530184

Sandia National Laboratories
Waste Isolation Pilot Plant

Features Events and Processes Reassessment for Recertification Report

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Sandia is a multiprogram laboratory operated by Sandia Corporation, a Lockheed Martin Company, for the United States Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

WIPP: 1.3.5.2.1.3: PLN: QA-L: DPRPI: PKG 523933

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ACRONYMS

CAG	Compliance Application Guidance
CARD	Compliance Application Review Document
CCA	Compliance Certification Application
CCDF	complementary cumulative distribution function
CDF	cumulative distribution function
CFR	Code of Federal Regulations
CH	contact-handled
CRA	Compliance Recertification Application
DBDSP	Delaware Basin Drilling Surveillance Program
DFR	driving force ratio
DOE	U.S. Department of Energy
DP	disturbed performance
DRZ	disturbed rock zone
EDTA	ethylene diamine tetra-acetate
EPA	Environmental Protection Agency
EPs	events and processes
ERMS	Electronic Record Management System
FEPs	features, events, and processes
FLAC	Fast Lagranian Analysis of Continua
H	human
HCN	historic, current and near future
LWA	Land Withdrawal Act
MB	marker bed
MgO	magnesium oxide
N	natural
NMBMMR	New Mexico Bureau of Mines and Mineral Resources
PA	performance assessment
PAVT	performance assessment verification test
RH	remote-handled
RTC	Response to Comments Document
SKI	Statens Kärnkraftinspektion
SMC	Salado mass concrete
SNL	Sandia National Laboratories
SO-C	screened-out consequence
SO-P	screened-out probability
SO-R	screened-out regulatory
TRU	transuranic
TSD	Technical Support Document
UP	undisturbed performance
VOCs	volatile organic compounds
W	waste and repository-induced
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant
WPO	WIPP Project Office

1. INTRODUCTION

The United States Department of Energy (DOE) has developed the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico for the disposal of transuranic wastes generated by defense programs. In May of 1998, the Environmental Protection Agency (EPA) certified that the WIPP would meet the disposal standards (EPA 1998a) established in Title 40 Code of Federal Regulations (CFR) Part 191, Subparts B and C (EPA 1993), thereby allowing the WIPP to begin waste disposal operations. This certification was based on performance assessment (PA) calculations that were included in the DOE's Compliance Certification Application (CCA) (DOE 1996a). These calculations demonstrate that the cumulative releases of radionuclides to the accessible environment will not exceed those allowed by the EPA standard.

To assure that PA calculations account for important aspects of the disposal system, features, events, and processes (FEPs) considered to be potentially important to the disposal system are identified. These FEPs are used as a tool for determining what phenomena and components of the disposal system can and should be dealt with in PA calculations. For the WIPP CCA, a systematic process was used to compile, analyze, screen and document FEPs for use in PA. The FEPs assessment process is described in detail in Section 6.4 in the CCA and the results of the original assessment are contained in CCA Appendix SCR.

The WIPP Land Withdrawal Act (LWA) (U.S. Congress 1992) requires the WIPP to be recertified (demonstrate continued compliance with the disposal standards) every five years. As such, the DOE must submit a recertification application that demonstrates to EPA that the WIPP continues to comply with their requirements for radioactive waste disposal. The DOE will describe changes to the WIPP long-term compliance baseline during the previous five-year period in the Compliance Recertification Application (CRA). This document describes the process and results of the CCA FEPS baseline reassessment for the CRA. The results of this reassessment will be presented to the EPA for recertification in a revised Appendix SCR (or equivalent document).

The process used to reassess the FEPs for recertification mirrors that used for the CCA except that the focus for this reassessment was to assess the validity of the original arguments and decisions in consideration of new or different information that has become available since WIPP's initial certification. Administrative changes have also been made to the FEPs baseline to align EPA and DOE FEPs numbering schemes.

This reassessment has concluded that, of the original 237 FEPs, 106 have not changed (67 element 1 FEPs and 39 no-change reassessed FEPs). Additionally, 120 FEPs required updates to their FEP descriptions and/or screening arguments. Seven of the original baseline FEPs screening decisions required a change from their original screening decisions. Four of the original baseline FEPs have been deleted or combined with other closely related FEPs. Finally, two new FEPs have been added to the baseline. These two FEPs were previously addressed in an existing FEP; they have been separated for clarity. Table 1.1 summarizes the CRA FEP reassessment results.

EPA FEP I.D.	FEP Name	Summary of Change
Table 1.1 FEPs Reassessment Summary Results		
FEPs Combined with other FEPs		
N17	Lateral Dissolution	Combined with N16, *"Shallow Dissolution."* N17 removed from baseline.
N19	Solution Chimneys	Combined with N20, *"Breccia Pipes."* N19 removed from Baseline.
H33	Flow Through Undetected Boreholes	Combined with H31, *"Natural Borehole Fluid Flow."* H33 removed from baseline.
W38	Investigation Boreholes	Addressed in H31, *"Natural Borehole Fluid Flow,"* and H33, *"Flow Through Undetected Boreholes."* W38 removed from baseline.
FEPs With Changed Screening Decisions		
W50	Galvanic Coupling	SO-P to SO-C
W68	Organic Complexation	SO-C to UP
W69	Organic Ligands	SO-C to UP
H27	Liquid Waste Disposal	SO-R to SO-C
H28	Enhanced Oil and Gas Production	SO-R to SO-C
H29	Hydrocarbon Storage	SO-R to SO-C
H41	Surface Disruptions	SO-C to UP (HCN)
New FEPs for CRA		
H58	Solution Mining for Potash	Separated from H13, *"Potash Mining."*
H59	Solution Mining for Other Resources	Separated from H13, *"Potash Mining."*

2. ORIGINAL FEPS PROCESS

2.1 Requirement for Features, Events and Processes

The origin of FEPs is related to the EPA's radioactive waste disposal standard's requirement to use PA methodology. The DOE was required to demonstrate that the WIPP complied with the Containment Requirements of 40 CFR § 191.13 (EPA 1993). These requirements state that the DOE must use PA to demonstrate that the probabilities of cumulative radionuclide releases from the disposal system during the 10,000 years following closure will fall below specified limits. The PA analyses supporting this determination must be quantitative and must consider uncertainties caused by all *significant processes and events* that may affect the disposal system, including inadvertent human intrusion into the repository during the future. The scope of performance assessment is further defined by EPA at 40 CFR § 194.32 (EPA 1996a), which states:

> Any compliance application(s) shall include information which:
> (1) Identifies all potential processes, events or sequences and combinations of processes and events that may occur during the regulatory time frame and may affect the disposal system;

(2) Identifies the processes, events or sequences and combinations of processes and events included in performance assessments; and
(3) Documents why any processes, events or sequences and combinations of processes and events identified pursuant to paragraph (e)(1) of this section were not included in performance assessment results provided in any compliance application.

Therefore, the PA methodology includes a process that compiles a comprehensive list of the FEPs that are relevant to disposal system performance. Those FEPs that are shown by screening analysis to have the potential to affect performance are represented in scenarios and quantitative calculations using a system of linked computer models to describe the interaction of the repository with the natural system, both with and without human intrusion. For the CCA, the DOE undertook a FEPs program by first compiling a comprehensive FEPs list which were then subjected to a screening process that eventually lead to the set of FEPs used in PA to demonstrate WIPP's compliance with the long-term disposal standards.

2.2 FEPs List Development for the CCA

As a starting point, the DOE assembled a list of potentially relevant FEPs from the compilation developed by Stenhouse et al. (1993) for the Swedish Nuclear Power Inspectorate Statens Kärnkraftinspektion (SKI). The SKI list was based on a series of FEP lists developed for other disposal programs and is considered to be the best-documented and most comprehensive starting point for the WIPP. For the SKI study, an initial raw FEP list was compiled based on nine different FEP identification studies.

The compilers of the SKI list eliminated a number of FEPs as irrelevant to the particular disposal concept under consideration in Sweden; these FEPs were reinstated for the WIPP effort, and several FEPs on the SKI list were subdivided to facilitate screening for the WIPP. Finally, to ensure comprehensiveness, other FEPs specific to the WIPP were added based on review of key project documents and broad examination of the preliminary WIPP list by both project participants and stakeholders. The initial unedited list is contained in Attachment 1 of CCA Appendix SCR. The initial unedited FEP list was restructured and revised to derive the comprehensive WIPP FEP list used in the CCA. The number of FEPs was reduced to 237 in the CCA to avoid the ambiguities caused by the use of a generic list. Restructuring the list did not remove any substantive issues from the discussion. As discussed in more detail in Attachment 1 of Appendix SCR, the following steps were used to reduce the initial unedited list to the appropriate WIPP FEP list used in the CCA.

- References to subsystems were eliminated because the SKI subsystem classification was not appropriate for the WIPP disposal concept. For example, in contrast to the Swedish disposal concept, canister integrity does not have a role in post-operational performance of the WIPP, and the terms near-field, far-field, and biosphere are not unequivocally defined for the WIPP site.

- Duplicate FEPs were eliminated. Duplicate FEPs arose in the SKI list because individual FEPs could act in different subsystems. FEPs have a single entry in the CCA list whether they are applicable to several parts of the disposal system or to a single part only. For example, the FEP "Gas Effects." Disruption appears in the seals, backfill, waste, canister, and near-field subsystems in the initial FEP list. These FEPs are represented by the single FEP, "Disruption Due to Gas Effects."

- FEPs that are not relevant to the WIPP design or inventory were eliminated. Examples include FEPs related to high-level waste, copper canisters, and bentonite backfill.

- FEPs relating to engineering design changes were eliminated because they were not relevant to a compliance application based on the DOE's design for the WIPP. Examples of such FEPs are Design Modifications: Canister and Design Modification: Geometry.

- FEPs relating to constructional, operational, and decommissioning errors were eliminated. The DOE has administrative and quality control procedures to ensure that the facility will be constructed, operated, and decommissioned properly.

- Detailed FEPs relating to processes in the surface environment were aggregated into a small number of generalized FEPs. For example, the SKI list includes the biosphere FEPs Inhalation of Salt Particles, Smoking, Showers and Humidifiers, Inhalation and Biotic Material, Household Dust and Fumes, Deposition (wet and dry), Inhalation and Soils and Sediments, Inhalation and Gases and Vapors (indoor and outdoor), and Suspension in Air, which are represented by the FEP Inhalation.

- FEPs relating to the containment of hazardous metals, volatile organic compounds (VOCs), and other chemicals that are not regulated by 40 CFR Part 191 were not included.

- A few FEPs have been renamed to be consistent with terms used to describe specific WIPP processes (for example, Wicking, Brine Inflow).

These steps resulted in a list of 237 WIPP-relevant FEPs retained for further consideration in the first certification PA. The 237 were screened to determine which would be included in the PA models and scenarios for the CCA.

2.3 Criteria for Screening of FEPs and Categorization of Retained FEPs

The purpose of FEP screening is to identify those FEPs that should be accounted for in performance assessment calculations, and those FEPs that need not be considered further. The DOE's process of removing FEPs from consideration in performance assessment calculations involved the structured application of explicit screening criteria. The criteria used to screen out FEPs are explicit regulatory exclusions (SO-R), probability (SO-P), or consequence (SO-C). All three criteria are derived from regulatory requirements. FEPs not screened as SO-R, SO-P, or SO-C were retained for inclusion in performance assessment calculations and are classified as either undisturbed performance (UP) or disturbed performance (DP) FEPs.

2.3.1 Regulation (SO-R)

Specific FEP screening criteria are stated in 40 CFR Part 191 and 40 CFR Part 194. Such screening criteria relating to the applicability of particular FEPs represent screening decisions made by the EPA. That is, in the process of developing and demonstrating the feasibility of the 40 CFR Part 191 standard and the 40 CFR Part 194 criteria, the EPA considered and made conclusions on the relevance, consequence, or probability of occurrence of particular FEPs and, in so doing, allowed for some FEPs to be eliminated from consideration.

2.3.2 Probability of occurrence of a FEP leading to significant release of radionuclides (SO-P)

Low-probability events can be excluded on the basis of the criterion provided in 40 CFR § 194.32(d), which states, "performance assessments need not consider processes and events that have less than one chance in 10,000 of occurring over 10,000 years" (EPA 1996a). In practice, for most FEPs screened out on the basis of low probability of occurrence, it has not been possible to estimate a meaningful quantitative probability. In the absence of quantitative probability estimates, a qualitative argument was used.

2.3.3 Potential consequences associated with the occurrence of the FEPs (SO-C)

The DOE recognizes two uses for this criterion:

(1) FEPs can be eliminated from performance assessment calculations on the basis of insignificant consequence. Consequence can refer to effects on the repository or site or to radiological consequence. In particular, 40 CFR §194.34(a) states that "The results of performance assessments shall be assembled into "complementary, cumulative distribution functions" (CCDFs) that represent the probability of exceeding various levels of cumulative release caused by all significant processes and events" (EPA 1996a). The DOE has omitted events and processes from performance assessment calculations where there is a reasonable expectation that the remaining probability distribution of cumulative releases would not be significantly changed by such omissions.

(2) FEPs that are potentially beneficial to subsystem performance may be eliminated from performance assessment calculations if necessary to simplify the analysis. This argument may be used when there is uncertainty as to exactly how the FEP should be incorporated into assessment calculations or when incorporation would incur unreasonable difficulties.

In some cases the effects of the occurrence of a particular event or process, although not necessarily insignificant, can be shown to lie within the range of uncertainty of another FEP already accounted for in the performance assessment calculations. In such cases the event or process may be considered to be included in performance assessment calculations implicitly, within the range of uncertainty associated with the included FEP.

Although some FEPs could be eliminated from performance assessment calculations on the basis of more than one criterion, the most practical screening criterion was used for classification. In particular, a regulatory screening classification was used in preference to a probability or consequence screening classification. FEPs that have not been screened out based on any one of the three criteria were included in the performance assessment.

2.3.4 Undisturbed Performance (UP) FEPs

FEPs classified as UP are accounted for in calculations of undisturbed performance of the disposal system. Undisturbed performance is defined in 40 CFR § 191.12 as "the predicted behavior of a disposal system, including consideration of the uncertainties in predicted behavior, if the disposal system is not disrupted by human intrusion or the occurrence of unlikely natural events" (EPA 1993). The UP FEPs are accounted for in the performance assessment calculations to evaluate compliance with the Containment Requirements in 40 CFR § 191.13. Undisturbed performance assessment calculations are also used to demonstrate with the individual and groundwater protection requirements of 40 CFR § 191.15 and 40 CFR 191 Subpart C, respectively.

2.3.5 Disturbed Performance (DP) FEPs

FEPs classified as DP are accounted for only in assessment calculations for disturbed performance. The DP FEPs that remain following the screening process relate to the potential disruptive effects of future drilling and mining events in the controlled area. Consideration of both DP and UP FEPs is required to evaluate compliance with 40 CFR § 191.13.

2.4 FEP Categories and Timeframes

In the following sections, FEPs are discussed under the categories Natural (N) FEPs, Human-Initiated (H) Events and Processes (EPs) and Waste- and Repository-Induced (W) FEPs . FEPs are also considered within time frames for which they may occur. Due to the regulatory requirements concerning human activities, two time periods were used when evaluating Human-Initiated EPs. These timeframes were defined as Historical, Current, and Near-Future Human Activities (HCN) and Future Human Activities (Future). These time frames are also discussed in the following section.

2.4.1 Natural FEPs

Natural FEPs are those that relate to hydrologic, geologic and climate conditions that have the potential to affect long-term performance of the WIPP disposal system over the regulatory timeframe. These FEPs do not include the impacts of other human related activities such as the effect of boreholes on FEPs related to natural changes in groundwater chemistry. Only natural events and processes are included within the screening process.

Consistent with 40 CFR § 194.32(d), the DOE has screened out several natural FEPs from performance assessment calculations on the basis of a low probability of occurrence at or near the WIPP site. In particular, natural events for which there is no evidence indicating that they have occurred within the Delaware Basin have been screened on this basis. For FEPs analysis, the probabilities of occurrence of these events are assumed to be zero. Quantitative, nonzero probabilities for such events, based on numbers of occurrences, cannot be ascribed without considering regions much larger than the Delaware Basin, thus neglecting established geological understanding of the events and processes that occur within particular geographical provinces.

In considering the overall geological setting of the Delaware Basin, the DOE has eliminated many FEPs from performance assessment calculations on the basis of low consequence. Events and processes that have had little effect on the characteristics of the region in the past are expected to be of low consequence for the regulatory time period.

2.4.2 Human-Initiated Events and Processes

Human-Initiated EPs (Human FEPs) are those associated with human activities in the past, present, and future. EPA provided guidance in their regulations concerning which human activities are to be considered, the severity, and the manner in which to include them in the future predictions.

The scope of performance assessments is clarified with respect to human-initiated events and processes in 40 CFR § 194.32. At 40 CFR § 194.32(a) the EPA states that,

> "Performance assessments shall consider natural processes and events, mining, deep drilling, and shallow drilling that may affect the disposal system during the regulatory time frame."

Thus, performance assessments must include consideration of human-initiated EPs relating to mining and drilling activities that might take place during the regulatory time frame. In particular, performance assessments must consider the potential effects of such activities that might take place within the controlled area at a time when institutional controls cannot be assumed to completely eliminate the possibility of human intrusion.

Further criteria concerning the scope of performance assessments are provided at 40 CFR § 194.32(c):

> "Performance assessments shall include an analysis of the effects on the disposal system of any activities that occur in the vicinity of the disposal system prior to disposal and are expected to occur in the vicinity of the disposal system soon after disposal. Such activities shall include, but shall not be limited to, existing boreholes and the development of any existing leases that can be reasonably expected to be developed in the near future, including boreholes and leases that may be used for fluid injection activities."

In order to implement the criteria in 40 CFR § 194.32, relating to the scope of performance assessments, the DOE has divided human activities into three categories. Distinctions are made between (1) human activities that are currently taking place and those that took place prior to the time of the compliance application, (2) human activities that might be initiated in the near future after submission of the compliance application, and (3) human activities that might be initiated after repository closure. The first two categories of EPs are considered under undisturbed performance, and EPs in the third category lead to disturbed performance conditions.

(1) Historical and current human activities (HC) include resource extraction activities that have historically taken place and are currently taking place outside the controlled area. These activities are of potential significance insofar as they could affect the geological, hydrological, or geochemical characteristics of the disposal system or groundwater flow pathways outside the disposal system. Current human activities taking place within the controlled area are essentially those associated with development of the WIPP repository. Historic human activities include existing boreholes.

(2) Near-future human activities include resource extraction activities that may be expected to occur outside the controlled area based on existing plans and leases. Thus, the near future includes the expected lives of existing mines and oil and gas fields, and the expected lives of new mines and oil and gas fields that the DOE expects will be developed based on existing plans and leases. These activities are of potential significance insofar as they could affect the geological, hydrological, or geochemical characteristics of the disposal system or groundwater flow pathways outside the disposal system. The only human activities that are expected to occur within the controlled area in the near future are those associated with development of the WIPP repository. The DOE assumes that any activity that is expected to be initiated in the near future, based on existing plans and leases, will be initiated prior to repository closure. Activities initiated prior to repository closure are assumed to continue until their completion.

(3) Future human activities (Future) include activities that might be initiated within or outside the controlled area after repository closure. This includes drilling and mining for resources within the disposal system at a time when institutional controls cannot be assumed to completely eliminate the possibility of such activities. Future human activities could influence the transport of contaminants within and outside the disposal system by directly removing waste from the disposal system or altering the geological, hydrological, or geochemical characteristics of the disposal system.

2.4.2.1 Scope of Future Human Activities in Performance Assessment

Performance assessments must consider the effects of future human activities on the performance of the disposal system. The EPA has provided criteria relating to future human activities in 40 CFR § 194.32(a), which limits the scope of consideration of future human actions in performance assessments to mining and drilling.

