

1. Is the "peer review" relevant to the CCA?	Yes - This review addresses waste characterization and gas generation issues.
2. Was there a formal report prepared by the reviewer?	Yes - There was a formal report.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - This review addressed the adequacy of plans for testing to be done for waste characterization and performance assessment.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - This review addressed the adequacy of the work and made recommendations for changes.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - The team members are recognized as experts in their respective disciplines.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - Although the Team Leader was a DOE staff member, he had no organizational responsibility for the WIPP project. Also, the professional stature of the ITR members and the oversight of the Technical Oversight Board served to ensure the independence of the ITR team review.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

Mr. William Hamilton, Independent Consultant
Dr. Mujid Kazimi, Massachusetts Institute of Technology
Mr. Dennis Lachel, Lachel and Associates, Inc.
Mr. John Maddox, Independent Consultant
Ms. Debra Marsh, Marsh Consulting Group, Ltd.

They provided a solid reference point of experience and ideas against which the ITR team tested its ideas regarding lines of inquiry, and the logic and validity of findings and conclusions. The results of the review were discussed with the TOB, and their guidance was used in preparation of the ITR report.

The following statements are excerpted from the "Executive Summary" of the ITR report.

"*Principal Assessment*

The review team concluded that: ***there is no scientific, regulatory, or operational imperative to perform the Bin or Alcove tests at WIPP with radioactive waste****. Other tests can and should be performed at WIPP and elsewhere to confirm information used for regulatory compliance demonstration and certification. This is an assessment of the technical justification for the tests, not of the ability of site personnel to perform the tests or of the repository to accept TRU waste.*

Path Forward Recommendation

Preparation and submission of compliance and permitting packages at the earliest possible date are the foundation of the recommended path forward. All other near term work elements should support these activities. All regulatory permits, approvals, and certification should be acquired before any in situ confirmatory or operational tests are performed in WIPP with radioactive waste.

A lack of clear guidance from cognizant regulators on specific requirements for regulatory compliance should be the only source of future delay in operating WIPP as a TRU waste repository. While most, although not all, of the relevant regulations exist, no clear statement of what constitutes acceptable submissions has been produced by the regulatory bodies....The ITR team believes that delay will be minimized by making the regulators part of the process through early submission of the regulatory packages.

Although all regulations do not exist and existing regulations may change, the ITR team believes that sufficient gas generation information is available to complete the performance assessments and other elements required to prepare and submit compliance and permitting packages within 18 months. The recommended conceptual

> *compliance and permitting process will allow the TRU waste disposal phase to begin in three years if specified milestones are met...*
>
> *Bench-scale laboratory tests using simulated and/or actual waste should be continued or completed, and additional tests initiated if required. Results of bench-scale tests will not only explain individual gas generation mechanisms but also the synergistic effects of combined mechanisms....*
>
> *..... These tests can be performed above ground, at WIPP or elsewhere, unencumbered by mine safety regulations.."*

As recommended by the ITR, the bin and alcove tests were subsequently abandoned and the WIPP program was redirected to completing the regulatory compliance documentation on an accelerated schedule. Bench-scale laboratory tests using actual TRU wastes are being conducted at LANL and the INEL.

9.4.14 Performance Assessment Reviews

In 1989, SNL prepared a performance assessment methodology report (Marietta et al. 1989) which provided information on the performance assessment process that was being developed to demonstrate compliance with criteria under development for 40 CFR Part 191, Subpart B. Formal comments on the methodology report were provided to the DOE by the EPA and the New Mexico Environment Department (NMED). The DOE responses to the comments were subsequently provided in the 1990 Performance Assessment report.

The DOE, through SNL, published iterative performance assessment reports describing the WIPP disposal system beginning with the first performance assessment report in 1990 (Bertram-Howery et al. 1990), followed by subsequent iterations in 1991 and 1992. Each updated report constituted a substantial revision of the previous document based on new information, experiments and comments from interested individuals. With regard to comments from interested parties, a number of these reviews could be classified as peer reviews for the purposes of this application. An evaluation of these reviews against the screening criteria for peer reviews is provided in Table 9-21.

This section is grouped into four divisions: Section 9.4.14.1 addresses the review of the 1990 Performance Assessment report; Section 9.4.14.2 addresses 1991 Performance Assessment report reviews; Section 9.4.14.3 addresses reviews of the 1992 Performance Assessment report: and Section 9.4.14.4 summarizes the DOE's responses to the comments provided to the DOE as a result of those reviews. Only comments from the EPA, the New Mexico State Attorney General (AG), the NMED, and Intera, Inc. are discussed in this section. Comments from groups such as the NAS and the EEG are addressed in Sections 9.4.1 and 9.4.10, respectively.

Table 9-21. External Review of the WIPP Performance Assessment Reports

1. Is the "peer review" relevant to the CCA?	Yes - The reviews specifically focused on the PA reports.
2. Was there a formal report prepared by the reviewer?	Yes - The reviews evaluated the adequacy of the WIPP PA reports.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The reviews addressed the adequacy of the PA reports.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The reviews were based on evaluations of the PA.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - The reviewing organizations are recognized as experts in their respective disciplines.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Yes - The reviewers were independent of the WIPP project.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	N/A

9.4.14.1 1990 Performance Assessment Report

The first performance assessment report (Bertram-Howery et al. 1990) was issued in December 1990. As noted above, the 1990 report provided responses to the EPA and NMED comments that had been received on the 1989 methodology document.

Several groups reviewed and commented on the 1990 report. In particular, several requests were made from the NMED and others for additional clarification of several aspects of the report. Specific responses to the comments provided by the various reviews were developed and subsequently documented in the 1991 Performance Assessment report.

9.4.14.2 1991 Performance Assessment Report

The second performance assessment report (WIPP Performance Assessment Division 1991) was issued in December 1991. The 1991 report included responses to comments that had been received from the reviews of the 1990 report.

Intera, Inc. was requested by the SNL WIPP Performance Assessment Division to review Volumes 1-4 of the 1991 WIPP Performance Assessment report (WIPP Performance Assessment Division 1991). Although the independence of the review could be questioned because it was contracted directly by the WIPP Performance Assessment Division, it is provided here for completeness; the results of the review were important in establishing the direction of performance assessment. The review's purpose, as stated in the Intera report (see Appendix PEER), was to consider

> *"technical questions pertaining to the performance assessment methodology and its application and results, as well as issues of organization, presentation and flow of information between the various sections, chapters and volumes."*

The review is contained in a March 1992 report (see Appendix PEER). The report summary states the following:

> *"Our major technical concerns are in the general area of treatment of uncertainty in the assessment, including in particular treatment of scenario uncertainty, data and parameter uncertainty, and model uncertainty...."*

> *"We have also suggested a possible modification to the methodology for generating CCDFs for human intrusion events, and have noted that the treatment of human intrusion, as a particular class of scenarios, is imbalanced in places..."*

> *"With regard to presentation and organization of the report, there is substantial room for improvement....In particular, the report is excessively long, and very much in need of a good summary of the order of 100 pages (or less). More attention needs to be paid*

to the relevance of the information presented to the final assessment results, and to the potential audience for the report. Excessive use of mathematics is made throughout the report, and figures are too few in number, are poorly explained or are too complex. In addition, relatively minor errors are rife, particularly in Volume 3."

The Intera comments were carefully considered by SNL during the preparation of the succeeding report. Accordingly, appropriate modifications were incorporated in the 1992 Performance Assessment report. Specific responses to the various third-party reviews were documented in the 1992 Performance Assessment report.

9.4.14.3 <u>1992 Performance Assessment Report</u>

The third performance assessment report (WIPP Performance Assessment Department 1992) was published in December of 1992. This report provided responses to comments that had been received on the 1991 Performance Assessment report. As with the earlier performance assessment reports, several groups reviewed, and provided comments on, the 1992 report. In particular, the EPA, the NMED, the EEG, and the AG provided comments to the DOE. Comments received from the EPA, NMED, and the AG are discussed below. Comments from the EEG are discussed in Section 9.4.10.13.