Criteria concerning future mining: The EPA provides additional criteria concerning the type of future mining that should be considered by the DOE in 40 CFR § 194.32(b):

> "Assessments of mining effects may be limited to changes in the hydraulic conductivity of the hydrogeologic units of the disposal system from excavation mining for natural resources. Mining shall be assumed to occur with a one in 100 probability in each century of the regulatory time frame. Performance assessments shall assume that mineral deposits of those

> resources, similar in quality and type to those resources currently extracted from the Delaware Basin, will be completely removed from the controlled area during the century in which such mining is randomly calculated to occur. Complete removal of such mineral resources shall be assumed to occur only once during the regulatory time frame."

Thus, consideration of future mining may be limited to mining within the controlled area at the locations of resources that are similar in quality and type to those currently extracted from the Delaware Basin. Potash is the only resource that has been identified within the controlled area in quality similar to that currently mined from underground deposits elsewhere in the Delaware Basin. The hydrogeological impacts of future potash mining within the controlled area are accounted for in calculations of the disturbed performance of the disposal system. Consistent with 40 CFR § 194.32(b), all economically recoverable resources in the vicinity of the disposal system (outside the controlled area) are assumed to be extracted in the near future.

Criteria concerning future drilling: With respect to consideration of future drilling, in the preamble to 40 CFR Part 194, the EPA

> "...reasoned that while the resources drilled for today may not be the same as those drilled for in the future, the present rates at which these boreholes are drilled can nonetheless provide an estimate of the future rate at which boreholes will be drilled."

Criteria concerning the consideration of future deep and shallow drilling in performance assessments are provided in 40 CFR § 194.33. The EPA also provides a criterion in 40 CFR § 194.33(d) concerning the use of future boreholes subsequent to drilling.

> "With respect to future drilling events, performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of the borehole."

Thus, performance assessments need not consider the effects of techniques used for resource extraction and recovery that would occur subsequent to the drilling of a borehole in the future. Theses activities are screened SO-R.

The EPA provides an additional criterion that limits the severity of human intrusion scenarios that must be considered in performance assessments. In 40 CFR § 194.33(b)(1) the EPA states that,

> "Inadvertent and intermittent intrusion by drilling for resources (other than those resources provided by the waste in the disposal system or engineered barriers designed to isolate such waste) is the most severe human intrusion scenario."

Screening of future human-initiated EPs: Future human-initiated EPs accounted for in performance assessment calculations for the WIPP are those associated with mining and deep drilling within the controlled area at a time when institutional controls cannot be assumed to eliminate completely the possibility of such activities. All other future human-initiated EPs, if not eliminated from performance assessment calculations based on regulation, have been eliminated based on low consequence or low probability. For example, the effects of future shallow drilling within the controlled area were eliminated from CCA performance assessment calculations on the basis of low consequence to the performance of the disposal system.

2.4.3 Waste- and Repository-Induced FEPs

The waste- and repository-induced FEPs are those that relate specifically to the waste material, waste containers, shaft seals, MgO backfill, panel closures, repository structures, and investigation boreholes. All FEPs related to radionuclide chemistry and radionuclide migration are included in this category. FEPs related to radionuclide transport resulting from future borehole intersections of the WIPP excavation are defined as waste- and repository-induced FEPs.

3. SCOPE OF CRA FEPS ASSESSMENT

The scope of the CRA FEPs assessment includes a complete reassessment of the information contained in the compliance baseline, as well as any new information relating to the screening decisions, justifications and basis originally documented in CCA Appendix SCR. The reassessment was composed of two elements. In the first element, a process was used to identify those FEPs that require an in-depth review as well as those unaffected since the first certification of WIPP. The second element reassesses in detail each FEP potentially affected by new information. For the second element, a common set of tools was developed and used to assist in the identification of new information related to each FEP further evaluated in the reassessment. These tools included the baseline FEPs list, related experimental results, literature search materials, and DOE and EPA documents that contain the FEP positions and information relating to changes incorporated into the WIPP baseline. Each FEP that was not eliminated in the first element was subjected to a thorough review resulting in a meaningful and current FEPs baseline. The objective of this task was to update the FEPs baseline where appropriate and was not intended to add or bolster existing arguments where the original FEPs information remains sufficient, accurate, and current.

As was done in the previous FEPs assessment that led up to the writing of Appendix SCR, the scope of this reassessment does not address the implementation of the FEPs into PA. FEPS are implemented in the applicable scenarios and conceptual models and are determined adequate in part via independent peer review. The FEPs screening only identifies those FEPs for further consideration and does not include activities associated with actual implementation of the FEP within the PA methodology.

As discussed in Section 2.2, the FEPs process started with approximately 1200 FEPs that were evaluated for their relevance to WIPP. The process resulted in 237 FEPs for consideration in the FEPs screening used in the first certification PA. A review of the criteria used to identify the 237 FEPs (the bulleted list in Section 2.2) indicates that the criteria are still valid. The criteria used are still appropriate because no changes have been made to the governing regulations, thereby maintaining regulatory screening criteria. In addition, the process to remove duplicates and consolidate FEPs remains appropriate and no changes have been made to the design of the disposal system that would impact the original criteria. Therefore, the assessment that led to the original 237 FEPs continues to be appropriate. Only the 237 FEPs were included in the scope of the CRA FEPs reassessment. This activity has been conducted according to Sandia Analysis Plan AP-095, Revision 2, "*Compliance Recertification FEPs Reassessment Analysis Plan,*" (ERMS #525773).

3.1 Reassessment Element 1: Identify FEPs that Require In-Depth Review

The CCA FEP baseline was approved by the EPA during their compliance determination. EPA's justification for approval is documented in their Technical Support Document for Section 194.32, titled "Scope of Performance Assessments." As discussed in Section 3.0, the scope of the FEPs reassessment is to update the FEPs baseline to account for new information or impacts from changes since the CCA. Not all FEPs require reassessment because of their screening decision. FEPs that were screened-in during the original CCA FEPs screening do not require reassessing since they are currently accounted for in PA. As mentioned previously in Section 3.0, this reassessment does not judge the adequacy of how a FEP is implemented within the PA methodology. The reassessment ensures that the original screening arguments continue to be acceptable. Because FEPs that relate to human activity FEPs are the most likely to be influenced by change since the 1996 certification, and because human FEPs relate directly to intrusion events, they have been reassessed regardless of their original screening decision. As a result, a sorting process was developed to identify FEPs that are most likely to be impacted by change and those that do not require further evaluation for the purposes of recertification. This process sorted and identified FEPs that were subjected to the reassessment process.

3.1.1 Sorting Process

Initial sorting of the 237 FEPs listed in the baseline FEPs list is necessary to identify those FEPs that require extensive review and those FEPs that may be excluded. Because FEPs related to human activities are of significant importance to intrusion scenarios within the WIPP PA, and because human activities have the potential to change frequently, all FEPs related to human activities were identified for an extensive review.

Alternatively, those FEPs currently accounted for in either disturbed or undisturbed scenarios may be excluded from extensive review because their effects are currently included in PA. Furthermore, the WIPP monitoring and reporting activities have not identified information that would suggest removal of these FEPs from consideration in PA. Finally, FEPs screened out on regulatory basis (other than Human FEPs as described above) can be excluded from further consideration within this reassessment because the regulatory basis has not been modified since WIPP's original certification. Figure 3.1 provides a logic diagram of this sorting process within the first element of the reassessment.

Using the sorting criteria above resulted in the elimination of 76 FEPs from further review (Element 1 FEPs), and identified 161 FEPs that proceeded through the second element of the reassessment.

3.2 Develop FEPs Reassessment Tools

The next step in the FEPs reassessment process was to compile all relevant compliance baseline information from the original certification for each FEP to be reassessed. This information included DOE's FEP information and screening position and the EPA's certification information. This information was needed to update the original FEPs basis in Appendix SCR to be current and consistent with EPA's certification basis. Examples of the FEP information include, but were not limited to:

- Original Appendix SCR and CCA positions;
- EPA's position from Technical Support Document (TSD) 193.32 Scope of Performance Assessment;
- Information contained in EPA Docket A93-02;
- Reference to WIPP Project Office (WPO) numbers, electronic records management system (ERMS) numbers;
- Compliance Application Review Documents (CARD) references;
- Listing of FEPs side efforts;
- Change-related information described in correspondence between DOE and EPA concerning proposed changes to the WIPP baseline and EPA acceptance of proposed changes occurring since WIPP's initial certification; and
- Experimental results, monitoring data, new human activities.

3.3 Outline of FEPs Reassessment Process

The process for reassessing FEPs is described in the flow chart of Figure 3.1. The basic process consists of: (1) compiling a file of information for each FEP containing all relevant information from the compliance baseline; (2) research activities relating to the FEP and FEP baseline information; (3) determining if the FEP baseline requires updating and if so in what manner; (4) developing revised text for an updated Appendix SCR (or equivalent document) for the CRA; and (5) documenting the assessment in a formal records package.

3.3.1 Compile FEP Information

As stated earlier, the objective of the reassessment is to update each FEP to ensure that the information relating to the screening decisions is current and valid. The tools derived in the previous step are intended to help in the reassessment by providing most of the information that comprise the original FEPs basis and screening decision. However, there were varying degrees of analysis and documentation relating to each FEP such that the reviewer for each FEP had to be diligent in his research of baseline information to ensure a complete compilation of relevant baseline materials. Examples of review materials may include analysis plans, analysis packages, test plans, experimental results, publications, seminar materials, etc. These materials were compiled and properly referenced in the FEPs 2003 records package (ERMS# 525161, SNL 03). Each FEP reassessed has been identified by a discrete record number within this package.

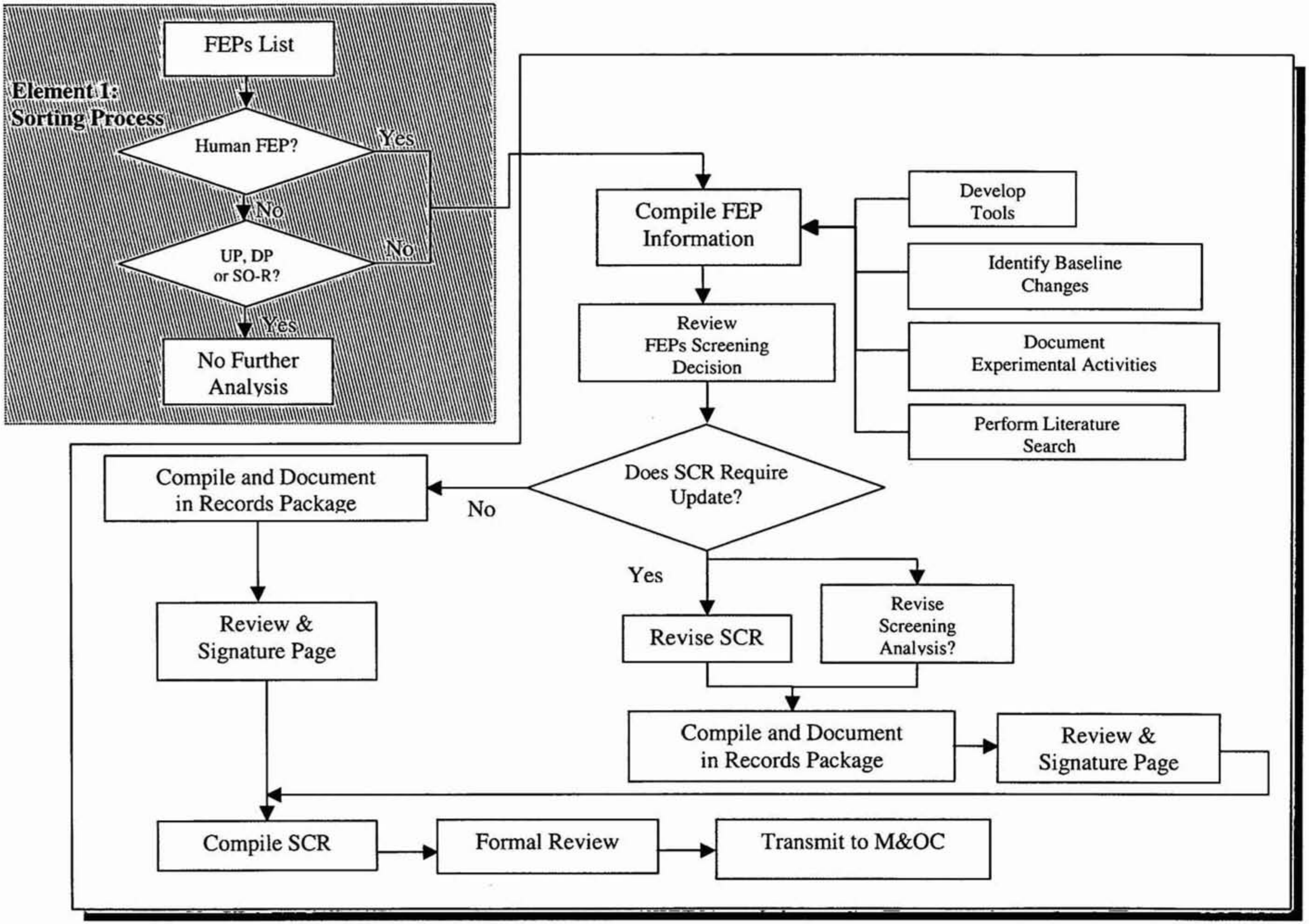

Figure 3.1: FEPs Reassessment Process Flow

3.3.2 Review Original FEP Screening Decision

In this step, the original FEPs screening decisions and analysis were reviewed. If the original decision and supporting materials were acceptable as written, no further action was required. In some instances, the screening decisions required changes to either the argument or the actual decision. As mentioned earlier, the same screening criteria used in the original FEPs screening were used in this reassessment.

3.3.3 Determine if Original Screening Bases Requires Revision

This step in the reassessment process determined if the FEPs description and decision in CCA Appendix SCR was adequate as written. In most cases, no changes were necessary, however many FEPs descriptions were changed to update and consolidate compliance baseline information.

As stated earlier, with the exception of H FEPs, the screened-in FEPs were excluded from the reassessment. In all cases of the H FEPs with DP and UP, the screening decision did not change as a result of the reassessment; such FEPs remain screened in. Similarly, all H FEPs with a SO-R screening decision remain screened-out, unless new information affecting the regulatory basis was to emerge[1]. However, additional documentation of these assessments was included in the H FEPs records packages because these FEPs are of significant importance to intrusion scenarios within the WIPP PA, and because human activities have the potential to change frequently.

4. FEPS REASSESSMENT RESULTS

The FEPs reassessment results in a new FEPs baseline. As discussed in Section 3.1.1, 76 FEPs were classified as Element 1 FEPs and thus were not reassessed further. As such, their descriptions, screening arguments and screening decisions remain as they were in CCA Appendix SCR (included by reference). Of the 161 FEPs that were included in Element 2 of the reassessment, only seven FEP screening decisions were changed. However, most were modified in some way. In addition, two FEPs have been added to the baseline. These FEPs were previously accounted for in a broader FEP. This change more clearly represents the FEP and aids in the screening process. Table 4.1 outlines the results of the assessment, and subsequent sections of this document present the actual screening decisions and supporting arguments. Those FEPs not separated by gridlines in the first column of Table 4.1 have been addressed by group, due to close similarity with other FEPs within that group. This grouping process was formerly used in the CCA, and also by the EPA in their TSD for §194.32 (EPA 1998c). Also, each of the FEPs reassessed are discussed in subsequent sections of this document in a format similar to that used in the CCA Appendix SCR.

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[1] For example, a FEP formerly classified as SO-R using the regulatory basis of the "future states assumption" may no longer be valid should the future state change.

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
N1	Stratigraphy	Element 1 FEP	N/A	UP
N2	Brine reservoirs	Element 1 FEP	N/A	DP
N3	Changes in regional stress	No	Additional information added to FEP text, no change to italicised text.	SO-C
N4	Regional tectonics	No	Additional information added to FEP text, no change to italicised text.	SO-C
N5	Regional uplift and subsidence	No	Additional information added to FEP text, no change to italicised text.	SO-C
N6	Salt deformation	No	No change	SO-P
N7	Diapirism	No	No change	SO-P
N8	Formation of fractures	No	Original FEP text revised and replaced, reference to other FEP removed from italicised text	SO-P UP (Repository)
N9	Changes in fracture properties	No	Original FEP text revised and replaced, reference to other FEP removed from italicised text	SO-C UP (Near Repository)
N10	Formation of new faults	No	Additional information added to FEP text, no change to italicised text.	SO-P
N11	Fault movement	No	Additional information added to FEP text, no change to italicised text.	SO-P
N12	Seismic activity	Element 1 FEP	N/A	UP
N13	Volcanic activity	No	Italicised text changed, FEP text unchanged	SO-P
N14	Magmatic activity	No	No changes	SO-C
N15	Metamorphic activity	No	No changes	SO-P

Table 4.1 FEPs Reassessment Results

EPA FEP I.D.	FEP Name	Screening Decision Changed	Reassessment Results	Screening Classification
N16	Shallow Dissolution	No	N16 and N17 (lateral dissolution) combined, N17 deleted from baseline. FEP text modified and additional information added.	UP
N17	Lateral dissolution	No	Combined with N16 (shallow dissolution) - Deleted from baseline – see N16	NA
N19	Solution chimneys	No	Combined with N20 and deleted from baseline	NA
N18	Deep dissolution	No	Both italicised and FEP text revised.	SO-P
N20 N21	Breccia pipes	No	N20 and N19 (Solution chimneys) combined, Both italicised and FEP text revised.	SO-P
	Collapse breccias	No	Both italicised and FEP text revised.	SO-P
N22	Fracture infills	No	No changes	SO-C
N23	Saturated groundwater flow	Element 1 FEP	N/A	UP
N24	Unsaturated groundwater flow	Element 1 FEP	N/A	UP SO-C in Culebra
N25	Fracture flow	Element 1 FEP	N/A	UP
N26	Density effects on groundwater flow	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N27	Effects of preferential pathways	Element 1 FEP	N/A	UP UP in Salado and Culebra

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
N28	Thermal effects on groundwater flow	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N29	Saline intrusion [hydrogeological effects]	No	Reference to other FEPs removed from the italicised text. FEP text unchanged.	SO-P
N30	Freshwater intrusion [hydrogeological effects]	No	Reference to other FEPs removed from the italicised text. FEP text unchanged.	SO-P
N31	Hydrological response to earthquakes	No	Reference to other FEPs removed from the italicised text. FEP text unchanged.	SO-C
N32	Natural gas intrusion	No	Reference to other FEPs removed from the italicised text. FEP text unchanged.	SO-P
N33	Groundwater geochemistry	Element 1 FEP	N/A	UP
N34	Saline intrusion (geochemical effects)	No	FEP N34 and N38 described together. FEP Text revised and replaced, italicised text revised to removed reference to other FEPs	SO-C
N38	Effects of dissolution	No	FEP N34 and N38 are described together. FEP Text revised and replaced, italicised text revised to removed reference to other FEPs	SO-C
N35	Freshwater intrusion (geochemical effects)	No	FEP N35, N36 and N37 are described together. FEP Text revised and replaced, italicised text revised to removed reference to other FEPs	SO-C

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
N36	Changes in groundwater Eh	No	FEP N35, N36 and N37 are described together. FEP Text revised and replaced, italicised text revised to removed reference to other FEPs	SO-C
N37	Changes in groundwater pH	No	FEP N35, N36 and N37 are described together. FEP Text revised and replaced, italicised text revised to removed reference to other FEPs	SO-C
N39	Physiography	Element 1 FEP	N/A	UP
N40	Impact of a large meteorite	No	No changes	SO-P
N41	Mechanical weathering	No	No changes	SO-C
N42	Chemical weathering	No	No changes	SO-C
N43	Aeolian erosion	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N44	Fluvial erosion	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N45	Mass wasting [erosion]	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N46	Aeolian deposition	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N47	Fluvial deposition	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N48	Lacustrine deposition	No	Reference to other FEPs removed from FEP and italicised text	SO-C