9.4.14.3.1 <u>EPA Review of the 1992 Performance Assessment Report</u>

The EPA's review of the 1992 iteration of performance assessment was provided in two separate transmittals. The first group of review comments addressed only Volumes 1 through 3. The second set of comments primarily addressed Volumes 4 and 5.

<u>Review of Volumes 1 through 3</u>

In January 1994, the EPA provided extensive comments on Volumes 1 through 3 of the 1992 iteration of the performance assessment. The EPA grouped its discussion of the issues into six primary categories: (1) format and content; (2) access to information; (3) regulatory issues; (4) use of expert panel elicitation and investigator judgement; (5) models; and (6) QA. The EPA comments and the DOE responses for each comment are provided in Appendix PEER.

<u>Volumes 4 and 5</u>

In October of 1994, the EPA provided final comments to the DOE on the 1992 iteration of performance assessment. Although the comments addressed the entire performance assessment, the primary focus was Volumes 4 and 5. The EPA grouped its comments into five primary categories: (1) scenarios, (2) BRAGFLO and SANCHO computer code relationships, (3) Culebra groundwater modeling, (4) inventory, and (5) institutional controls. The EPA comments and the DOE responses for each comment are provided in Appendix PEER.

9.4.14.3.2 New Mexico Attorney General Review of the 1992 Performance Assessment Report

The New Mexico Attorney General also provided comments on the 1992 Performance Assessment report. These comments are provided in Appendix PEER, together with the DOE responses.

As part of his review, the Attorney General contracted with Dr. Elisabeth Paté-Cornell. Dr. Paté-Cornell is a Professor of Industrial Engineering and Engineering Management at Stanford University and is currently president of the Society for Risk Analysis. She has written and lectured extensively on probabilistic risk assessment and has testified in Congress on proposed legislation on the subject. Dr. Paté-Cornell prepared a report for the Attorney General, entitled "Conservatism of the Performance Assessment and Decision Criteria for WIPP." The comments are provided in Appendix PEER with a cover letter documenting its transmittal from the AG to the DOE.

9.4.14.3.3 NMED Review of the 1992 Performance Assessment Report

The NMED also provided comments on the 1992 Performance Assessment report. The comments are provided in Appendix PEER together with the DOE responses. The NMED's comments were detailed but focused upon several issues relevant to screening scenarios and events for performance assessment. Within this context the NMED provided detailed comments on three primary issues:

- additional groundwater migration pathways: the Dewey Lake (Redbeds) Formations and Magenta Member of the Rustler;

- subsidence potential related to dissolution of evaporite units caused by downward percolation of meteoric or groundwater through inner or outer zones of boreholes; and,

- subsidence potential related to extraction of oil and gas adjacent to the facility boundary.

9.4.14.4 DOE Response to Comments on the 1990, 1991, and 1992 Performance Assessment Reports

In summary, the DOE responded to comments from interested groups and individuals by revision of subsequent performance assessment reports and by providing specific responses to those comments in the subsequent reports. Chapter 6.0 is the result of many years of work on performance assessment activities by the DOE. Performance assessment has undergone extensive revision as a result of input from groups such as the EPA, the NMED, the EEG, and the Attorney General.

9.4.15 Technical Support Group Reviews

During 1993, the Technical Support Group (TSG) was tasked by the DOE to provide recommendations on the following topics:

- Experimental Plan for Tracer Testing in the Culebra Dolomite
- Performance Assessment Parameters
- Large-Scale Seals Test Program.

Evaluation of the resulting reviews against the screening criteria developed for this application indicated that the first two appear to qualify as peer reviews (see Table 9-22). As regards the large-scale seals test program, it was determined that the review team was mostly comprised of subcontractors with a long working relationship with the WIPP project. The reviewers' independence could also be questioned for the other two reviews; however, the case for the review's independence was stronger. These reviews are included in this application for the sake of completeness and because they were significant in terms of the performance assessment program. The reports were provided to the appropriate recent peer review panels for consideration. A brief discussion of the selected reviews is presented below.