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
N49	Mass wasting [deposition]	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N50	Soil development	No	Clarification text added to the FEP text	SO-C
N51	Stream and river flow	No	No changes	SO-C
N52	Surface water bodies	No	No changes	SO-C
N53	Groundwater discharge	Element 1 FEP	N/A	UP
N54	Groundwater recharge	Element 1 FEP	N/A	UP
N55	Infiltration	Element 1 FEP	N/A	UP
N56	Changes in groundwater recharge and discharge	Element 1 FEP	N/A	UP
N57	Lake formation	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N58	River flooding	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N59	Precipitation [e.g. rainfall]	Element 1 FEP	N/A	UP
N60	Temperature	Element 1 FEP	N/A	UP
N61	Climate change	Element 1 FEP	N/A	UP
N62	Glaciation	No	Reference to other FEPs removed from FEP and italicised text	SO-P
N63	Permafrost	No	Reference to other FEPs removed from FEP and italicised text	SO-P
N64	Seas and oceans	No	No changes	SO-C
N65	Estuaries	No	No changes	SO-C
N66	Coastal erosion	No	No changes	SO-C
N67	Marine sediment transport and deposition	No	No changes	SO-C
N68	Sea level changes	No	No changes	SO-C

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
N69	Plants	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N70	Animals	No	Reference to other FEPs removed from FEP and italicised text	SO-C
N71	Microbes	No	Additional information added to FEP text, reference to other FEPs removed from italicised text.	SO-C (UP - for colloidal effects and gas generation)
N72	Natural ecological development	No	No changes	SO-C
W1	Disposal geometry	Element 1 FEP	N/A	UP
W2	Waste inventory	Element 1 FEP	N/A	UP
W3	Heterogeneity of waste forms	Element 1 FEP	N/A	DP
W4	Container form	No	Both italicised and FEP text revised	SO-C
W5	Container material inventory	Element 1 FEP	N/A	UP
W6	Seal geometry	Element 1 FEP	N/A	UP
W7	Seal physical properties	Element 1 FEP	N/A	UP
W8	Seal chemical composition	No	Both italicised and FEP text revised	SO-C Beneficial SO-C
W9	Backfill physical properties	No	Both italicised and FEP text revised	SO-C
W10	Backfill chemical composition	Element 1 FEP	N/A	UP
W11	Post-closure monitoring	No	Additional information added to FEP text.	SO-C
W12	Radionuclide decay and in-growth	Element 1 FEP	N/A	UP
W13	Heat from radioactive decay	No	No change to Italicised text, new concluding paragraph added to FEP text.	SO-C

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
W14	Nuclear criticality: heat	No	No change to Italicised text, additional information added to FEP text.	SO-P
W15	Radiological effects on waste	No	No change to Italicised text, FEP text revised.	SO-C
W16	Radiological effects on containers	No	No change to Italicised text, FEP text revised.	SO-C
W17	Radiological effects on seals	No	No Changes	SO-C
W18	Disturbed rock zone	Element 1 FEP	N/A	UP
W19	Excavation-induced changes in stress	Element 1 FEP	N/A	UP
W20	Salt creep	Element 1 FEP	N/A	UP
W21	Changes in the stress field	Element 1 FEP	N/A	UP
W22	Roof falls	Element 1 FEP	N/A	UP
W23	Subsidence	No	Minor changes to FEPs text, no changes to italicised text.	SO-C
W24	Large scale rock fracturing	No	Minor changes to FEPs text, no changes to italicised text.	SO-P
W25	Disruption due to gas effects	Element 1 FEP	N/A	UP
W26	Pressurization	Element 1 FEP	N/A	UP
W27	Gas explosions	Element 1 FEP	N/A	UP
W28	Nuclear explosions	No	Reference to other FEPs removed from italicised text, FEP text revised.	SO-P

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
W29	Thermal effects on material properties	No	Additional information added to FEP text, grouped with similar FEPs; italicised text unchanged	SO-C
W30	Thermally-induced stress changes	No	Additional information added to FEP text, grouped with similar FEPs; italicised text unchanged	SO-C
W31	Differing thermal expansion of repository components	No	Additional information added to FEP text, grouped with similar FEPs; italicised text unchanged	SO-C
W72	Exothermic reactions	No	Additional information added to FEP text, grouped with similar FEPs; italicised text unchanged	SO-C
W73	Concrete Hydration	No	Additional information added to FEP text, grouped with similar FEPs; italicised text unchanged	SO-C
W32	Consolidation of waste	Element 1 FEP	N/A	UP
W33	Movement of containers	No	Reference to other FEPs removed from italicised text, FEP text revised	SO-C
W34	Container integrity	No	Reference to other FEPs removed from italicised text, FEP text revised	SO-C Beneficial
W35	Mechanical effects of backfill	No	Both italicised and FEP text revised.	SO-C

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
W36	Consolidation of seals	Element 1 FEP	N/A	UP
W37	Mechanical degradation of seals	Element 1 FEP	N/A	UP
W38	Investigation boreholes	Yes	Encompassed in FEPS W31 and W33, FEP W38 deleted from baseline.	NA
W39	Underground boreholes	Element 1 FEP	N/A	UP
W40	Brine inflow	Element 1 FEP	N/A	UP
W41	Wicking	Element 1 FEP	N/A	UP
W42	Fluid flow due to gas production	Element 1 FEP	N/A	UP
W43	Convection	No	Reference to other FEPs removed from italicised text, FEP text revised	SO-C
W44	Degradation of organic material	Element 1 FEP	N/A	UP
W45	Effects of temperature on microbial gas generation	Element 1 FEP	N/A	UP
W46	Effects of pressure on microbial gas generation	No	Reference to other FEPs removed from italicised text, FEP text revised	SO-C
W47	Effects of radiation on microbial gas generation	No	Reference to other FEPs removed from italicised text, FEP text revised	SO-C
W48	Effects of biofilms on microbial gas generation	Element 1 FEP	N/A	UP
W49	Gases from metal corrosion	Element 1 FEP	N/A	UP
W50	Galvanic coupling	Yes	Decision changed from SO-P to SO-C. Both italicised and FEP text revised.	SO-C
W51	Chemical effects of corrosion	Element 1 FEP	N/A	UP
W52	Radiolysis of brine	No	Both italicised and FEP text revised.	SO-C
W53	Radiolysis of cellulose	No	FEP text revised	SO-C

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
W54	Helium gas production	No	Both italicised and FEP text revised.	SO-C
W55	Radioactive gases	No	Reference to other FEPs removed from italicised text, no change to FEP text	SO-C
W56	Speciation	Element 1 FEP	N/A	UP UP in disposal rooms and Culebra. SO-C elsewhere, and beneficial SO-C in cementitious seals
W57	Kinetics of speciation	No	Both italicised and FEP text revised.	SO-C
W58	Dissolution of waste	Element 1 FEP	N/A	UP
W59	Precipitation of secondary minerals	No	Both italicised and FEP text revised.	SO-C-Beneficial
W60	Kinetics of precipitation and dissolution	No	Both italicised and FEP text revised.	SO-C
W61	Actinide sorption	Element 1 FEP	N/A	UP
W62	Kinetics of sorption	Element 1 FEP	N/A	UP
W63	Changes in sorptive surfaces	Element 1 FEP	N/A	UP
W64	Effects of metal corrosion	Element 1 FEP	N/A	UP
W65	Reduction-oxidation fronts	No	Reference to other FEPs removed from FEP and italicised text	SO-P
W66	Reduction-oxidation kinetics	Element 1 FEP	N/A	UP
W67	Localized reducing zones	No	Changes to FEPs text, no changes to italicised text.	SO-C
W68	Organic complexation	Yes	Decision changed from SO-C to UP. Both italicised and FEP text revised.	UP

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
W69	Organic ligands	Yes	Decision changed from SO-C to UP. Both italicised and FEP text revised.	UP
W71	Kinetics of organic complexation	No	Both italicised and FEP text revised.	SO-C
W70	Humic and fulvic acids	Element 1 FEP	N/A	UP
W74	Chemical degradation of seals	Element 1 FEP	N/A	UP
W75	Chemical degradation of backfill	No	FEP text unchanged, reference to other FEPs removed from FEP and italicised text	SO-C
W76	Microbial growth on concrete	Element 1 FEP	N/A	UP
W77	Solute transport	Element 1 FEP	N/A	UP
W78	Colloid transport	Element 1 FEP	N/A	UP
W79	Colloid formation and stability	Element 1 FEP	N/A	UP
W80	Colloid filtration	Element 1 FEP	N/A	UP
W81	Colloid sorption	Element 1 FEP	N/A	UP
W82	Suspensions of particles	Element 1 FEP	N/A	DP
W83	Rinse	No	Reference to other FEPs removed from italicised text, no change to FEP text	SO-C
W84	Cuttings	Element 1 FEP	N/A	DP
W85	Cavings	Element 1 FEP	N/A	DP
W86	Spallings	Element 1 FEP	N/A	DP
W87	Microbial transport	Element 1 FEP	N/A	UP
W88	Biofilms	No	Both italicised and FEP text revised.	SO-C Beneficial

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
W89	Transport of radioactive gases	No	No change to Italicised text, additional information added to FEP text.	SO-C
W90	Advection	Element 1 FEP	N/A	UP
W91	Diffusion	Element 1 FEP	N/A	UP
W92	Matrix diffusion	Element 1 FEP	N/A	UP
W93	Soret effect	No	No changes	SO-C
W94	Electrochemical effects	No	Both italicised and FEP text revised.	SO-C
W95	Galvanic coupling	No	Reference to other FEPs removed from italicised text, no change to FEP text	SO-P
W96	Electrophoresis	No	Both italicised and FEP text revised.	SO-C
W97	Chemical gradients	No	Reference to other FEPs removed from italicised text, additional information added to FEP text.	SO-C
W98	Osmotic processes	No	Reference to other FEPs removed from italicised text, FEP text revised.	SO-C
W99	Alpha recoil	No	Reference to other FEPs removed from italicised text, FEP text revised.	SO-C
W100	Enhanced diffusion	No	Both italicised and FEP text revised.	SO-C
W101	Plant uptake	No	No changes	SO-R
W102	Animal uptake	No	No changes	SO-R
W103	Accumulation in soils	No	No changes	SO-C
W104	Ingestion	No	No changes	SO-R
W105	Inhalation	No	No changes	SO-R
W106	Irradiation	No	No changes	SO-R
W107	Dermal sorption	No	No changes	SO-R
W108	Injection	No	No changes	SO-R

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
H1	Oil and gas exploration	No	Italicised text revised and the FEP text revised to remove reference to other FEPs	SO-C (HCN) DP (Future)
H2	Potash exploration	No	Reference to other FEPs removed from FEP and italicised text	SO-C (HCN) DP (Future)
H3	Water resources exploration	No	Both italicised and FEP text revised.	SO-C (HCN) SO-C (Future)
H5	Groundwater exploitation	No	Both italicised and FEP text revised.	SO-C (HCN) SO-C (Future)
H4	Oil and gas exploitation	No	Both italicised and FEP text revised.	SO-C (HCN) DP (Future)
H6	Archaeological investigations	No	Both italicised and FEP text revised.	SO-R (HCN) SO-R (Future)
H7	Geothermal	No	Both italicised and FEP text revised.	SO-R (HCN) SO-R (Future)
H8	Other resources	No	Reference to other FEPs removed from italicised and FEP text, additional information added to FEP text.	SO-C (HCN) DP (Future)
H9	Enhanced oil and gas recovery	No	Both italicised and FEP text revised.	SO-C (HCN) DP (Future)
H10	Liquid waste disposal	No	Both italicised and FEP text revised.	SO-R (HCN) SO-R (Future)
H11	Hydrocarbon storage	No	Both italicised and FEP text revised.	SO-R (HCN) SO-R (Future)
H12	Deliberate drilling intrusion	No	Both italicised and FEP text revised.	SO-R (HCN) SO-R (Future)
H13	Conventional Underground Potash Mining Formerly called "Potash Mining"	No	Name changed from "Potash Mining" to "Conventional Underground Potash Mining". Both italicised and FEP text revised.	UP (HCN) DP (Future)
H14	Other resources	No	Both italicised and FEP text revised.	SO-C (HCN) SO-R (Future)
H15	Tunneling	No	Both italicised and FEP text revised.	SO-R (HCN) SO-R (Future)

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
H16	Construction of underground facilities (for example storage, disposal, accommodation)	No	Both italicised and FEP text revised.	SO-R (HCN) SO-R (Future)
H17	Archaeological excavations	No	Both italicised and FEP text revised.	SO-C (HCN) SO-R (Future)
H18	Deliberate mining intrusion	No	Both italicised and FEP text revised.	SO-R (HCN) SO-R (Future)
H19	Explosions for resource recovery	No	Both italicised and FEP text revised.	SO-C (HCN) SO-R (Future)
H20	Underground nuclear device testing	No	No changes	SO-C (HCN) SO-R (Future)
H21	Drilling fluid flow	No	Reference to other FEPs removed from FEP and italicised text	SO-C (HCN) DP (Future)
H22	Drilling fluid loss	No	Reference to other FEPs removed from FEP and italicised text	SO-C (HCN) DP (Future)
H23	Blowouts	No	Reference to other FEPs removed from FEP and italicised text	SO-C (HCN) DP (Future)
H24	Drilling-induced geochemical changes	No	Reference to other FEPs removed from FEP and italicised text	UP (HCN) DP (Future)
H25	Oil and gas extraction	No	No changes	SO-C (HCN) SO-R (Future)
H26	Groundwater extraction	No	No changes	SO-C (HCN) SO-R (Future)
H27	Liquid waste disposal	Yes	Additional information added to the original FEP text. Screening changed in italicised text from SO-R to SO-C (future).	SO-C (HCN) SO-C (Future)

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
H28	Enhanced oil and gas production	Yes	Additional information added to the original FEP text. Screening changed in italicised text from SO-R to SO-C (future).	SO-C (HCN) SO-C (Future)
H29	Hydrocarbon storage	Yes	Additional information added to the original FEP text. Screening changed in italicised text from SO-R to SO-C (future).	SO-C (HCN) SO-C (Future)
H30	Fluid-injection induced geochemical changes	No	Reference to other FEPs removed from FEP and italicised text.	UP (HCN) SO-R (Future)
H31	Natural borehole fluid flow	No	H31 and H33 combined. Both FEP text and italicised text revised to include H33.	SO-C (HCN) DP (Future)
H32	Waste-induced borehole flow	No	Both FEP text and italicised text revised.	SO-R (HCN) DP (Future)
H33	Flow through undetected boreholes	Yes	Combined with H31 and deleted from FEPs baseline.	NA
H34	Borehole-induced solution and subsidence	No	Reference to other FEPs removed from FEP and italicised text, additional information added to FEP text.	SO-C (HCN) SO-C (Future)
H35	Borehole-induced mineralization	No	Reference to other FEPs removed from FEP and italicised text, additional information added to FEP text.	SO-C (HCN) SO-C (Future)

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
H36	Borehole-induced geochemical changes	No	Reference to other FEPs removed from FEP and italicised text, additional information added to FEP text.	UP (HCN) DP (Future)
H37	Changes in groundwater flow due to mining	No	Reference to other FEPs removed from FEP and italicised text, additional information added to FEP text.	UP (HCN) DP (Future)
H38	Changes in geochemistry due to mining	No	Reference to other FEPs removed from FEP and italicised text, additional information added to FEP text.	SO-C (HCN) SO-R (Future)
H39	Changes in groundwater flow due to explosions	No	No changes	SO-C (HCN) SO-R (Future)
H40	Land use changes	No	Reference to other FEPs removed from italicised text, additional information added to FEP text.	SO-R (HCN) SO-R (Future)
H41	Surface disruptions	Yes	Reference to other FEPs removed from italicised text, additional information added to FEP text.	~~SO-C (HCN)~~ UP (HCN) SO-R (Future)
H42	Damming of streams or rivers	No	Reference to other FEPs removed from FEP and italicised text	SO-C (HCN) SO-R (Future)
H43	Reservoirs	No	Reference to other FEPs removed from FEP and italicised text	SO-C (HCN) SO-R (Future)
H44	Irrigation	No	Reference to other FEPs removed from FEP and italicised text	SO-C (HCN) SO-R (Future)

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
H45	Lake usage	No	Reference to other FEPs removed from FEP and italicised text, additional information added to FEP text.	SO-R (HCN) SO-R (Future)
H46	Altered soil or surface water chemistry by human activities	No	Reference to other FEPs removed from FEP and italicised text.	SO-C (HCN) SO-R (Future)
H47	Greenhouse gas effects	No	No changes	SO-R (HCN) SO-R (Future)
H48	Acid rain	No	No changes	SO-R (HCN) SO-R (Future)
H49	Damage to the ozone layer	No	No changes	SO-R (HCN) SO-R (Future)
H50	Coastal water use	No	No changes	SO-R (HCN) SO-R (Future)
H51	Sea water use	No	No changes	SO-R (HCN) SO-R (Future)
H52	Estuarine water use	No	No changes	SO-R (HCN) SO-R (Future)
H53	Arable farming	No	No changes	SO-C (HCN) SO-R (Future)
H54	Ranching	No	No changes	SO-C (HCN) SO-R (Future)
H55	Fish farming	No	No changes	SO-R(HCN) SO-R (Future)
H56	Demographic change and urban development	No	Reference to other FEPs removed from FEP and italicised text.	SO-R (HCN) SO-R (Future)
H57	Loss of records	No	Additional information added to FEP text, italicised text modified to remove reference to another FEP.	NA (HCN) DP (Future)
H58	Solution Mining for Potash	Yes	New FEP, Sol. Mining was contained in various other FEPs – see H13	SO-R (HCN) SO-R (Future)

Table 4.1 FEPs Reassessment Results				
EPA FEP I.D.	**FEP Name**	**Screening Decision Changed**	**Reassessment Results**	**Screening Classification**
H59	Solution Mining for Other Resources	Yes	New FEP, Sol. Mining was contained in various other FEPs – see H13	SO-C (HCN) SO-C (Future)

5. NATURAL FEPS

This section presents the reassessment analysis results of natural FEPs identified in Section 3.1. Of the 72 natural FEPs in the compliance baseline, 56 were identified as requiring reassessment. Natural FEPs are those natural features, events or process that may be important to the performance of the disposal system. Assessment of natural FEPs is done in the absence of human influences on the features, events or processes being analyzed. Table 4-1 provides details regarding the FEPs reassessment. Of the 72 natural FEPs, 32 remain completely unchanged, 38 were updated to include additional information or were edited for clarity and completeness, and 2 were deleted from the baseline by combining with other more appropriate FEPs. No screening decisions for natural FEPs were changed. The remainder of this section provides details and results of those natural FEPs that underwent Element 2 of this reassessment.

EPA FEP Number: N3, N4 & N5
FEP Title: Regional Tectonics (N3)
Change in Regional Stress (N4)
Regional Uplift and Subsidence (N5)

SCR Section Number: SCR.1.1.2
Screening Decision: SO-C

Summary:

The DOE's screening designations for WIPP regional tectonics, changes in regional stress, regional uplift and subsidence appears to be technically valid. DOE described the WIPP site as located in an area with no evidence of significant tectonic activity, with a low level of stress in the region. The WIPP is located in an area of tectonic quiescence. Seismic monitoring conducted for the WIPP since the CCA continues to record small events at distance from the WIPP, and these events are mainly in areas associated with hydrocarbon production. Two nearby events (magnitude 3.5, 10/97, and magnitude 2.8, 12/98) are related to rockfalls in the Nash Draw mine and are not tectonic in origin (DOE 1999). These events did not cause any damage at the WIPP. There are no known nearby active faults, and one of the main tectonic features is a slight eastward dip to pre-Cenozoic formations within the basin. There is no geologic evidence of continuing tilting. These studies show short-term benchmark movements consistent with the basin tilt. The screening arguments appear reasonable, and the screening arguments and screening decisions remain unchanged. Additional information on tectonics has been added.

Italicized Text

The effects of regional tectonics, regional uplift and subsidence, and changes in regional stress have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Regional tectonics encompasses two related issues of concern: the overall level of regional stress and whether any significant *changes in regional stress* might occur.

The tectonic setting and structural features of the area around the WIPP are described in CCA Section 2.1.5. In summary, there is no geological evidence for Quaternary regional tectonics in the Delaware Basin. The eastward tilting of the region has been dated as mid-Miocene to Pliocene by King (1948, pp. 120 - 121) and is associated with the uplift of the Guadalupe Mountains to the west. Fault zones along the eastern margin of the basin, where it flanks the Central Basin Platform, were active during the Late Permian. Evidence for this includes the displacement of the Rustler Formation (hereafter referred to as the Rustler) observed by Holt and Powers (1988, pp. 4 - 14) and the thinning of the Dewey Lake Redbeds (hereafter referred to as the Dewey Lake) reported by Schiel

(1994). There is, however, no surface displacement along the trend of these fault zones, indicating that there has been no significant Quaternary movement. Other faults identified within the evaporite sequence of the Delaware Basin are inferred by Barrows' figures in Borns et al. (1983, pp. 58 - 60) to be the result of salt deformation rather than regional tectonic processes. According to Muehlberger et al. (1978, p. 338), the nearest faults on which Quaternary movement has been identified lie to the west of the Guadalupe Mountains and are of minor regional significance. The effects of regional tectonics and changes in regional stress have therefore been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

There are no reported stress measurements from the Delaware Basin, but a low level of regional stress has been inferred from the geological setting of the area (see CCA Section 2.1.5). The inferred low level of regional stress and the lack of Quaternary tectonic activity indicate that regional tectonics and any changes in regional stress will be minor and therefore of low consequence to the performance of the disposal system. Even if rates of regional tectonic movement experienced over the past 10 million years continue, the extent of regional uplift and subsidence over the next 10,000 years would only be about several feet (approximately 1 meter). This amount of uplift or subsidence would not lead to a breach of the Salado because the salt would deform plastically to accommodate this slow rate of movement. Uniform regional uplift or a small increase in regional dip consistent with this past rate could give rise to downcutting by rivers and streams in the region. The extent of this downcutting would be little more than the extent of uplift, and reducing the overburden by 1 or 2 meters would have no significant effect on groundwater flow or contaminant transport in units above or below the Salado. Thus, the effects of regional uplift and subsidence have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Tectonic Setting and Site Structural Features

The DOE has screened out, on the basis of either probability or consequence or both, all tectonic, magmatic, and structural related processes. The screening discussions can be found in CCA Appendix SCR. The information needed for this screening is included here and covers regional tectonic processes such as subsidence and uplift and basin tilting, magmatic processes such as igneous intrusion and events such as volcanism, and structural processes such as faulting and loading and unloading of the rocks because of long-term sedimentation or erosion. Discussions of structural events, such as earthquakes, are considered to the extent that they may create new faults or activate old faults. The seismicity of the area is considered in CCA Section 2.6 for the purposes of determining seismic design parameters for the facility.

Tectonics

The processes and features included in this section are those more traditionally considered part of tectonics, processes that develop the broad-scale features of the earth.

Salt dissolution is a different process that can develop some features resembling those of tectonics.

Most broad-scale structural elements of the area around the WIPP developed during the Late Paleozoic (Appendix GCR, pp. 3-58 to 3-77). There is little historical or geological evidence of significant tectonic activity in the vicinity, and the level of stress in the region is low. The entire region tilted slightly during the Tertiary, and activity related to Basin and Range tectonics formed major structures southwest of the area. Seismic activity is specifically addressed in a separate section.

Broad subsidence began in the area as early as the Ordovician, developing a sag called the Tobosa Basin. By Late Pennsylvanian to Early Permian time, the Central Basin Platform developed (Figure 2-19), separating the Tobosa Basin into two parts: the Delaware Basin to the west and the Midland Basin to the east. The Permian Basin refers to the collective set of depositional basins in the area during the Permian Period. Southwest of the Delaware Basin, the Diablo Platform began developing either in the Late Pennsylvanian or Early Permian. The Marathon Uplift and Ouachita tectonic belt limited the southern extent of the Delaware Basin.

According to Brokaw et al. (1972, p. 30), pre-Ochoan sedimentary rocks in the Delaware Basin show evidence of gentle downwarping during deposition, while Ochoan and younger rocks do not. A relatively uniform eastward tilt, generally from about 75 to 100 feet per mile (14 to 19 meters per kilometer), has been superimposed on the sedimentary sequence. P.B. King (1948, pp. 108 and 121) generally attributes the uplift of the Guadalupe and Delaware mountains along the west side of the Delaware Basin to the later Cenozoic, though he also notes that some faults along the west margin of the Guadalupe Mountains have displaced Quaternary gravels.

P.B. King (1948, p. 144) also infers the uplift from the Pliocene-age deposits of the Llano Estacado. Subsequent studies of the Ogallala of the Llano Estacado show that it varies in age from Miocene (about 12 million years before present) to Pliocene (Hawley 1993). This is the most likely range for uplift of the Guadalupe Mountains and broad tilting to the east of the Delaware Basin sequence.

Analysis of the present regional stress field indicates that the Delaware Basin lies within the Southern Great Plains stress province. This province is a transition zone between the extensional stress regime to the west and the region of compressive stress to the east. An interpretation by Zoback and Zoback (1991, p. 350) of the available data indicates that the level of stress in the Southern Great Plains stress province is low. Changes to the tectonic setting, such as the development of subduction zones and a consequent change in the driving forces, would take much longer than 10,000 years to occur.

To the west of the Southern Great Plains province is the Basin and Range province, or Cordilleran Extension province, where according to Zoback and Zoback (1991, pp. 348-351) normal faulting is the characteristic style of deformation. The eastern boundary of the Basin and Range province is marked by the Rio Grande Rift. Sanford et al. (1991,

230) note that, as a geological structure, the Rift extends beyond the relatively narrow geomorphological feature seen at the surface, with a magnetic anomaly at least 300 miles (500 kilometers) wide. On this basis, the Rio Grande Rift can be regarded as a system of axial grabens along a major north-south trending structural uplift (a continuation of the Southern Rocky Mountains). The magnetic anomaly extends beneath the Southern Great Plains stress province, and regional-scale uplift of about 3,300 feet (1,000 meters) over the past 10 million years also extends into eastern New Mexico.

To the east of the Southern Great Plains province is the large Mid-Plate province that encompasses central and eastern regions of the conterminous United States and the Atlantic basin west of the Mid-Atlantic Ridge. The Mid-Plate province is characterized by low levels of paleo- and historic seismicity. Where Quaternary faulting has occurred, it is generally strike-slip and appears to be associated with the reactivation of older structural elements.

Zoback et al. (1991) report no stress measurements from the Delaware Basin. The stress field in the Southern Great Plains stress province has been defined from borehole measurements in west Texas and from volcanic lineaments in northern New Mexico. These measurements were interpreted by Zoback and Zoback (1991, p. 353) to indicate that the least principal horizontal stress is oriented north-northeast and south-southwest and that most of the province is characterized by an extensional stress regime.

There is an abrupt change between the orientation of the least principal horizontal stress in the Southern Great Plains and the west-northwest orientation of the least principal horizontal stress characteristic of the Rio Grande Rift. In addition to the geological indications of a transition zone as described above, Zoback and Zoback (1980, p. 6134) point out that there is also evidence for a sharp boundary between these two provinces. This is reinforced by the change in crustal thickness from about 24 miles (40 kilometers) beneath the Colorado Plateau to about 30 miles (50 kilometers) or more beneath the Southern Great Plains east of the Rio Grande Rift. The base of the crust within the Rio Grande Rift is poorly defined but is shallower than that of the Colorado Plateau (Thompson and Zoback 1979, p. 152). There is also markedly lower heat flow in the Southern Great Plains (typically < 60 m Wm-2) reported by Blackwell et al. (1991, p. 428) compared with that in the Rio Grande Rift (typically > 80 m Wm-2) reported by Reiter et al. (1991, p. 463).

On the eastern boundary of the Southern Great Plains province, there is only a small rotation in the direction of the least principal horizontal stress. There is, however, a change from an extensional, normal faulting regime to a compressive, strike-slip faulting regime in the Mid-Plate province. According to Zoback and Zoback (1980, p. 6134), the available data indicate that this change is not abrupt and that the Southern Great Plains province can be viewed as a marginal part of the Mid-Plate province.

EPA FEP Number: N6 & N7
FEP Title: Salt Deformation (N6)
Diapirism (N7)

SCR Section Number: SCR.1.1.3.1
Screening Decision: SO-P

Summary:

The DOE presented extensive evidence that some of the evaporites in the northern Delaware Basin have been deformed and proposed that the likely mechanism for deformation is gravity foundering of the more dense anhydrites in less dense halite (e.g., Anderson and Powers 1978; Jones 1981; Borns et al. 1983; Borns 1987). Diapirism occurs when the deformation is penetrative, i.e., halite beds disrupt overlying anhydrites. As Anderson and Powers (1978) suggested, this may have happened northeast of the WIPP at the location of drillhole ERDA-6. This is the only location where diapirism has been suggested for the evaporites of the northern Delaware Basin. The geologic situation suggests that deformation occurred before the Miocene-Pliocene Ogallala Formation was deposited (Jones, 1981). Mechanical modeling is consistent with salt deformation occurring over about 700,000 years to form the deformed features known in the northern part of the WIPP site (Borns et al. 1983). The DOE drew the conclusion that evaporites at the WIPP site are deformed too slowly to affect performance of the disposal system.

Because brine reservoirs appear to be associated with deformation, Powers et al. (1996) prepared detailed structure elevation maps of various units from the base of the Castile Formation upward through the evaporites in the northern Delaware Basin. Drillholes are far more numerous for this study than at the time of the study by Anderson and Powers (1978). Subdivisions of the Castile appear to be continuous in the vicinity of ERDA 6 and at ERDA 6. There is little justification for interpreting diapiric piercement at that site. The location and distribution of evaporite deformation in the area of the WIPP site is similar to that proposed by earlier studies (e.g., Anderson and Powers 1978; Borns et al. 1983; Borns and Shaffer 1985).

Surface domal features at the northwestern end of Nash Draw were of undetermined origin prior to WIPP investigations (e.g., Vine 1963), but extensive geophysical studies were conducted of these features as part of early WIPP studies (see Powers 1996). Two of the domal features were drilled, demonstrating that they had a solution-collapse origin (breccia pipes) and were not related in any way to salt diapirism (Snyder and Gard 1982).

A more recent study of structure for the Culebra Dolomite Member of the Rustler Formation (Powers 2002) shows that the larger deformation associated with deeper units is reflected by the Culebra, although the structural relief is muted. In addition, evaporite deformation in the northern part of the WIPP site, associated with the area earlier termed the "disturbed zone" (Powers et al. 1978), is hardly observable on a map of Culebra structure (Powers 2002). There is no evidence of more recent deformation at the WIPP site based on such maps.

These findings are consistent with the DOE position in the CCA that diapirism can be eliminated from performance assessment calculations on the basis of low probability of occurrence. Although this discussion includes more recent information, the FEP's screening decision remains unchanged.

Italicized Text

Natural salt deformation and diapirism at the WIPP site over the next 10,000 years on a scale severe enough to significantly affect performance of the disposal system has been eliminated from performance assessment calculations on the basis of low probability of occurrence.

FEP Text

Deformation

Deformed salt in the lower Salado and upper strata of the Castile has been encountered in a number of boreholes around the WIPP site; the extent of existing salt deformation is summarized in CCA Section 2.1.6.1, and further detail is provided in CCA Appendix DEF.

A number of mechanisms may result in *salt deformation*: in massive salt deposits, buoyancy effects or *diapirism* may cause salt to rise through denser, overlying units; and in bedded salt with anhydrite or other interbeds, gravity foundering of the interbeds into the halite may take place. Results from rock mechanics modeling studies (see CCA Appendix DEF) indicate that the time scale for the deformation process is such that significant natural deformation is unlikely to occur at the WIPP site over any time frame significant to waste isolation. Thus, natural salt deformation and diapirism severe enough to alter existing patterns of groundwater flow or the behavior of the disposal system over the regulatory period has been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

EPA FEP Number **N8**
FEP Title: **Formation of Fractures**

SCR Section Number **SCR.1.1.3.2**
Screening Decision: **SO-P, UP (Repository)**

Summary:

The text for formation of fractures has been revised and replaced. The screening argument has been updated although the screening decision remains unchanged.

Italicized Text

The formation of fractures has been eliminated from performance assessment calculations on the basis of a low probability of occurrence over 10,000 years.

FEP Text

The *formation of fractures* requires larger changes in stress than are required for changes to the properties of existing fractures to overcome the shear and tensile strength of the rock. It has been concluded from the regional tectonic setting of the Delaware Basin that no significant changes in regional stress are expected over the regulatory period. EPA agrees that fracture formation in the Rustler is likely a result of halite dissolution and subsequent overlying unit fracturing loading/unloading, as well as the syn- and post-depositional processes. Intraformational post-depositional dissolution of the Rustler Formation has been ruled out as a major contributor to Rustler salt distribution and thus to new fracture formation based on work by Holt and Powers [ibid., CCA Appendix DEF, Section DEF3.2] and Powers and Holt (1999, 2000), who believe that depositional facies and syndepositional dissolution account for most of the patterns on halite distribution in the Rustler. The argument against developing new fractures in the Rustler during the regulatory period appears reasonable. The formation of new fracture sets in the Culebra has therefore been eliminated from performance assessment calculations on the basis of a low probability of occurrence over 10,000 years.

Repository-induced fracturing of the DRZ and Salado interbeds is accounted for in performance assessment calculations.

A mechanism such as salt diapirism could develop fracturing in the Salado, but there is little evidence of diapirism in the Delaware Basin. Salt deformation has occurred in the vicinity of the WIPP, and fractures have developed in deeper Castile anhydrites as a consequence. Deformation rates are slow, and it is highly unlikely that this process will induce significant new fractures in the Salado during the regulatory time period. Surface domal features at the northwestern end of Nash Draw were of undetermined origin prior to WIPP investigations (e.g., Vine 1963), but extensive geophysical studies were conducted of these features as part of early WIPP studies (see Powers 1996). Two of the domal features were drilled, demonstrating that they had a solution-collapse origin (breccia pipes) and were not related in any way to salt diapirism (Snyder and Gard 1982).

The argument against developing new fractures within the Salado Formation during the regulatory period via regional stress therefore appears reasonable. Editorial changes for clarity are suggested, as well as separating the two FEPs into discrete arguments. Although the discussion of fracture development has been revised to include more recent information, the screening decision remains unchanged.

EPA FEP Number: N9
FEP Title: Changes in Fracture Properties

SCR Section Number: SCR.1.1.3.2
Screening Decision: SO-C, UP (near repository)

Summary:

The text change in fracture properties has been revised and replaced. The screening argument has been updated although the screening decision remains unchanged

Italicized Text

Naturally induced changes in fracture properties that may affect groundwater flow or radionuclide transport in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Groundwater flow in the region of the WIPP and transport of any released radionuclides may take place along fractures. The rate of flow and the extent of transport will be influenced by fracture characteristics. Changes in fracture properties could arise through natural changes in the local stress field, for example, through tectonic processes, erosion or sedimentation changing the amount of overburden, dissolution of soluble minerals along beds in the Rustler or upper Salado, or dissolution or precipitation of minerals in fractures.

Tectonic processes and features (N3 Changes in Regional Stress; N4 Tectonics; N5 Regional uplift and subsidence; N6 Salt deformation; N7 Diapirism) have been screened out of performance assessment. These processes are not expected to change the character of fractures significantly during the regulatory period.

Surface erosion or deposition (e.g., FEPs N41-N49) are not expected to change significantly the overburden on the Culebra during the regulatory period. The relationship between Culebra transmissivity (T) and depth is significant (Holt, 2002; Holt and Powers, 2002), but the potential change to Culebra T based on deposition or erosion from these processes over the regulatory period is insignificant.

Shallow dissolution (FEP N16), where soluble beds from the upper Salado or Rustler are removed by groundwater, has been extensively considered. There are no direct effects on the Salado at depths of the repository. Extensive study of the upper Salado and Rustler halite units (Holt and Powers 1988 [CCA Appendix FAC]; Powers and Holt 1999, 2000; Powers 2002) indicates little potential for dissolution at the WIPP site during the regulatory period. Existing fracture properties are expressed through the relationship between Culebra T values and geologic factors at and near the WIPP site (Holt 2002;

Holt and Powers 2002). These will be incorporated in performance assessment (see N16 Shallow dissolution).

Mineral precipitation within fractures (N22) is expected to be beneficial to performance, and it has been screened out on the basis of low consequence. Natural dissolution of fracture fillings within the Culebra is incorporated within FEP N16 (Shallow dissolution). There is no new information on the distribution of fracture fillings within the Culebra. The effects of fracture fillings are also expected to be represented in the distribution of Culebra T values around the WIPP site and are thus incorporated into performance assessment.

Repository induced fracturing of the DRZ and Salado interbeds is accounted for in performance assessment calculations, as was discussed in FEPs discussions for W18 and W19.

EPA FEP Number(s): N10 & N11
FEP Title(s): Formation of New Faults (N10)
Fault Movement (N11)

SCR Section Number: SCR.1.1.3.3
Screening Decision: SO-P

Summary:

The DOE's screening designation for fault formation and movement remain technically valid. No changes have been made to the FEP screening decision, however the screening argument text was revised to include information on seismic monitoring since the CCA and the nearby rockfalls of non-tectonic origin in potash mines.

Italicized Text

The naturally induced fault movement and formation of new faults of sufficient magnitude to significantly affect the performance of the disposal system have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text

Faults are present in the Delaware Basin in both the units underlying the Salado and in the Permian evaporite sequence (see CCA Section 2.1.5.3). According to Powers et al. (1978, included as Appendix GCR to the CCA), there is evidence that movement along faults within the pre-Permian units affected the thickness of Early Permian strata, but these faults did not exert a structural control on the deposition of the Castile, the Salado, or the Rustler. Fault zones along the margins of the Delaware Basin were active during the Late Permian Period. Along the eastern margin, where the Delaware Basin flanks the Central Basin Platform, Holt and Powers (1988, included as Appendix FAC to the CCA) note that there is displacement of the Rustler, and Schiel (1994) notes that there is thinning of the Dewey Lake. There is, however, no surface displacement along the trend of these fault zones, indicating that there has been no significant Quaternary movement. Muehlberger et al. (1978, p. 338) note that the nearest faults on which Quaternary movement has been identified lie to the west of the Guadalupe Mountains.

The WIPP is located in an area of tectonic quiescence. Seismic monitoring conducted for the WIPP since the CCA continues to record small events at distance from the WIPP, and these events are mainly in areas associated with hydrocarbon production. Two nearby events (magnitude 3.5, 10/97, and magnitude 2.8, 12/98) are related to rockfalls in the Nash Draw mine and are not tectonic in origin (DOE 1999). These events did not cause any damage at the WIPP. The absence of Quaternary fault scarps and the general tectonic setting and understanding of its evolution indicate that large-scale, tectonically-induced fault movement within the Delaware Basin can be eliminated from performance assessment calculations on the basis of low probability over 10,000 years. The stable tectonic setting also allows the formation of new faults within the basin over the next 10,000 years to be eliminated from performance assessment calculations on the basis of low probability of occurrence.

Evaporite dissolution at or near the WIPP site has the potential for developing fractures in the overlying beds. Three zones (top of Salado, M1/H1 of the Los Medaños Member, and M2/H2 of the Los Medaños Member) with halite underlie the Culebra Dolomite Member at the site (Powers 2002). The upper Salado is present across the site, and there is no indication of dissolution of this area will occur in the regulatory period or cause faulting at the site. The Los Medaños units show both mudflat facies and halite-bearing facies within or adjacent to the WIPP site (Powers 2002). Although the distribution of halite in the Rustler is mainly due to depositional facies and syndepositional dissolution (Holt and Powers 1988; Powers and Holt 1999, 2000), the possibility of past or future halite dissolution along the margins cannot be ruled out (Holt and Powers 1988; Beauheim and Holt 1999). If halite in the lower Rustler has been dissolved along the depositional margin, it has not occurred recently or has been of no consequence, as there is no indication on the surface or in Rustler structure of new (or old) faults in this area (e.g., Powers et al. 1978; Powers 2002).