The members of the review teams included expertise in geochemistry, geomechanics, hydrology, physical chemistry, NEPA compliance, performance assessment, and waste management. The members involved in the reviews included the following:

Paul Drez (TSG Core Member), Independent Consultant
Paul Cloke, Science Applications International Corporation - Nevada
David Dennison, Advanced Sciences, Inc. - Denver
Darrel Dunn, Advanced Sciences, Inc. - Denver
John Kircher, Battelle
David Lechel, Independent Consultant
John Schatz, Independent Consultant
Jim Tollison, Independent Consultant
Rose Zeiler, Advanced Sciences, Inc. - Denver

9.4.15.1 Review of Experimental Plan for Tracer Testing in the Culebra Dolomite

The review team was asked to address whether additional experiments for fluid flow and transport characterization of the Culebra are necessary. Additionally, if these experiments were determined to be necessary, the team was asked to evaluate whether the planned Culebra Tracer Tests, as described in the proposed Test Plan, would provide the data necessary to establish whether the Culebra retards radionuclide transport sufficiently to demonstrate that the Culebra is an effective geologic barrier.

Table 9-22. Technical Support Group Reviews

1. Is the "peer review" relevant to the CCA?	Yes - The reviews involved aspects of site characterization and PA.
2. Was there a formal report prepared by the reviewer?	Yes - Reports were prepared.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The reviews addressed the adequacy of WIPP plans and programs.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The reports addressed the adequacy of work prepared by the WIPP project.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Yes - The reviewers are recognized experts in their respective disciplines.
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Partially - Although several of the reviewers were independent, some of the TSG members involved in the reports discussed in this section routinely participated in the WIPP Project over a period of several years as subcontractors to the DOE.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	Yes - The reports were significant in terms of their impact on the WIPP performance assessment program. The reports were also provided to the recent peer review panels.

The formal report that was prepared by the team as a result of the review is provided in Appendix PEER, together with the transmittal letter to the DOE.

The recommendations from the TSG report on tracer testing in the Culebra dolomite were considered in the planning of ongoing hydrological studies and testing performed at the WIPP site. In addition, the review resulted in enhanced communication between the Principal Investigators generating data and the performance assessment staff. The TSG report was provided to the recent conceptual models peer review panel for its consideration.

9.4.15.2 Performance Assessment Parameters

A copy of the report that resulted from the TSG review of the performance assessment parameters is provided in Appendix PEER. The purpose of the TSG review, as stated in the transmittal letter to the DOE, was to

> *"conduct a detailed review of many of the parameters that form the basis for the PA calculations for the WIPP Project. This effort emphasized the key 49 PA parameters that were sampled in the 1992 PA calculations, and, as time permitted, included a preliminary review of an additional 80 parameters. Data type, data quality, data interpretation, and source documentation were evaluated and each reviewer categorized the data based on their professional judgment. A database called PERFORM was developed to help in the management of the reviews."*

From the report's "Summary of Findings," the team concluded that

> *"Results of the TSG review of PA parameters indicate that improvement is needed in areas of Data Quality, Data Interpretation, and Source Documentation. It is the opinion of the TSG that this needs to be accomplished to ensure regulatory compliance.*

IRTs were subsequently formed to specifically review, and qualify where appropriate, existing data. As discussed in Chapter 5.0, the IRTs were successful in qualifying a large amount of the data that had been collected prior to establishment of a qualified QA program. Data which were not qualified by the IRTs were qualified by three of the recent peer review panels, as discussed in Sections 9.3.4, 9.3.5, and 9.3.6.

Performance assessment parameter values were developed and controlled in accordance with the SNL QAPD and QAPs. QAP 9-2 was developed and used to document the selection, development, and entry of parameter values used in the performance assessment. The performance assessment database is controlled and maintained using SNL QAP 9-4. This QAP establishes the process for ensuring that parameter values and their associated documentation are maintained in a traceable, retrievable, and controlled environment and allow for the reproducibility of results.

Once the requirements controlling the development of parameter values (QAP 9-1 or QAP 9-5) are fulfilled, the parameter/distribution development is documented or referenced on the applicable WIPP Parameter Entry Form (Form 464). Form 464 provides a traceable link to the qualification of those portions of the data packages that support the parameter development.