The absence of Quaternary fault scarps and the general tectonic setting and understanding of its evolution indicate that large-scale, tectonically-induced fault movement within the Delaware Basin can be eliminated from performance assessment calculations on the basis of low probability over 10,000 years. The stable tectonic setting also allows the formation of new faults within the basin over the next 10,000 years to be eliminated from performance assessment calculations on the basis of low probability of occurrence.

EPA FEP Number: N13
FEP Title: Volcanic Activity

SCR Section Number: SCR.1.1.4.1
Screening Decision: SO-P

Summary:

The screening argument remains valid. The geological setting of the WIPP site within the large and stable Delaware Basin allows volcanic activity in the region of the WIPP repository to be eliminated from performance calculations on the basis of low probability of occurrence over the next 10,000 years. Changes were made to the italicized text to remove reference to other FEPs. No changes have been made to the FEP text, description or screening argument.

Italicized Text

Volcanic activity has been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text

Volcanic Activity

The Paleozoic and younger stratigraphic sequences within the Delaware Basin are devoid of locally derived volcanic rocks. Volcanic ashes (dated at 13 million years and 0.6 million year) do occur in the Gatuña Formation (hereafter referred to as the Gatuña), but these are not locally derived. Within eastern New Mexico and northern, central, and western Texas, the closest Tertiary volcanic rocks with notable areal extent or tectonic significance to the WIPP are approximately 100 miles (160 kilometers) to the south in the Davis Mountains volcanic area. The closest Quaternary volcanic rocks are 150 miles (250 kilometers) to the northwest in the Sacramento Mountains. No volcanic rocks are exposed at the surface within the Delaware Basin.

Volcanic activity is associated with particular tectonic settings: constructive and destructive plate margins, regions of intraplate rifting, and isolated hot-spots in intraplate regions. The tectonic setting of the WIPP site and the Delaware Basin is remote from plate margins, and the absence of past volcanic activity indicates the absence of a major hot spot in the region. Intraplate rifting has taken place along the Rio Grande some 120 miles (200 kilometers) west of the WIPP site during the Tertiary and Quaternary Periods. Igneous activity along this rift valley is comprised of sheet lavas intruded on by a host of small-to-large plugs, sills, and other intrusive bodies. However, the geological setting of the WIPP site within the large and stable Delaware Basin allows volcanic activity in the region of the WIPP repository to be eliminated from performance calculations on the basis of low probability of occurrence over the next 10,000 years.

EPA FEP Number: **N14**
FEP Title: **Magmatic Activity**

SCR Section Number: **SCR.1.1.4.1**
Screening Decision: **SO-C**

Summary:

The screening argument remains valid. The effects of magmatic activity have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Studies indicate that, within some 100 miles of the WIPP site, no magmatic activity has taken place since the early part of Basin and Range tectonism, which began in the mid-Tertiary. The closest igneous feature to the site is a lamprophyre dike or series of en echelon dikes, which approaches no nearer than about nine miles from the site; no associated igneous bodies have been found to approach or underlie the site itself. Magmatic activity in the Rio Grande Rift is too remote from the WIPP location to be of consequence to the performance of the disposal system. Thus, the effects of magmatic activity have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Changes were made to the italicized text to remove reference to other FEPs. No changes have been made to the FEP text, description or screening argument.

Italicized Text

The effects of magmatic activity have been eliminated from the performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Magmatic Activity

Magmatic activity is defined as the subsurface intrusion of igneous rocks into country rock. Deep intrusive igneous rocks crystallize at depths of several kilometers and have no surface or near-surface expression until considerable erosion has taken place. Alternatively, intrusive rocks may form from magma that has risen to near the surface or in the vents that give rise to volcanoes and lava flows. Magma near the surface may be intruded along subvertical and subhorizontal discontinuities (forming dikes and sills, respectively), and magma in volcanic vents may solidify as plugs. The formation of such features close to a repository or the existence of a recently intruded rock mass could impose thermal stresses inducing new fractures or altering the hydraulic characteristics of existing fractures.

The principal area of magmatic activity in New Mexico is the Rio Grande Rift, where extensive intrusions occurred during the Tertiary and Quaternary Periods. The Rio Grande Rift, however, is in a different tectonic province than the Delaware Basin, and its magmatic activity is related to the extensional stress regime and high heat flow in that region.

Within the Delaware Basin, there is a single identified outcrop of a lamprophyre dike about 40 miles (70 kilometers) southwest of the WIPP (see CCA Section 2.1.5.4 and Appendix GCR for more detail). Closer to the WIPP site, similar rocks have been exposed within potash mines some 10 miles (15 kilometers) to the northwest, and igneous rocks have been reported from petroleum exploration boreholes. Material from the subsurface exposures has been dated at around 35 million years. Some recrystallization of the host rocks took place alongside the intrusion, and there is evidence that minor fracture development and fluid migration also occurred along the margins of the intrusion. However, the fractures have been sealed, and there is no evidence that the dike acted as a conduit for continued fluid flow.

Aeromagnetic surveys of the Delaware Basin have shown anomalies that lie on a linear southwest-northeast trend that coincides with the surface and subsurface exposures of magmatic rocks. There is a strong indication therefore of a dike or a closely related set of dikes extending for at least 70 miles (120 kilometers) across the region (see Section 2.1.5.4). The aeromagnetic survey conducted to delineate the dike showed a magnetic anomaly that is several miles (several kilometers) wide at depth and narrows to a thin trace near the surface. This pattern is interpreted as the result of an extensive dike swarm at depths of less than 2.5 miles (approximately 4.0 kilometers) near the Precambrian basement, from which a limited number of dikes have extended towards the surface.

Magmatic activity has taken place in the vicinity of the WIPP site in the past, but the igneous rocks have cooled over a long period. Any enhanced fracturing or conduits for fluid flow have been sealed by salt creep and mineralization. Continuing magmatic activity in the Rio Grande Rift is too remote from the WIPP location to be of consequence to the performance of the disposal system. Thus, the effects of magmatic activity have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N15**
FEP Title: **Metamorphic Activity**

SCR Section Number: **SCR.1.1.4.2**
Screening Decision: **SO-P**

Summary:

The WIPP site is located in an area with no evidence of significant tectonic activity and a low level of regional stress. Since the Permian age (~200-250 million year old) Salado was deposited, minimal structural deformation has occurred in the Delaware Basin, reflecting limited tectonic activity in the Delaware Basin. Given the geologic province and history of the area, the occurrence of volcanic/magmatic activity in the region and associated metamorphism appears very unlikely during the next 10,000 years. The screening argument remains valid. No changes have been made to the FEP text, description, screening argument or screening decision.

Italicized Text

Metamorphic activity has been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

FEP Text

Metamorphic activity, that is, solid-state recrystallization changes to rock properties and geologic structures through the effects of heat and/or pressure, requires depths of burial much greater than the depth of the repository. Regional tectonics that would result in the burial of the repository to the depths at which the repository would be affected by metamorphic activity have been eliminated from performance assessment calculations on the basis of low probability of occurrence; therefore, metamorphic activity has also been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

EPA FEP Number: N16
FEP Title: Shallow Dissolution

SCR Section Number SCR.1.1.5.1
Screening Decision: UP

Summary:

In the vicinity of the WIPP site, the processes described in CCA Appendix SCR as shallow dissolution (N16) and lateral dissolution (N17) extensively overlap. As a result, N16 and N17 have been combined and N17 has been deleted from the FEPs baseline. FEP N16 has been modified to account for the deletion of N17. For the CRA, all of these inter-related processes, and their attendant features, are considered as part of shallow dissolution, which is accounted for in performance assessment calculations.

Italicized Text

Shallow dissolution is accounted for in performance assessment calculations

FEP Text Dissolution

This section discusses a variety of styles of dissolution that have been active in the region of the WIPP or in the Delaware Basin. A distinction has been drawn between *shallow dissolution*, involving circulation of groundwater and mineral dissolution in the Rustler and at the top of the Salado in the region of the WIPP; and deep dissolution taking place in the Castile and the base of the Salado. Dissolution will initially enhance porosities, but continued dissolution may lead to compaction of the affected units with a consequent reduction in porosity. Compaction may result in fracturing of overlying brittle units and increased permeability. Extensive dissolution may create cavities (karst) and result in the total collapse of overlying units. This topic is discussed further in CCA Section 2.1.6.2

Shallow Dissolution.

In the region around WIPP, shallow dissolution by groundwater flow has removed soluble minerals from the upper Salado as well as the Rustler to form Nash Draw; extensive solution within the closed draw has created karst features including caves and dolines in the sulfate beds of the Rustler (see Lee, 1925; Bachman, 1980, 1985, 1987a). An alluvial doline drilled at WIPP 33, about 2800 ft west of the WIPP site boundary, is the nearest karst feature known in the vicinity of the site. Upper Salado halite dissolution in Nash Draw resulted in propagating fracturing upward through the overlying Rustler (Holt and Powers 1988). The margin of dissolution of halite from the upper Salado has commonly been placed west of the WIPP site, near, but east of, Livingston Ridge, the eastern boundary of Nash Draw. Halite occurs in the Rustler east of Livingston Ridge, with the margin generally progressively eastward in higher stratigraphic units (e.g., Snyder 1985; Powers and Holt 1995). The distribution of halite in the Rustler has commonly been attributed to shallow dissolution (e.g., Powers et al. 1978; Lambert, 1983; Bachman 1985; Lowenstein 1987). During early studies for the WIPP, the variability of transmissivity of the Culebra in the vicinity of the WIPP was commonly attributed to the effects of dissolution of Rustler halite and changes in fracturing as a consequence.

After a detailed sedimentologic and stratigraphic investigation of WIPP cores, shafts, and geophysical logs from the region around WIPP, the distribution of halite in the Rustler was attributed to depositional and syndepositional processes rather than post-depositional dissolution (Holt and Powers 1988; Powers and Holt 2000). Rustler exposures in shafts for the WIPP revealed extensive sedimentary structures in clastic units (Holt and Powers 1984, 1986, 1990), and the suite of features in these beds led these investigators (Holt and Powers 1988; Powers and Holt 1990, 2000) to re-interpret the clastic units. They conclude that the clastic facies represent mainly mudflat facies tracts adjacent to a salt pan. Although some halite likely was deposited in mudflat areas proximal to the salt pan, it was largely removed by syndepositional dissolution, as indicated by soil structures, soft sediment deformation, bedding, and small-scale vertical relationships (Holt and Powers 1988; Powers and Holt 1990, 1999, 2000). The depositional margins of halite in the Rustler are the likely points for past or future dissolution (e.g., Holt and Powers 1988; Beauheim and Holt 1990). Cores from drillholes at the H-19 drillpad near the Tamarisk Member halite margin show evidence of some dissolution of halite in the Tamarisk (Mercer et al. 1998), consistent with these predictions. The distribution of Culebra transmissivity values is not considered related to dissolution of Rustler halite, and other geological factors (e.g., depth, upper Salado dissolution) correlate well with Culebra transmissivity (e.g., Powers and Holt 1995; Holt and Powers 2002).

Since the CCA was completed, the WIPP has conducted additional work on shallow dissolution, principally of the upper Salado, and its possible relationship to the distribution of transmissivity (T) values for the Culebra as determined through testing of WIPP hydrology wells.

AP-088 (Beauheim 2002) noted that potentiometric surface values for the Culebra in many monitoring wells were outside the uncertainty ranges used to calibrate models of steady state heads for the unit. AP-088 directed the analysis of the relationship between geological factors and values of T at Culebra wells. The relationship between geological factors, including dissolution of the upper Salado as well as limited dissolution in the Rustler, and Culebra T is being used to evaluate differences between assuming steady state Culebra heads and changing heads.

Task 1 for AP-088 (Powers 2002) evaluated geological factors, including shallow dissolution in the vicinity of the WIPP site that related to Culebra T. A much more extensive drillhole geological database was developed than was previously available, utilizing sources of data from WIPP, potash exploration, and oil and gas exploration and development. The principal findings related to shallow dissolution are: 1) a relatively narrow zone (~ 200-400 m wide) could be defined as the margin of dissolution of the upper Salado in much of the area around WIPP, 2) the upper Salado dissolution margin commonly underlies surface escarpments such as Livingston Ridge, and 3) there are possible extensions or re-entrants of incipient upper Salado dissolution extending eastward from the general dissolution margin. The WIPP site proper is not affected by this process.

Culebra T correlates well with depth or overburden, which affects fracture apertures (Powers and Holt 1995, Holt and Powers 2002; Holt 2002). Dissolution of the upper Salado appears to increase T by one or more orders of magnitude (Holt 2002). Because there is no indication of upper Salado dissolution at the WIPP site, Holt (2002) did not include this factor for the WIPP site in estimates of base T values for the WIPP site and surroundings.

There is no new work since the CCA on the distribution of fracture fillings in the Culebra or on dissolution of the fillings. The effects of this process are represented in the distribution of Culebra T values around the WIPP site.

New work regarding shallow dissolution does not change the inclusion of the effects in the T field for the Culebra within performance assessment calculations. The new work provides a firmer basis for understanding the effects of shallow dissolution as represented in performance assessment.

The effects of *Shallow Dissolution* (including the impacts of lateral dissolution) have been included in performance assessment calculations.

EPA FEP Number: N17
FEP Title: Lateral Dissolution

SCR Section Number: SCR.1.1.5.1
Screening Decision: NA

Summary:

FEP N17 *Lateral Dissolution* is so similar to FEP N16 *Shallow Dissolution* as features and processes that they are better treated as a single FEP N16, Shallow Dissolution. Therefore, N17 has been deleted from the FEPs baseline and the text for N16 has been modified to address the combination of N16 and N17 into one FEP N16. Shallow dissolution is accounted for in performance assessment calculations, and this is appropriate.

EPA FEP Number: N18, N20 & N21
FEP Title: Deep Dissolution (N18)
Breccia Pipes (N20)
Collapse Breccias (N21)

SCR Section Number: SCR.1.1.5.1
Screening Decision: SO-P

Summary:

The DOE limited deep dissolution to processes involving dissolution of the Castile or basal Salado Formations and associated features such as breccia pipes (also known as solution chimneys – see FEP N19) with this process. The DOE found that deep dissolution is a process that may be operating in the Delaware Basin, but the process is limited by the hydraulic and geochemical characteristics of the expected source of water in the Delaware Mountain Group underlying the evaporite formations. Investigations of the WIPP site have not found evidence of specific features (e.g., breccia pipes, solution collapse, or solution chimneys) associated with deep dissolution. The EPA also concluded that the mechanism may be operating in the Delaware Basin, and that there is little evidence of deep dissolution at the WIPP site. The EPA concluded that the rate or magnitude of this process is not high enough that it is likely to threaten integrity of the WIPP over the next 10,000 years. These conclusions appear reasonable. The original description and screening arguments as presented in the CCA remain valid. The FEP text has been modified to clarify the arguments and the italicized text has been revised to remove reference to other FEPs.

Italicized Text

Deep dissolution and the formation of associated features (for example, solution chimneys, breccia pipes, collapse breccias) at the WIPP site have been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

FEP Text

This section discusses a variety of styles of dissolution that have been active in the region of the WIPP or in the Delaware Basin. A distinction has been drawn between *shallow dissolution*, involving circulation of groundwater and mineral dissolution in the Rustler and at the top of the Salado in the region of the WIPP; and *deep dissolution* taking place in the Castile and the base of the Salado. Dissolution will initially enhance porosities, but continued dissolution may lead to compaction of the affected units with a consequent reduction in porosity. Compaction may result in fracturing of overlying brittle units and increased permeability. Extensive dissolution may create cavities (karst) and result in the total collapse of overlying units. This topic is discussed further in CCA Section 2.1.6.2

Deep Dissolution

Deep dissolution refers to the dissolution of salt or other evaporite minerals in a formation at depth (see CCA Section 2.1.6.2). Deep dissolution is distinguished from shallow and lateral dissolution not only by depth, but also by the origin of the water. Dissolution by groundwater from deep water-bearing zones can lead to the formation of cavities. Collapse of overlying beds leads to the formation of *collapse breccias* if the overlying rocks are brittle or to deformation if the overlying rocks are ductile. If dissolution is extensive, *breccia pipes* or *solution chimneys* may form above the cavity. These pipes may reach the surface or pass upwards into fractures and then into microcracks that do not extend to the surface. Breccia pipes may also form through the downward percolation of meteoric waters, as discussed earlier. Deep dissolution is of concern because it could accelerate contaminant transport through the creation of vertical flow paths that bypass low-permeability units in the Rustler. If dissolution occurred within or beneath the waste panels themselves, there could be increased circulation of groundwater through the waste as well as a breach of the Salado host rock.

Features identified as being the result of deep dissolution are present along the northern and eastern margins of the Delaware Basin. In addition to features that have a surface expression or that appear within potash mine workings, deep dissolution has been cited by Anderson et al. (1972, p. 81) as the cause of lateral variability within evaporite sequences in the lower Salado.

Exposures of the McNutt Potash Member of the Salado within a mine near Nash Draw have shown a breccia pipe containing cemented brecciated fragments of formations higher in the stratigraphic sequence. At the surface, this feature is marked by a dome, and similar domes have been interpreted as dissolution features. The depth of dissolution has not been confirmed, but the collapse structures led Anderson (1978, p. 52) and Snyder et al. (1982, p. 65) to postulate dissolution of the Capitan Limestone at depth; collapse of the Salado, Rustler, and younger formations; and subsequent dissolution and hydration by downward percolating waters. San Simon Sink (see CCA Section 2.1.6.2), some 20 miles (35 kilometers) east-southeast of the WIPP site, has also been interpreted as a solution chimney. Subsidence has occurred there in historical times according to Nicholson and Clebsch (1961, p. 14), suggesting that dissolution at depth is still taking place. Whether this is the result of downwards-percolating surface water or of deep groundwater has not been confirmed. The association of these dissolution features with the inner margin of the Capitan Reef suggest that they owe their origins, if not their continued development, to groundwaters derived from the Capitan Limestone.

Dissolution within the Castile and Lower Salado Formations

The Castile contains sequences of varved anhydrite and carbonate (that is, laminae deposited on a cyclical basis) that can be correlated between several boreholes. On the basis of these deposits, a basin-wide uniformity in the depositional environment of the Castile evaporites was assumed. The absence of varves from all or part of a sequence and the presence of brecciated anhydrite beds have been interpreted by Anderson et al. (1972) as evidence of dissolution. Holt and Powers (CCA Appendix FAC) have questioned the assumption of a uniform depositional environment and contend that the anhydrite beds are lateral equivalents of halite sequences without significant postdepositional dissolution. Wedges of brecciated anhydrite along the margin of the Castile have been interpreted by Robinson and Powers (1987, p. 78) as gravity-driven clastic deposits, rather than the result of deep dissolution.

Localized depressions at the top of the Castile and inclined geophysical marker units at the base of the Salado have been interpreted by Davies (1983, p. 45) as the result of deep dissolution and subsequent collapse or deformation of overlying rocks. The postulated cause of this dissolution was circulation of undersaturated groundwaters from the Bell Canyon Formation (hereafter referred to as the Bell Canyon). Additional boreholes (notably WIPP-13, WIPP-32, and DOE-2) and geophysical logging led Borns and Shaffer (1985) to conclude that the features interpreted by Davies as being dissolution features are the result of irregularities at the top of the Bell Canyon. These irregularities led to localized depositional thickening of the Castile and lower Salado sediments.

Collapse Breccias at Basin Margins

Collapse breccias are present at several places around the margins of the Delaware Basin. Their formation is attributed to relatively fresh groundwater from the Capitan Limestone that forms the margin of the basin. Collapse breccias corresponding to features on geophysical records that have been ascribed to deep dissolution have not been found in boreholes away from the margins. These features have been reinterpreted as the result of early dissolution prior to the deposition of the Salado.

Summary of Deep Dissolution

Deep dissolution features have been identified within the Delaware Basin, but only in marginal areas underlain by Capitan Reef. There is a low probability that deep dissolution will occur sufficiently close to the waste panels over the regulatory period to affect groundwater flow in the immediate region of the WIPP. Deep dissolution at the WIPP site has therefore been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

EPA FEP Number: N19
FEP Title: Solution Chimneys

SCR Section Number: SCR.1.1.5.1
Screening Decision: NA

Summary:

Solution chimneys (N19) and breccia pipes (N20) are equivalent, as used in the CCA and supporting documents for the WIPP. Both the DOE and EPA discussions during the original certification did not make a clear distinction between the two. These FEPs should be combined and treated under FEP N20 Breccia Pipes. The screening arguments will not change by combining the FEPs.

EPA FEP Number: N22
FEP Title: Fracture Infill

SCR Section Number: SCR.1.1.5.2
Screening Decision: SO-C

Summary:

The existing evidence of fracture fillings in the Rustler, mainly by gypsum and halite, suggests that these fillings formed earlier under conditions that differ from the hydrogeological conditions prevailing today. Over the regulatory period, additional fracture fillings are expected to be limited because climate changes are unlikely to affect this process. The original argument that the formation of additional fracture fillings will be beneficial and that the effects should be eliminated on the basis of beneficial consequence to performance remain unchanged. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

The effects of fracture infills have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

FEP Text Mineralization

Precipitation of minerals as *fracture infills* can reduce hydraulic conductivities. The distribution of infilled fractures in the Culebra closely parallels the spatial variability of lateral transmissivity in the Culebra (see CCA Section SCR.1.1.5.1). The secondary gypsum veins in the Rustler have not been dated. Strontium isotope studies (Siegel et al. 1991, pp. 5-53 to 5-57) indicate that the infilling minerals are locally derived from the host rock rather than extrinsically derived, and it is inferred that they reflect an early phase of mineralization and are not associated with recent meteoric waters.

Stable isotope geochemistry in the Rustler has also provided information on mineral stabilities in these strata. Both Chapman (1986, p. 31) and Lambert and Harvey (1987, p. 207) imply that the mineralogical characteristics of units above the Salado have been stable or subject to only minor changes under the various recharge conditions that have existed during the past 0.6 million year-the period since the formation of the Mescalero caliche and the establishment of a pattern of climate change and associated changes in recharge that led to present-day hydrogeological conditions. No changes in climate are expected other than those experienced during this period, and for this reason, no changes are expected in the mineralogical characteristics other than those expressed by the existing variability of fracture infills and diagenetic textures. Formation of fracture infills will reduce transmissivities and will therefore be of beneficial consequence to the performance of the disposal system.

EPA FEP Number: **N26**
FEP Title: **Density Effect on Groundwater Flow**

SCR Section Number: **SCR.1.2.1**
Screening Decision: **SO-C**

Summary:

The effects of natural density variations on groundwater flow have been screened out on the basis of low consequence. No changes have been made to the FEP description, argument, or screening decision. The FEP description was modified to remove reference to other FEPs.

Italicized Text

Density effects on groundwater flow have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The most transmissive unit in the Rustler, and hence the most significant potential pathway for transport of radionuclides to the accessible environment, is the Culebra. The properties of Culebra groundwaters are not homogeneous, and spatial variations in groundwater density (CCA Section 2.2.1.4.1.2) could influence the rate and direction of groundwater flow. A comparison of the gravity-driven flow component and the pressure-driven component in the Culebra, however, shows that only in the region to the south of the WIPP are head gradients low enough for density gradients to be significant (Davies 1989, p. 53). Accounting for this variability would rotate groundwater flow vectors towards the east (down-dip) and hence fluid in the high transmissivity zone would move away from the zone. Excluding brine density variations within the Culebra from performance assessment calculations is therefore a conservative assumption, and *density effects on groundwater flow* have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N28**
FEP Title: **Thermal Effects on Groundwater Flow**

SCR Section Number: **SCR.1.2.2**
Screening Decision: **SO-C**

Summary:

Thermal effects on groundwater flow have been screened out on the basis of low consequence. No changes have been made to the FEP description, argument, or screening decision. The text was modified to remove reference to other FEPs.

Italicized Text

Natural thermal effects on groundwater flow have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Thermal Effects

The geothermal gradient in the region of the WIPP has been measured at about 50°C per mile (30°C per kilometer). Given the generally low permeability in the region, and the limited thickness of units in which groundwater flow occurs (for example the Culebra), natural convection will be too weak to have a significant effect on groundwater flow. No natural FEPs have been identified that could significantly alter the temperature distribution of the disposal system or give rise to *thermal effects on groundwater flow*. Such effects have therefore been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: N29
FEP Title: Saline Intrusion (hydrogeological effects)

SCR Section Number: SCR.1.2.2
Screening Decision: SO-P

Summary:

Natural saline intrusion has been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years. This is because no natural events or processes have been identified that could result in saline intrusion into units above the Salado or cause a significant increase in fluid density. No changes have been made to the FEP description, screening argument, or screening decision. Reference to other FEPs has been removed from the italicized text.

Italicized Text

Changes in groundwater flow arising from saline intrusion has been eliminated from performance assessment calculations on the basis of a low probability of occurrence over 10,000 years.

FEP Text

No natural events or processes have been identified that could result in *saline intrusion* into units above the Salado or cause a significant increase in fluid density. Natural saline intrusion has therefore been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years. Saline intrusion arising from human-initiated events such as drilling into a pressurized brine pocket is discussed in FEPs H21 through H24.

EPA FEP Number: **N30**
FEP Title: **Freshwater Intrusion (hydrogeological effects)**

SCR Section Number: **SCR.1.2.2**
Screening Decision: **SO-P**

Summary:

Natural freshwater intrusion has been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years. This is because no natural events or processes have been identified that could result in freshwater intrusion into units above the Salado or cause a significant decrease in fluid density. No changes have been made to the FEP description, screening argument, or screening decision. Reference to other FEPs has been removed from the italicized text.

Italicized Text

Changes in groundwater flow arising freshwater intrusion have been eliminated from performance assessment calculations on the basis of a low probability of occurrence over 10,000 years.

FEP Text

A number of FEPs, including climate change, can result in changes in infiltration and recharge (see discussions for FEPs N53 through N55). These changes will affect the height of the water table and hence could affect groundwater flow in the Rustler through changes in head gradients. The generally low transmissivity of the Dewey Lake and the Rustler, however, will prevent any significant changes in groundwater density from occurring within the Culebra over the timescales for which increased precipitation and recharge are anticipated. No other natural events or processes have been identified that could result in *freshwater intrusion* into units above the Salado or cause a significant decrease in fluid density. Freshwater intrusion has therefore been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

EPA FEP Number: **N31**
FEP Title: **Hydrological Response to Earthquakes**

SCR Section Numbers: **SCR.1.2.2**
Screening Decision: **SO-C**

Summary:

Hydrological responses to earthquakes have been screened out on the basis of low consequence to WIPP. No changes have been made to the FEP description, screening argument, or screening decision. Reference to other FEPs has been removed from the italicized text.

Italicized Text

A hydrological response to earthquakes has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Hydrological Effects of Seismic Activity

There are a variety of *hydrological responses to earthquakes*. Some of these responses, such as changes in surface-water flow directions, result directly from fault movement. Others, such as changes in subsurface water chemistry and temperature, probably result from changes in flow pathways along the fault or fault zone. According to Bredehoeft et al. (1987, p. 139), further away from the region of fault movement two types of changes to groundwater levels may take place as a result of changes in fluid pressure:

- The passage of seismic waves through a rock mass causes a volume change, inducing a transient response in the fluid pressure, which may be observed as a short-lived fluctuation of the water level in wells.
- Changes in volume strain can cause long-term changes in water level. A buildup of strain occurs prior to rupture and is released during an earthquake. The consequent change in fluid pressure may be manifested by the drying up or reactivation of springs some distance from the region of the epicenter.

Fluid pressure changes induced by the transmission of seismic waves can produce changes of up to several meters in groundwater levels in wells, even at distances of thousands of kilometers from the epicenter. These changes are temporary, however, and levels typically return to pre-earthquake levels in a few hours or days. Changes in fluid pressure arising from changes in volume strain persist for much longer periods, but they are only potentially consequential in tectonic regimes where there is a significant buildup of strain. The regional tectonics of the Delaware Basin indicate that such a buildup has a low probability of occurring over the next 10,000 years (see FEPs N3 and N4).

The expected level of seismic activity in the region of the WIPP will be of low consequence to the performance of the disposal system in terms of groundwater flow or contaminant transport. Changes in groundwater levels resulting from more distant earthquakes will be too short in duration to be significant. Thus, the hydrological effects of earthquakes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N32**
FEP Title: **Natural Gas Intrusion**

SCR Section Number: **SCR.1.2.2**
Screening decision: **SO-P**

Summary:

Changes in groundwater flow due to natural intrusion of gas have been screened out on the basis of low probability. The screening argument remains valid; no new information casts any doubt on its validity. No changes have been made to the FEP description, screening argument, or screening decision. The italicized text has been modified to remove reference to other FEPs.

Italicized Text

Changes in groundwater flow arising from natural gas intrusion have been eliminated from performance assessment calculations on the basis of a low probability of occurrence over 10,000 years.

FEP Text Natural Gas Intrusion

Hydrocarbon resources are present in formations beneath the WIPP (CCA Section 2.3.1.2), and natural gas is extracted from the Morrow Formation. These reserves are, however, some 14,000 feet (4,200 meters) below the surface, and no natural events or processes have been identified that could result in natural gas intrusion into the Salado or the units above. *Natural gas intrusion* has therefore been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

EPA FEP Number(s): **N34 and N38**
FEP Title(s): **Saline Intrusion (geochemical effects) (N34)**
Effects of Dissolution (N38)

SCR Section Number: **SCR.1.3.2**
Screening Decision: **SO-C**

Summary:

The decision to screen-out FEPs N34 and N38 on the basis of low consequence for the long-term performance of the WIPP remains valid. The following discussion provides additional justification for this decision. FEPs N34 and N38 are considered together here. The original FEPs text has been replaced.

The conclusion that "No natural events or processes have been identified that could result in saline intrusion into units above the Salado" (DOE 1996a, Appendix SCR) remains valid. The possibility that dissolution might result in an increase in the salinity of low-to-moderate-ionic-strength groundwaters in the Culebra also appears unlikely.

Nevertheless, saline intrusion and dissolution, in the unlikely event that they occur, would not affect the predicted transport of radionuclides in the Culebra because results obtained from laboratory studies with saline solutions were - for the most part- used to predict radionuclide transport for the CCA PA and the Performance Assessment Verification Test (PAVT). These results will also be used for the first WIPP Compliance Recertification Application (CRA) PA.

Italicized Text

The effects of saline intrusion and dissolution on groundwater chemistry have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The decision to screen-out FEPs N34 and N38 on the basis of low consequence for the long-term performance of the WIPP remains valid. FEPs N34 and N38 are considered together in this discussion because dissolution of minerals such as halite (NaCl), anhydrite ($CaSO_4$), or gypsum ($CaSO_4 \cdot 2H_2O$) (N38) could - in the most extreme case - increase the salinity of groundwaters in the Culebra Member of the Rustler Formation to levels characteristic of those expected after saline intrusion (N34).

The conclusion that "No natural events or processes have been identified that could result in saline intrusion into units above the Salado" (CCA Appendix SCR) remains valid. Injection of Castile-Fm. or Salado brines into the Culebra as a result of human intrusion, an anthropogenically induced event, was included in the performance assessment (PA) calculations for the WIPP Compliance Certification Application (CCA) and the EPA's

Performance Assessment Verification Test (PAVT), and will be included in the first WIPP Compliance Recertification Application (CRA). Laboratory studies carried out to evaluate radionuclide transport in the Culebra following human intrusion produced data that can also be used to evaluate the consequences of natural saline intrusion (see below).

The possibility that dissolution of halite, anhydrite, or gypsum might result in an increase in the salinity of low-to-moderate-ionic-strength groundwaters in the Culebra also appears unlikely, despite the presence of halite in the Los Medaños under most of the WIPP Site (Siegel and Lambert 1991, Figure 1-13), including the expected Culebra off-site transport pathway (the direction of flow from the point(s) at which brines from the repository would enter the Culebra in the event of human intrusion to the south or south-southeast and eventually to the boundary of the WIPP Site). (The Los Medaños Member of the Rustler, formerly referred to as the unnamed lower member of the Rustler, underlies the Culebra.) A dissolution-induced increase in the salinity of Culebra groundwaters is unlikely because: (1) the dissolution of halite is known to be rapid; (2) (moderate-ionic-strength) groundwaters along the off-site transport pathway (and at many other locations in the Culebra) have had sufficient time to dissolve significant quantities of halite, if this mineral is present in the subjacent Los Medaños and if Culebra fluids have been in contact with it; (3) the lack of high-ionic-strength groundwaters along the offsite transport pathway (and elsewhere in the Culebra) implies that halite is present in the Los Medaños but Culebra fluids have not contacted it, or that halite is not present in the Los Medaños. Because halite dissolves so rapidly if contacted by undersaturated solutions, this conclusion does not depend on the nature and timing of Culebra recharge (i.e., whether the Rustler has been a closed hydrologic system for several thousand to a few tens of thousands of years, or is subject to significant modern recharge).

Nevertheless, saline intrusion would not affect the predicted transport of Th, U, Pu, and Am in the Culebra. This is because: (1) the laboratory studies that quantified the retardation of Th, U, Np, Pu and Am for the CCA PA were carried out with both moderate-ionic-strength solutions representative of Culebra groundwaters along the expected offsite transport pathway, and with high-ionic-strength solutions representative of brines from the Castile and the Salado (Brush 1996; Brush and Storz 1996); (2) the results obtained with the saline (Castile and Salado) solutions were - for the most part - used to predict the transport of Pu(III) and Am(III); Th(IV), U(IV), Np(IV) and Pu(IV); and U(VI). The results obtained with the saline solutions were used for these actinide oxidation states because the extent to which saline and Culebra brines will mix along the offsite transport pathway in the Culebra was unclear at the time of the CCA PA; therefore, Brush (1996) and Brush and Storz (1996) recommended that PA use the results that predict less retardation. In the case of Pu(III) and Am(III); Th(IV), U(IV), Np(IV) and Pu(IV); and U(VI), the K_ds obtained with the saline solutions were somewhat lower than those obtained with the Culebra fluids. The K_ds recommended by Brush and Storz (1996) will also be used for the CRA PA. These K_ds are also based mainly on results obtained with saline solutions.

Finally, it is important to reiterate that the use of results from laboratory studies with saline solutions to predict radionuclide transport in the Culebra for the CCA PA, the

PAVT, and the CRA PA implements the effects of saline intrusion caused by human intrusion, not natural saline intrusion. The conclusions that natural saline intrusion is unlikely, that significant dissolution is unlikely, and that these events or processes would have no significant consequence - in the unlikely event that they occur - are still valid.

EPA FEP Number: N35, N36 & N37
FEP Title: Freshwater Intrusion (Geochemical Effects) (N35)
Change in Groundwater Eh (N36)
Changes in groundwater pH (N37)

SCR Section Number: SCR.1.3.2
Screening Decision: SO-C

Summary:

The decision to screen-out FEPs N35, N36, and N37 on the basis of low consequence for the long-term performance of the WIPP remains valid. However, the following discussion provides additional justification for this decision. FEPs N35, N36, and N37 are considered together here.

The most likely mechanism for (natural) intrusion of freshwater into the Culebra (FEP N35), changes in groundwater Eh (N36), and changes in groundwater pH (N37) is (natural) recharge of the Culebra. There is still considerable uncertainty regarding the extent and timing of recharge of the Culebra. If recharge occurs mainly during periods of high precipitation (pluvials) associated with periods of continental glaciation, the consequences of such recharge are probably already reflected in the ranges of geochemical conditions currently observed in the Culebra as a whole, as well as along the likely offsite transport pathway. Therefore, the occurrence of another pluvial during the 10,000-year WIPP regulatory would have no significant, additional consequence for the long-term performance of the repository. If, on the other hand, significant recharge occurs throughout both phases of the glacial-interglacial cycles, the conclusion that the effects of pluvial and modern recharge are inconsequential (are already reflected by existing variations in geochemical conditions) is also still valid.

The decision to screen-out FEPs N35, N36, and N37 on the basis of low consequence for the long-term performance of the WIPP remains valid. However, the following discussion provides additional justification for this decision. FEPs N35, N36, and N37 are considered together in this discussion because the same process is the most likely cause, and – perhaps – the only plausible cause, for all three of these events or changes in these important geochemical properties of groundwaters in the Culebra Member of the Rustler Formation. The original FEP text has been replaced and the italicized text revised to remove reference to other FEPs.

Italicized Text

The effects of freshwater intrusion on groundwater chemistry have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Changes in groundwater Eh and pH have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Natural changes in the groundwater chemistry of the Culebra and other units that resulted from saline intrusion or *freshwater intrusion* could potentially affect chemical retardation and the stability of colloids. Changes in *groundwater Eh* and *groundwater pH* could also affect the migration of radionuclides (see FEPs W65 to W70). No natural events or processes have been identified that could result in saline intrusion into units above the Salado, and the magnitude of any natural temporal variation due to the effects of dissolution on groundwater chemistry, or due to changes in recharge is likely to be no greater than the present spatial variation. These FEPs related to the effects of future natural changes in groundwater chemistry have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

The most likely mechanism for (natural) intrusion of freshwater into the Culebra (FEP N35), changes in groundwater Eh (N36), and changes in groundwater pH (N37) is (natural) recharge of the Culebra. (Other FEPs consider possible anthropogenically induced recharge). These three FEPs are closely related because an increase in the rate of recharge could reduce the ionic strength(s) of Culebra groundwaters, possibly enough to saturate the Culebra with (essentially) freshwater, at least temporarily. Such a change in ionic strength could, if enough atmospheric O_2 remained in solution, also increase the Eh of Culebra groundwaters enough to oxidize Pu from the relatively immobile +III and +IV oxidation states (Pu(III) and Pu(IV)) – the oxidation states expected under current conditions (Brush 1996; Brush and Storz 1996) - to the relatively mobile +V and +VI oxidation states (Pu(V) and Pu(VI)). Similarly, recharge of the Culebra with freshwater could also change the pH of Culebra groundwaters from the currently observed range of about 6 to 7 to mildy acidic values, thus (possibly) decreasing the retardation of dissolved Pu and Am. (These changes in ionic strength, Eh, and pH could also affect mobilities of Th, U, and Np, but the long-term performance of the WIPP is much less sensitive to the mobilities of these radioelements than to those of Pu and Am.)

There is still considerable uncertainty regarding the extent and timing of recharge of the Culebra. Lambert (1986), Lambert and Carter (1987), Lambert and Harvey (1987), and Lambert (1991) used a variety of stable and radiogenic, isotopic-dating techniques to conclude that the Rustler (and the Dewey Lake Fm.) have been closed hydrologic systems for several thousand to a few tens of thousands of years. In other words, the last significant recharge of the Rustler occurred during the late Pleistocene in response to higher levels of precipitation and infiltration associated with the most recent continental glaciation of North America, and the current flow field in the Culebra is the result of the slow discharge of groundwater from this unit. Other investigators have agreed that it is possible that Pleistocene recharge has contributed to present-day flow patterns in the Culebra, but that current patterns are also consistent with significant current recharge (Haug et al. 1987; Davies 1989). Still others (Chapman 1986, 1988) have rejected Lambert's interpretations in favor of exclusively modern recharge, at least in some areas. For example, the low-salinity of Hydrochemical Zone B south of the WIPP Site could represent dilution of Culebra groundwater with significant quantities of recently introduced meteoric water (see Siegel et al. 1991, pp. 2-57 – 2-62 and Figure 2-17 for definitions and locations of the four hydrochemical facies in the Culebra in and around the WIPP Site).