9.4.16 NEPA Reviews

The NEPA requires formal analysis, documentation and an appropriate level of review for proposed major federal actions involving potentially significant environmental impacts. NEPA documentation and the associated public review and comment periods have provided environmental input and opposing viewpoints from a variety of sources for the DOE decisions regarding development of the WIPP. An evaluation of the external NEPA reviews against the screening criteria is provided in Table 9-23.

NEPA documentation of the WIPP includes the 1980 FEIS (DOE 1980a) and the 1990 FSEIS (DOE 1990a). Another environmental impact statement, the Disposal Phase Supplemental Environmental Impact Statement (SEIS-II) is currently in preparation.

A Draft Environmental Impact Statement (DEIS) (DOE 1979) was prepared by the DOE and provided to the public for review in April 1979. The significance of impacts associated with the various alternatives were assessed. Comments on the DEIS were obtained during seven days of public hearings and a 141-day written-comment period. A total of 167 persons presented oral statements on the WIPP during the public hearings that were held in Santa Fe, Carlsbad, and Hobbs, New Mexico; Idaho Falls, Idaho; and, Odessa, Texas. Ninety-three letters, several longer than 50 pages, were received during the written-comments period. Commenters included: federal agencies such as the EPA, the NRC, the Department of the Interior, and the Department of Health, Education and Welfare; agencies from at least 26 states, including several New Mexico agencies; and, groups such as the EEG.

In response to the comments, the DEIS was extensively revised to prepare the FEIS, which was published in October 1980. Comments were grouped into 30 major issues, which were then discussed in Chapter 15 of the FEIS. Appendix P of the FEIS reproduced in full the comments received from various federal agencies and the cover letters from all official responses from the various states. Copies of all comments received, including transcripts of the public hearings, were placed in the DOE public reading rooms for WIPP. The DOE Record of Decision, published January 28, 1981, announced the DOE decision to proceed with the construction of surface and subsurface facilities in southeastern New Mexico.

Table 9-23. NEPA Documentation Reviews

1. Is the "peer review" relevant to the CCA?	Yes - NEPA documentation addresses long term performance, siting issues, mitigation, etc. which are directly CCA relevant.
2. Was there a formal report prepared by the reviewer?	Yes - The results of the public reviews were submitted to the DOE. The DOE formally compiled comments and responses.
3. Was the review a "peer review" rather than a "technical review"? a. A peer review's purpose is to confirm the adequacy of the work being reviewed. b. A technical review verifies compliance to predetermined requirements; industry standards; or common scientific, engineering and industry practice.	Yes - The reviews focussed on the adequacy of NEPA documentation prepared for the DOE.
4. Was the review a "peer review" rather than an "expert judgment"? a. A peer review confirms the adequacy of the work being reviewed. b. An expert judgment is used to elicit either numerical values for parameters (variables) or essentially unknowable information.	Yes - The review evaluated the adequacy of environmental documentation produced for the DOE.
5. Was the technical expertise of the reviewer at least that needed to perform the original work?	Mixed - The technical expertise of the reviewers varied widely, but included several public agencies and oversight groups (e.g., NRC, EEG).
6. Were the reviewers independent? a. Were the reviewers involved as a participant, supervisor, technical reviewer or advisor in the work being reviewed? b. Did the reviewers have sufficient freedom from funding considerations to assure the work was impartially reviewed?	Mostly - Very few of the reviewers had any affiliation with the WIPP or DOE.
7. If the answer to any of the above questions is no, is there an overriding consideration which would still serve to qualify the review as an appropriate and acceptable "peer review"?	Yes - The public comments on the WIPP NEPA documents have, in aggregate, provided an extensive and thorough review of many issues, several of which are relevant to the CCA.

A draft SEIS (DOE 1989) was published and provided to the public in April 1989. During the 90-day comment period, the DOE held nine public hearings at locations in Colorado, Georgia, Idaho, New Mexico, Oregon, Texas, and Utah. In addition to the testimony of nearly 1,000 individuals who spoke at the hearings, the DOE received 1,275 written documents and two petitions with a combined total of approximately 2,200 signatures.