The current program to explain the cause(s) of the rising water levels observed in Culebra monitoring wells may elucidate the nature and timing of recharge. However, the justification of this screening decision does not depend on how this issue is resolved. If recharge occurs mainly during periods of high precipitation (pluvials) associated with periods of continental glaciation, the consequences of such recharge are probably already reflected in the ranges of geochemical conditions currently observed in the Culebra as a whole, as well as along the likely offsite transport pathway (the direction of flow from the point(s) at which brines from the repository would enter the Culebra in the event of human intrusion to the south or south-southeast and eventually to the boundary of the WIPP Site). Hence, the effects of recharge, (possible) freshwater intrusion, and (possible) concomitant changes in groundwater Eh and pH can be screened out on the basis of low consequence to the performance of the far-field barrier. The reasons for the conclusion that the effects of pluvial recharge are inconsequential (are already included among existing variations in geochemical conditions) are: (1) as many as 50 continental glaciations and associated pluvials have occurred since the late Pliocene Epoch 2.5 million years ago (2.5 Ma BP); (2) the glaciations and pluvials that have occurred since about 0.5 to 1 Ma BP have been significantly more severe than those that occurred prior to 1 Ma BP (see, for example, Servant 2001); (3) the studies that quantified the retardation of Th, U, Np, Pu and Am for the WIPP CCA PA calculations and the EPA's Performance Assessment Verification Test (PAVT) were carried out under conditions that encompass those observed along the likely Culebra offsite transport pathway (Brush 1996; Brush and Storz 1996) (4) these studies demonstrated that conditions in the Culebra are favorable for retardation of actinides despite the effects of as many as 50 periods of recharge.

It is also worth noting that the choice of the most recent glacial maximum as an upper limit for possible climatic changes during the 10,000 year WIPP regulatory period (Swift 1991; DOE 1996, Appendix CLI) established conservative upper limits for precipitation and recharge of the Culebra at the WIPP Site. The review by Swift (1991), later incorporated in CCA Appendix CLI, provides evidence that precipitation in New Mexico did not attain its maximum level (about 60-100% of current precipitation) until a few thousand years before the last glacial maximum. Swift pointed out that:

> "Prior to the last glacial maximum 22 to 18 ka BP, evidence from mid-Wisconsin faunal assemblages in caves in southern New Mexico, including the presence of extralimital species such as the desert tortoise that are now restricted to warmer climates, suggests warm summers and mild, relatively dry winters (Harris 1987, 1988). Lacustrine evidence confirms the interpretation that conditions prior to and during the glacial advance that were generally drier than those at the glacial maximum. Permanent water did not appear in what was later to be a major lake in the Estancia Valley in central New Mexico until sometime before 24 ka BP

(Bachhuber 1989). Late-Pleistocene lake levels in the San Agustin Plains in western New Mexico remained low until approximately 26.4 ka BP, and the $\delta^{18}O$ record from ostracode shells suggests that mean annual temperatures at that location did not decrease significantly until approximately 22 ka BP (Phillips et al. 1992)."

Therefore, it is likely that precipitation and recharge did not attain levels characteristic of the most recent glacial maximum until about 70,000-75,000 years after the last galciation had begun. High-resolution, deep-sea $\delta^{18}O$ data (and other data) reviewed by Servant (2001, Figures 1 and 2) support the conclusion that, although the volume of ice incorporated in continental ice sheets can expand rapidly at the start of a glaciation rapidly, attainment of maximum volume does not occur until a few thousand or a few tens of thousands of years prior to the termination of the approximately 100,000-year glaciations that have occurred during the last 0.5-1 Ma BP. Therefore, it is unlikely that precipitation and recharge will reach their maximum levels during the 10,000-year regulatory period.

If, on the other hand, significant recharge occurs throughout both phases of the glacial-interglacial cycles, the conclusion that the effects of pluvial and modern recharge are inconsequential (are already reflected by existing variations in geochemical conditions) is also still valid.

EPA FEP Number: **N38 (see N34)**
FEP Title: **Effects of Dissolution**

SCR Section Number: **SCR.1.3.2**
Screening Decision: **SO-C**

Summary:

See discussion in FEP N34.

EPA FEP Number: **N40**
FEP Title: **Impact of a Large Meteorite**

SCR Section Number: **SCR.1.4.2**
Screening Decision: **SO-P**

Summary:

The original description and screening argument remains valid. The probability of meteorite impact not only directly above the WIPP repository, but also near the repository, was found to be significantly less than one in one million (in 10,000 years). Calculations were based upon observed meteorite impact occurrence in the geologic past. DOE's screening argument is reasonable and well supported. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

Disruption arising from the impact of a large meteorite has been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text

Meteors frequently enter the earth's atmosphere, but most of these are small and burn up before reaching the ground. Of those that reach the ground, most produce only small impact craters that would have no effect on the postclosure integrity of a repository 2,150 feet (650 meters) below the ground surface. While the depth of a crater may be only one-eighth of its diameter, the depth of the disrupted and brecciated material is typically one-third of the overall crater diameter (Grieve 1987, p. 248). Direct disruption of waste at the WIPP would only occur with a crater larger than 1.1 miles (1.8 kilometers) in diameter. Even if waste were not directly disrupted, the impact of a large meteorite could create a zone of fractured rocks beneath and around the crater. The extent of such a zone would depend on the rock type. For sedimentary rocks, the zone may extend to a depth of half the crater diameter or more (Dence et al. 1977, p. 263). The impact of a meteorite causing a crater larger than 0.6 mile (1 kilometer) in diameter could thus fracture the Salado above the repository.

Geological evidence for meteorite impacts on earth is rare because many meteorites fall into the oceans and erosion and sedimentation serve to obscure craters that form on land. Dietz (1961) estimated that meteorites that cause craters larger than 0.6 mile (1 kilometer) in diameter strike the earth at the rate of about one every 10,000 years (equivalent to about 2×10^{-13} impacts per square kilometer per year). Using observations from the Canadian Shield, Hartmann (1965, p. 161) estimated a frequency of between 0.8×10^{-13} and 17×10^{-13} per square kilometer per year for impacts causing craters larger than 0.6 mile (1 kilometer). Frequencies estimated for larger impacts in studies reported by Grieve (1987, p. 263) can be extrapolated to give a rate of about 1.3×10^{-12} per square kilometer per year for craters larger than 0.6 mile (1 kilometer). It is commonly assumed that meteorite impacts are randomly distributed across the earth's surface, although Halliday (1964, pp. 267-277) calculated that the rate of impact in polar regions would be some 50 to 60 percent of that in equatorial regions. The frequencies reported by Grieve (1987) would correspond to an overall rate of about one per 1,000 years on the basis of a random distribution.

Assuming the higher estimated impact rate of 17×10^{-13} impacts per square kilometer per year for impacts leading to fracturing of sufficient extent to affect a deep repository and assuming a repository footprint of 0.9 mile x 1.0 mile (1.4 kilometers x 1.6 kilometers) for the WIPP yields a frequency of about 4×10^{-12} impacts per year for a direct hit above the repository. This impact frequency is several orders of magnitude below the screening limit of 10-4 per 10,000 years provided in 40 CFR § 194.32(d).

Meteorite hits directly above the repository footprint are not the only impacts of concern, however, because large craters may disrupt the waste panels even if the center of the crater is outside the repository area. It is possible to calculate the frequency of meteorite impacts that could disrupt a deep repository such as the WIPP by using the conservative model of a cylinder of rock fractured to a depth equal to one-half the crater diameter, as shown in CCA Appendix SCR Figure SCR-1. The area within which a meteorite could impact the repository is calculated by

$$S_D = \left(L + 2 \times \frac{D}{2} \right) \times \left(W + 2 \times \frac{D}{2} \right) ,$$

Where

L	=	length of the repository footprint (kilometers)
W	=	width of the repository footprint (kilometers)
D	=	diameter of the impact crater (kilometers)
S_D	=	area of the region where the crater would disrupt the repository (square kilometers).

There are insufficient data on meteorites that have struck the earth to derive a distribution function for the size of craters directly. Using meteorite impacts on the moon as an analogy, however, Grieve (1987, p. 257) derived the following distribution function:

$$F_D \propto D^{-1.8} ,$$

where

F_D = frequency of impacts resulting in craters larger than D (impacts per square kilometer per year).

If f(D) denotes the frequency of impacts giving craters of diameter D, then the frequency of impacts giving craters larger than D is

$$F_D = \int_D^{\infty} f(D)dD$$

and

$$f(D) = F_1 \times 1.8 \times D^{-2.8} ,$$

where

F_I = frequency of impacts resulting in craters larger than 1 kilometer (impacts per square kilometer per year)
$f(D)$ = frequency of impacts resulting in craters of diameter D (impacts per square kilometer per year).

The overall frequency of meteorite impacts that could disrupt or fracture the repository is thus given by

$$N = \int_{2h}^{\infty} f(D) \times S_D dD ,$$

Where

h = depth to repository (kilometers)
N = frequency of impacts leading to disruption of the repository (impacts per year)

$$N = 1.8F_1\left[1.8LW(2h)^{-1.8} + 0.8(L+W)(2h)^{-0.8} - 0.2(2h)^{0.2}\right].$$

If it is assumed that the repository is located at a depth of 650 meters and has a footprint area of 0.9 mile x 1.0 mile (1.4 kilometers x 1.6 kilometers) and that meteorites creating craters larger than 1 kilometer in diameter hit the earth at a frequency (F_I) of 17×10^{-13} impacts per square kilometer per year, then the above equation gives a frequency of approximately 1.3×10^{-11} impacts per year for impacts disrupting the repository. If impacts are randomly distributed over time, this corresponds to a probability of 1.3×10^{-7} over 10,000 years.

Similar calculations have been performed that indicate rates of impact of between 10-12 and 10-13 per year for meteorites large enough to disrupt a deep repository (see, for example, Hartmann 1979, Kärnbränslesakerhet 1978, Claiborne and Gera 1974, Cranwell et al. 1990, and Thorne 1992). Meteorite impact can thus be eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

Assuming a random or nearly random distribution of meteorite impacts, cratering at any location is inevitable given sufficient time. Although repository depth and host-rock lithology may reduce the consequences of a meteorite impact, there are no repository locations or engineered systems that can reduce the probability of impact over 10,000 years.

EPA FEP Number: **N41 & N42**
FEP Title(s): **Mechanical Weathering (N41)**
Chemical Weathering (N42)

SCR Section Number: **SCR.1.4.3.1**
Screening Decision: **SO-C**

Summary:

The screening argument for Mechanical Weathering and Chemical Weathering remains valid. While the DOE has indicated that erosional processes, including mechanical weathering, can occur in the WIPP area, weathering has been screened out of the performance assessment calculations based on low consequence to the performance of the disposal system. This seems reasonable since mechanical weathering should be limited to the surface environment and have little effect on the WIPP performance. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of chemical and mechanical weathering have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Mechanical weathering and *chemical weathering* are assumed to be occurring at or near the surface around the WIPP site, through processes such as exfoliation and leaching. The extent of these processes is limited and they will contribute little to the overall rate of erosion in the area or to the availability of material for other erosional processes. The effects of chemical and mechanical weathering have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: N43
FEP Title: Aeolian Erosion

SCR Section Number: SCR.1.4.3.2
Screening Decision: SO-C

Summary:

The screening argument for Aeolian Erosion remains valid. While the DOE has indicated that erosional processes, including aeolian (also spelled eolian) erosion, can occur in the WIPP area, these processes can been screened out of the performance assessment calculations based on low consequence to the performance of the disposal system. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of aeolian erosion in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The geomorphological regime on the Mescalero Plain (Los Medaños) in the region of the WIPP is dominated by aeolian processes. Dunes are present in the area, and although some are stabilized by vegetation, *aeolian erosion* will occur as they migrate across the area. Old dunes will be replaced by new dunes, and no significant changes in the overall thickness of aeolian material are likely to occur.

Erosion from wind, water, and mass wasting will continue in the WIPP region throughout the next 10,000 years at rates similar to those occurring at present. These rates are too low to affect the performance of the disposal system significantly. Thus, the effects of fluvial and aeolian erosion and mass wasting have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N44**
FEP Title: **Fluvial Erosion**

SCR Section Number: **SCR.1.4.3.2**
Screening Decision: **SO-C**

Summary:

The screening argument for Fluvial Erosion remains valid. While the DOE has indicated that erosional processes, including fluvial erosion, can occur in the WIPP area, these processes would not significantly affect repository performance and can be screened out on the basis of low consequence. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of fluvial erosion the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Currently, precipitation in the region of the WIPP is too low (about 13 inches [33 centimeters] per year) to cause perennial streams, and the relief in the area is too low for extensive sheet flood erosion during storms. An increase in precipitation to around 24 inches (61 centimeters) per year in cooler climatic conditions could result in perennial streams, but the nature of the relief and the presence of dissolution hollows and sinks will ensure that these streams remain small. Significant *fluvial erosion* is not expected during the next 10,000 years.

Erosion from wind, water, and mass wasting will continue in the WIPP region throughout the next 10,000 years at rates similar to those occurring at present. These rates are too low to affect the performance of the disposal system significantly. Thus, the effects of fluvial erosion have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N45**
FEP Title: **Mass Wasting (erosion)**

SCR Section Number: **SCR.1.4.3.2**
Screening Decision: **SO-C**

Summary:

The screening argument for Mass Wasting remains valid. While the DOE has indicated that erosional processes, including mass wasting, can occur in the WIPP area, the possibility that these processes would significantly affect the repository is very remote. Mass wasting has been screened out of the performance assessment calculations based on low consequence to the performance of the disposal system. This seems reasonable since surface erosion processes over the next 10,000 years have little effect on the WIPP performance. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of mass wasting in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Mass wasting (the downslope movement of material caused by the direct effect of gravity) is important only in terms of sediment erosion in regions of steep slopes. In the vicinity of the WIPP, mass wasting will be insignificant under the climatic conditions expected over the next 10,000 years.

Erosion from wind, water, and mass wasting will continue in the WIPP region throughout the next 10,000 years at rates similar to those occurring at present. These rates are too low to affect the performance of the disposal system significantly. Thus, the effects of mass wasting have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N46**
FEP Title: **Aeolian Deposition**

SCR Section Number: **SCR.1.4.3.3**
Screening Decisions: **SO-C**

Summary:

The screening argument for Aeolian Deposition remains valid. The DOE has concluded that sedimentation rates from all processes, including aeolian deposition, are too low to affect the performance of the disposal system at WIPP over the next 10,000 years. The possibility that these processes would significantly affect the repository is remote. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of aeolian deposition in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The geomorphological regime on the Mescalero Plain (Los Medaños) in the region of the WIPP, is dominated by aeolian processes, although some dunes are stabilized by vegetation, no significant changes in the overall thickness of aeolian material are expected to occur. Vegetational changes during periods of wetter climate may further stabilize the dune fields, but *aeolian deposition* is not expected to significantly increase the overall thickness of the superficial deposits.

Sedimentation from wind, water, and mass wasting is expected to continue in the WIPP region throughout the next 10,000 years at the low rates similar to those occurring at present. These rates are too low to significantly affect the performance of the disposal system. Thus, the effects of fluvial and aeolian erosion and mass wasting have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: N47
FEP Title: Fluvial Deposition

SCR Section Number: SCR.1.4.3.3
Screening Decision: SO-C

Summary:

The screening argument for Fluvial Deposition remains valid. The DOE has concluded that sedimentation rates from all processes, including fluvial environments, are too low to affect the performance of the disposal system at WIPP over the next 10,000 years. There are no perennial streams within the WIPP boundary, and geological evidence does not indicate any perennial streams since the Mescalero caliche formed about 500,000 years before present. The EPA concluded that limited water courses at WIPP will limit fluvial deposition. The Pecos River valley is too distant from the WIPP to be a factor in fluvial sedimentation. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of fluvial deposition in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The limited extent of water courses in the region of the WIPP, under both present-day conditions and under the expected climatic conditions, will restrict the amount of *fluvial deposition* and lacustrine deposition in the region.

Sedimentation from wind, water, and mass wasting is expected to continue in the WIPP region throughout the next 10,000 years at the low rates similar to those occurring at present. These rates are too low to significantly affect the performance of the disposal system. Thus, the effects of fluvial deposition have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N48**
FEP Title: **Lacustrine Deposition**

SCR Section Number: **SCR.1.4.3.3**
Screening Decision: **SO-C**

Summary:

The screening argument for Lacustrine Deposition remains valid. The DOE has concluded that sedimentation rates from all processes, including lacustrine environments, are too low to affect the performance of the disposal system at WIPP over the next 10,000 years. The EPA concluded during the original certification that limited water courses at WIPP will limit lacustrine deposition. The Pecos River valley is too distant from the WIPP to be a factor in lacustrine sedimentation. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of lacustrine deposition in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The geomorphological regime on the Mescalero Plain (Los Medaños) in the region of the WIPP is dominated by aeolian processes, but although some dunes are stabilized by vegetation, no significant changes in the overall thickness of aeolian material are expected to occur. Vegetational changes during periods of wetter climate may further stabilize the dune fields, but aeolian deposition is not expected to significantly increase the overall thickness of the superficial deposits.

The limited extent of water courses in the region of the WIPP, under both present-day conditions and under the expected climatic conditions, will restrict the amount of fluvial deposition and lacustrine deposition in the region.
Mass wasting may be significant if it results in dams or modifies streams. In the region around the WIPP, the Pecos River forms a significant water course some 12 miles (19 kilometers) away, but the broadness of its valley precludes either significant mass wasting or the formation of large impoundments.

Sedimentation from wind, water, and mass wasting is expected to continue in the WIPP region throughout the next 10,000 years at the low rates similar to those occurring at present. These rates are too low to significantly affect the performance of the disposal system. Thus, the effects of aeolian, fluvial, and lacustrine deposition and sedimentation resulting from mass wasting have been eliminated from performance assessment calculations on the basis of low consequence.

EPA FEP Number: **N49**
FEP Title: **Mass Wasting Deposition**

SCR Section Number: **SCR.1.4.3.3**
Screening Decision: **SO-C**

Summary:

The screening argument for mass wasting remains valid. While the DOE has indicated that erosional processes, as well as mass wasting, can occur in the WIPP area, the effect of weathering are of low consequence to the performance of the disposal system. This seems reasonable since mass wasting is limited to the surface and has little effect on the WIPP performance. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects mass wasting deposition in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

SCR FEP Text

The geomorphological regime on the Mescalero Plain (Los Medaños) in the region of the WIPP is dominated by aeolian processes, but although some dunes are stabilized by vegetation, no significant changes in the overall thickness of aeolian material are expected to occur. Vegetational changes during periods of wetter climate may further stabilize the dune fields, but aeolian deposition is not expected to significantly increase the overall thickness of the superficial deposits.

The limited extent of water courses in the region of the WIPP, under both present-day conditions and under the expected climatic conditions, will restrict the amount of fluvial deposition and lacustrine deposition in the region.

Mass wasting may be significant if it results in dams or modifies streams. In the region around the WIPP, the Pecos River forms a significant water course some 12 miles (19 kilometers) away, but the broadness of its valley precludes either significant mass wasting or the formation of large impoundments.

Sedimentation from wind, water, and mass wasting is expected to continue in the WIPP region throughout the next 10,000 years at the low rates similar to those occurring at present. These rates are too low to significantly affect the performance of the disposal system. Thus, the effects of aeolian, fluvial, and lacustrine deposition and sedimentation resulting from mass wasting have been eliminated from performance assessment calculations on the basis of low consequence.

EPA FEP Number: **N50**
FEP Title: **Soil Development**

SCR Section Number: **SCR.1.4.4**
Screening Decision: **SO-C**

Summary:

Soil development at the WIPP has been screened out of the performance assessment calculations by the DOE, based on low consequence to the performance of the disposal system. Soils at the WIPP site (Mescalero caliche and overlying Berino soil) indicate general surface stability over a period of about the last 600,000 years. Uranium-series trend dates indicate that these are fossil soils. Soil development at the WIPP affects infiltration and can have an effect on performance. The groundwater basin model has been used to account for hydraulic characteristics of these units. EPA reviewed and found the DOE methodology and conclusions were technically adequate (CARD 14.B.4&5) (EPA 1998d). The EPA found the argument presented in SCR 1.4.4 reasonable to screen out soil development based on low consequence (TSD for 194.14 IV B.5) (EPA 1998c). The FEPs supporting text can be clarified by modifying some of the discussion of age of the Mescalero based on radiometric techniques. The screening decision is not changed by these clarifications.