The DOE reviewed the comments, categorized them by issue, revised the draft SEIS as appropriate, and prepared a comment-response document (Volume 3 of the FSEIS) that presents synopses of the comments and the DOE's responses. Indices to the comments were provided in Volumes 4 and 5 of the FSEIS and served to help locate specific questions or statements and the DOE response. Volumes 6 through 13 of the FSEIS reproduce the public comments received on the draft SEIS and transcripts of oral testimony provided during the public hearings. The draft SEIS was extensively revised, as a result of the comments, in development of the FSEIS, which was published in January 1990. The Record of Decision, dated June 22, 1990, documented the DOE determination to proceed with the phased development of the WIPP. The Record of Decision included a commitment to prepare SEIS-II before deciding whether to proceed with the WIPP disposal phase.

Preparation of the SEIS-II has been initiated. Public scoping activities have included

- publishing a Notice of Intent in the Federal Register on August 23, 1995 and a notice reopening the comment period, published on October 13, 1995,

- a public comment period from August 23, 1995 to October 16, 1995, and

- public scoping meetings held in Carlsbad, Albuquerque, and Santa Fe, New Mexico, in Boise, Idaho, and two meetings in Denver, Colorado.

The Implementation Plan (DOE 1996d), published in May 1996, documents the results of the scoping process and provides guidance for preparing SEIS-II. The public will have another opportunity to provide formal input and opposing viewpoints on the WIPP project during the SEIS-II development.

9.5 Current International Reviews

The WIPP project is participating in two ongoing peer review efforts by the international community. Both reviews involve performance assessment activities and are being managed by the Organization for Economic Cooperation and Development Nuclear Energy Agency (NEA). Participation in these international review activities allows WIPP to benefit from the experience of the world's leading experts in nuclear waste disposal and to take into account the approaches followed by other countries toward the safe disposal of radioactive waste.

9.5.1 NEA/International Atomic Energy Agency (IAEA) Review

Agreement was reached on June 7, 1996 between the DOE, the NEA and the IAEA to organize an international peer review of the long-term safety analysis of the WIPP. The objective of the joint NEA/IAEA peer review will be to examine whether the postclosure assessment of the WIPP described in this application is appropriate, technically sound and in conformity with international standards and practices.

The peer review will be organized jointly by the NEA and the IAEA and will be managed by the NEA. The agencies will appoint a group of independent international experts in the various disciplines involved in long-term safety assessments, such as geology, geochemistry, material sciences, radiation and environmental protection, and nuclear safety. This expert group, which will conduct the review, will include representatives from nuclear regulatory bodies, radioactive waste management agencies, universities and research institutions.

The review will begin in October 1996 and be conducted over a six-month period. The review will be based on detailed documentation provided by the DOE, a site visit to the WIPP, and discussions with the specialists in the WIPP project. A report containing the international expert group's findings will be developed during the review period.

9.5.2 GEOTRAP

GEOTRAP is an NEA project whose main objective is to build confidence in predictive modeling of radionuclide transport in geologic, heterogeneous media. The project focuses on the exchange of information and in-depth discussions on present approaches to acquiring and evaluating field data, testing, and developing adequate defensible models for performance assessment. The WIPP project's involvement in this project ensures the serious evaluation of its data collection and transport modeling efforts by experts from the international community.

A series of workshops will be held to promote the interaction and collaboration among scientists working in the relevant disciplines and the experts who are responsible for safety assessment studies and for site characterization and evaluation. Public status reports will review and summarize the lessons learned and put them into perspective.

The project is projected to run for a period of three years (starting August 1996). The following five workshops have been planned to date:

1. Field Tracer Transport Experiments: Design, Modeling, Interpretation, and Role in Predicting Radionuclide Transport;

2. Basis for Modeling the Effect of Spatial Variability on Radionuclide Migration;

3. The Characterization of Water Conducting Features and their Representation in Models of Radionuclide Migration;

4. Approaches to Confidence Building in Site-Specific Models of Radionuclide Migration for the Purposes of Performance Assessment; and,

5. Geological Evidence and Theoretical Bases for Radionuclide Retention Processes in Heterogeneous Media.

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