Italicized Text

Soil development has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The Mescalero caliche is a well-developed calcareous remnant of an extensive soil profile across the WIPP site and adjacent areas. Although this unit may be up to 10 feet (3 meters) thick, it is not continuous and does not prevent infiltration to the underlying formations. At Nash Draw, this caliche, dated in Lappin et al. (1989, pp. 2-4) at 410,000 to 510,000 years old, is present in collapse blocks, indicating some growth of Nash Draw in the late Pleistocene. Localized gypsite spring deposits about 25,000 years old occur along the eastern flank of Nash Draw, but the springs are not currently active. The Berino soil, interpreted as 333,000 years old (Rosholt and McKinney 1980, Table 5), is a thin soil horizon above the Mescalero caliche. The persistence of these soils on the Livingston Ridge and the lack of deformation indicates the relative stability of the WIPP region over the past half-million years.

Continued growth of caliche may occur in the future but will be of low consequence in terms of its effect on infiltration. Other soils in the area are not extensive enough to affect the amount of infiltration that reaches underlying aquifers. *Soil development* has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Although there is no net effect on the screening arguments, some of the original supporting evidence for this FEP in the CCA should be clarified. The evidence for age of the Mescalero caliche is presented in Rosholt and McKinney (1980), based on their uranium disequilibrium investigations. Rosholt and McKinney (1980, Table 5) reported the Mescalero began to form about 570,000 ± 111,000 years before present and ended formation about 420,000 ± 60,000 years before present. Rosholt and McKinney (1980, Table 5) also reported the uranium-trend age for the overlying Berino soil as 330,000 ± 75,000 years before present. The uranium-trend dates are consistent with the age of underlying formations, and they do not indicate current soil development in these horizons.

EPA FEPs Number: **N51**
FEPs Title: **Stream and River Flow**

SCR Section Number: **SCR.1.5.1**
Screening Decision: **SO-C**

Summary:

The original FEP description and screening argument remains valid; the original arguments have not changed. No changes have been made to the FEP text, description, screening argument or screening decision.

Italicized ext

Stream and river flow has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

No perennial streams are present at the WIPP site, and there is no evidence in the literature indicating that such features existed at this location since the Pleistocene (see, for example, Powers et al. 1978; and Bachman 1974, 1981, and 1987b). The Pecos River is approximately 12 miles (19 kilometers) from the WIPP site and more than 300 feet (90 meters) lower in elevation. Stream and river flow have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N52**
FEP Title: **Surface Water Bodies**

SCR Section Number: **SCR.1.5.2 Lacustrine**
Screening Decision: **SO-C**

Summary:

The original FEP description and screening argument remains valid; the original arguments have not changed. No changes have been made to the FEP text, description, screening argument or screening decision.

Italicized Text

The effects of surface water bodies have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

No standing *surface water bodies* are present at the WIPP site, and there is no evidence in the literature indicating that such features existed at this location during or after the Pleistocene (see, for example, Powers et al. 1978; and Bachman 1974, 1981, and 1987b). In Nash Draw, lakes and spoil ponds associated with potash mines are located at elevations 100 feet (30 meters) below the elevation of the land surface at the location of the waste panels. There is no evidence in the literature to suggest that Nash Draw was formed by stream erosion or was at any time the location of a deep body of standing water, although shallow playa lakes have existed there at various times. Based on these factors, the formation of large lakes is unlikely and the formation of smaller lakes and ponds is of little consequence to the performance of the disposal system. The effects of surface water bodies have therefore been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: N57 & N58
FEP Title: Lake Formation (N57)
River Flooding (N58)

SCR Section Number: SCR.1.5.4
Screening Decision: SO-C

Summary:

The original screening arguments remain valid. The original text has been modified to remove reference to other FEPs. No substantive changes have been made to the FEP descriptions, screening arguments or screening decision.

Italicized Text

The effects of river flooding and lake formation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Changes in recharge may affect groundwater flow and radionuclide transport in units such as the Culebra and Magenta dolomites. Changes in the surface environment driven by natural climate change are expected to occur over the next 10,000 years. Groundwater basin modeling (CCA Section 2.2.1.4) indicates that a change in recharge will affect the height of the water table in the area of the WIPP, and that this will in turn affect the direction and rate of groundwater flow.

The present-day water table in the vicinity of the WIPP is within the Dewey Lake at about 3,215 feet (980 meters) above mean sea level. An increase in recharge relative to present-day conditions would raise the water table, potentially as far as the ground surface locally. Similarly, a decrease in recharge could result in a lowering of the water table. The low transmissivity of the Dewey Lake and the Rustler ensures that any such lowering of the water table will be at a slow rate, and lateral discharge from the groundwater basin is expected to persist for several thousand years after any decrease in recharge. Under the anticipated changes in climate over the next 10,000 years, the water table will not fall below the base of the Dewey Lake, and dewatering of the Culebra is not expected to occur during this period.

Changes in groundwater recharge and discharge are accounted for in performance assessment calculations through definition of the boundary conditions for flow and transport in the Culebra.

Intermittent flooding of stream channels and the formation of shallow lakes will occur in the WIPP region over the next 10,000 years. These may have a short-lived and local effect on the height of the water table, but are unlikely to affect groundwater flow in the Culebra.

Future occurrences of playa lakes or other longer-term floods will be remote from the WIPP and will have little consequence on system performance in terms of groundwater flow at the site. There is no reason to believe that any impoundments or lakes could form over the WIPP site itself. Thus, *river flooding* and *lake formation* have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N62**
FEP Title: **Glaciation**

SCR Section Number: **SCR.1.6.2.2**
Screening Decision: **SO-P**

Summary:

Glaciation, as an event, has been screened out qualitatively on the basis of low probability. Although it is not practical to quantify the probability of such an event for WIPP, geological evidence indicates glaciation has not occurred at the site in the last few hundred million years and is not expected to occur at the site even if climatic changes occur similar to those during the Pleistocene Epoch. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of Glaciation have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text Glaciation

No evidence exists to suggest that the northern part of the Delaware Basin has been covered by continental glaciers at any time since the beginning of the Paleozoic Era. During the maximum extent of continental *glaciation* in the Pleistocene Epoch, glaciers extended into northeastern Kansas at their closest approach to southeastern New Mexico. There is no evidence that alpine glaciers formed in the region of the WIPP during the Pleistocene glacial periods.

According to the theory that relates the periodicity of climate change to perturbations in the earth's orbit, a return to a full glacial cycle within the next 10,000 years is highly unlikely (Imbrie and Imbrie 1980, p. 951).

Thus, glaciation has been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

EPA FEP Number: N63
FEP Title: Permafrost

SCR Section Number: SCR.1.6.2.2
Screening Decision: SO-P

Summary:

Permafrost, as an event, has been screened out qualitatively on the basis of low probability. Although it is not practical to quantify the probability of such an event for WIPP, geological evidence indicates glaciation has not occurred at the site in the last few hundred million years and is not expected to occur at the site even if climatic changes occur similar to those during the Pleistocene Epoch. Permafrost is considered linked to the processes that result in glaciation, and by association is screened out on the basis of probability. The original FEP description and screening decision have not changed. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of permafrost have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text Glaciation

No evidence exists to suggest that the northern part of the Delaware Basin has been covered by continental glaciers at any time since the beginning of the Paleozoic Era. During the maximum extent of continental *glaciation* in the Pleistocene Epoch, glaciers extended into northeastern Kansas at their closest approach to southeastern New Mexico. There is no evidence that alpine glaciers formed in the region of the WIPP during the Pleistocene glacial periods.

Glaciation (N62) has been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years. Similarly, a number of processes associated with the proximity of an ice sheet or valley glacier, such as *permafrost* and accelerated slope erosion (solifluction) have been eliminated from performance assessment calculations on the basis of low probability of occurrence over the next 10,000 years.

EPA FEP Number(s): N64 & N65
FEP Title(s): Seas and Oceans (N64)
Estuaries (N65)

SCR Section Number: SCR.1.7.1
Screening Decision: SO-C

Summary:

The original FEP descriptions and screening arguments remains valid. The effects of estuaries and seas and oceans have been eliminated from performance assessment calculations on the basis of low consequences, since the WIPP site is located more than 480 miles from the nearest marine surface water body (i.e., Pacific Ocean and Gulf of Mexico). This argument appears technically reasonable. No changes have been made to the FEP descriptions, screening arguments or screening decisions.

Italicized Text

The effects of estuaries, seas, and oceans have has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The WIPP site is more than 480 miles (800 kilometers) from the Pacific Ocean and from the Gulf of Mexico. *Estuaries* and *seas and oceans* have therefore been eliminated from performance assessment calculations on the basis of low consequence to the disposal system.

EPA FEPs Number(s): N66 and N67
FEPs Title(s): Coastal Erosion (N66)
Marine Sediment Transport and Deposition (N67)

SCR Section Number: SCR.1.7.2
Screening Decision: SO-C

Summary:

The screening argument for costal erosion and marine sediment transport and deposition remains valid. Coastal erosion and marine sediment transport and deposition have been eliminated from performance assessment calculations on the basis of low consequence, since the WIPP site is located more than 480 miles from the nearest marine surface water body (i.e., Pacific Ocean and Gulf of Mexico). This argument appears technically reasonable. The original descriptions and screening arguments remains valid. No changes have been made to the FEP descriptions, screening arguments or screening decisions.

Italicized Text

The effects of coastal erosion, and marine sediment transport and deposition have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The WIPP site is more than 480 miles (800 kilometers) from the Pacific Ocean and Gulf of Mexico. The effects of *coastal erosion* and *marine sediment transport and deposition* have therefore been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N68**
FEP Title: **Sea Level Changes**

SCR Section Number: **SCR.1.7.3**
Screening Decision: **SO-C**

Summary:

The screening argument for seal level changes remains valid. The effects of both long-term and short-term sea level changes have been eliminated from the performance assessment on the basis of low consequence to the performance of the disposal system. Because the WIPP site is located approximately 3,330 feet above sea level, a rise in sea level of a few meters or a fall in sea level would not impact the groundwater system in the WIPP region. Since this argument remains valid, the original description and screening argument remains the same. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

The effects of both short-term and long-term sea level changes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The WIPP site is some 3,330 feet (1,015 meters) above sea level. Global *sea level change* may result in sea levels as much as 460 feet (140 meters) below that of the present day during glacial periods, according to Chappell and Shackleton (1986, p. 138). This can have marked effects on coastal aquifers. During the next 10,000 years, the global sea level can be expected to drop towards this glacial minimum, but this will not affect the groundwater system in the vicinity of the WIPP. Short-term changes in sea level, brought about by events such as meteorite impact, tsunamis, seiches, and hurricanes may raise water levels by several tens of meters. Such events have a maximum duration of a few days and will have no effect on the surface or groundwater systems at the WIPP site. Anthropogenic-induced global warming has been conjectured by Warrick and Oerlemans (1990, p. 278) to result in longer-term sea level rise. The magnitude of this rise, however, is not expected to be more than a few meters, and such a variation will have no effect on the groundwater system in the WIPP region. Thus, the effects of both short-term and long-term sea level changes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number(s): N69 & N70
FEP Title(s): Plants (N69)
Animals (N70)

SCR Section Number: SCR.1.8.1
Screening Decision: SO-C

Summary:

The screening arguments for plants and animals remain valid. Plants play a role in the hydrological cycle by taking up water. The DOE has stated that the effects of flora and fauna have been eliminated from the performance assessment calculations on the basis of low consequence to the performance of the disposal system. This conclusion appears reasonable. No changes have been made to the FEP description, screening argument or screening decision. The text has been modified to remove reference to other FEPs.

Italicized Text

The effects of the natural plants and animals, (flora and fauna) in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The terrestrial and aquatic ecology of the region around the WIPP is described in CCA Section 2.4.1. The *plants* in the region are predominantly shrubs and grasses. The most conspicuous *animals* in the area are jackrabbits and cottontails. The effects of this flora and fauna in the region have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **N71**
FEP Title: **Microbes**

SCR Section Number: **SCR.1.8.1**
Screening Decision: **SO-C**
UP for colloidal effects and gas generation

Summary:

Microbes can be important in soil development. As dissolved actinide elements are introduced to the Culebra, it is possible that those dissolved actinides can sorb onto microbes. However, due to the size effect, microbes will be rapidly filtered out of the advective flow domain; hence, the effect of microbes on radionuclide transport in the Culebra will be insignificant. The original screening decision remains valid. Additional information has been included in the FEPs discussions.

Italicized Text

The effects of microbes the region of the WIPP has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The terrestrial and aquatic ecology of the region around the WIPP is described in CCA Section 2.4.1. The plants in the region are predominantly shrubs and grasses. The most conspicuous animals in the area are jackrabbits and cottontails. *Microbes* are presumed to be present with the thin soil horizons. The effects of this flora and fauna in the region have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Gillow et al. (2000) characterized the microbial distribution in Culebra groundwater at the WIPP site. Culebra groundwater contained $1.51 \pm 1.08 \times 10^5$ cells/ml. The dimension of the cells are 0.75 μm in length and 0.58 μm in width, right at the upper limit of colloidal particle size. Gillow et al. also found that at pH 5.0, Culebra denitrifier CDn ($0.90 \pm 0.02 \times 10^8$ cells/ml) removed 32% of the uranium added to sorption experiments, which is equivalent to 180± 10 mg U/g of dry cells. Another isolate from WIPP (Halomonas sp.) ($3.55 \pm 0.11 \times 10^8$ cells/ml) sorbed 79% of the added uranium. Due to their large sizes, microbial cells as colloidal particles will be rapidly filtered out in the Culebra formation. Therefore, the original FEP screening decision that microbes in groundwater have an insignificant impact on radionuclide transport in the Culebra formation remains valid. A similar conclusion has also been arrived for Sweden repository environments (Pedersen 1999).

EPA FEP Number: **N72**
FEP Title: **Natural Ecological Development**

SCR Section Number: **SCR.1.8.2**
Screening Decision: **SO-C**

Summary:

The region around the WIPP is sparsely vegetated as a result of the climate and poor soil quality. The effects of the indigenous fauna are of low consequence to the performance of the disposal system and no natural events or processes have been identified that would lead to a change in this fauna that would be of consequence to system performance. Natural ecological development has been eliminated from the performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening argument appears reasonable. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

The effects of natural ecological development likely to occur in the region of the WIPP have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The region around the WIPP is sparsely vegetated as a result of the climate and poor soil quality. Wetter periods are expected during the regulatory period, but botanical records indicate that, even under these conditions, dense vegetation will not be present in the region (Swift 1992; see Appendix CLI, p. 17). The effects of the indigenous fauna are of low consequence to the performance of the disposal system and no natural events or processes have been identified that would lead to a change in this fauna that would be of consequence to system performance. *Natural ecological development* in the region of the WIPP has therefore been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

6. HUMAN-INITIATED FEPS

Because Human FEPs are the most susceptible to change, all 57 Human FEPs were included in the FEPs reassessment regardless of the original screening decision (which was used as an indicator in the process to determine which FEPs to reassess). Table 4-1 provides details regarding the FEPs reassessment. Of the 57 Human FEPs, 13 remain unchanged, 39 were updated with new information or were edited for clarity and completeness, four screening decisions were changed, one FEP was deleted from the baseline by combining with other more appropriate FEPs, and two FEPs were added. The remainder of this section provides details and results of those human FEPs that underwent Element 2 of this reassessment.

EPA FEP Number: **H1**
FEP Title: **Oil and Gas Exploration**

SCR Section Number: **SCR.3.2.1**
Screening Decision: **SO-C (HCN)**
DP (Future)

Summary:

Regulations require that drilling for resources in the future be considered in performance assessment calculations. As such, deep drilling associated with oil and gas exploration in the future is accounted for in the performance assessment in disturbed performance scenarios (DP) via the drilling rate as calculated by the method prescribed by the EPA. For historic, current, and near future (HCN) time frames, deep drilling for oil and gas exploration has been screened out based on consequence. The screening decision of SO-C for HCN is largely based on the screening of FEPs H21 *Drilling Fluid Flow*, H22 *Drilling Fluid Loss*, and H23 *Blowouts*. Because oil and gas exploration is currently taking place, and will not occur within the land withdrawal boundary during the current time period nor in the near future (due to active institutional controls), the only possible impact to the repository could be from drilling fluid flow, fluid loss, or blowout in boreholes outside the WIPP land withdrawal boundary. The specific effects are discussed in detail within the screening discussions for FEPs H21, H22, and H23.

No substantive changes have been made to the screening argument and decision. Editorial changes have been made to separate this FEP from other FEPs grouped within the same section of Appendix SCR for clarity.

Italicized Text

The effects of historical, current, and near-future drilling associated with oil and gas exploration has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system (see screening discussion for H21, H22, and H23). Oil and gas exploration in the future is accounted for in disturbed performance scenarios through incorporation of the rate of future drilling as specified in 40 CFR 194.33.

FEP Text Historical, Current, and Near-Future Human-Initiated EPs

Resource exploration and exploitation are the most common reasons for drilling in the Delaware Basin and are the most likely reasons for drilling in the near future. The WIPP location has been evaluated for the occurrence of natural resources in economic quantities. Powers et al. (1978) (Appendix GCR, Chapter 8) investigated the potential for exploitation of potash, hydrocarbons, caliche, gypsum, salt, uranium, sulfur, and lithium. Also, in 1995, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) performed a reevaluation of the mineral resources at and within 1 mile (1.6 kilometers) around the WIPP site.

Drilling associated with *oil and gas exploration* currently takes place in the vicinity of the WIPP. For example, gas is extracted from reservoirs in the Morrow Formation, some 14,000 feet (4,200 meters) below the surface, and oil is extracted from shallower units within the Delaware Mountain Group, some 7,000 to 8,000 feet (2,150 to 2,450 meters) below the surface.

In summary, drilling associated with oil and gas exploration has taken place and is expected to continue in the Delaware Basin. The potential effects of existing and possible near-future boreholes on fluid flow and radionuclide transport within the disposal system are discussed in FEPs H25 through H36, where low consequence screening arguments are provided.

Future Human-Initiated EPs

Criteria in 40 CFR § 194.33 require the DOE to examine the historical rate of drilling for resources in the Delaware Basin. Thus, consistent with 40 CFR § 194.33(b)(3)(i), the DOE has used the historical record of deep drilling associated with *oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, potash exploration,* and drilling associated with *other resources* (sulfur exploration), in the Delaware Basin in calculations to determine the rate of future deep drilling in the Delaware Basin (see CCA Appendix DEL, Section DEL.7.4).

EPA FEP Number: **H2**
FEP Title: **Potash Exploration**

SCR Section Number: **SCR.3.2.1**
Screening Decision: **SO-C (HCN)**
DP (Future)

Summary:

Regulations require that drilling for resources in the future be considered in performance assessment calculations. As such, drilling and coring associated with *potash exploration* in the future is accounted for in the performance assessment in disturbed performance scenarios (DP) via the drilling rate as calculated by the method prescribed by the EPA. For historic, current, and near future (HCN) time frames, deep drilling due to potash exploration has been screened out based on consequence. The screening decision of SO-C for HCN is largely based on the screening of FEPs H21 *Drilling Fluid Flow*, H22 *Drilling Fluid Loss*, and H23 *Blowouts*. Because potash exploration is currently taking place, and will not occur within the land withdrawal boundary during the current time period nor in the near future (due to active institutional controls), the only possible impact to the repository could be from drilling fluid flow, fluid loss, or blowout in boreholes outside the WIPP land withdrawal boundary. The specific effects are discussed in detail within the screening discussions for FEPs H21, H22, and H23.

No substantive changes have been made to the screening argument and decision. Editorial changes have been made to separate this FEP from other FEPs grouped within the same section of Appendix SCR for clarity.

Italicized Text

The effects of historical, current, and near-future drilling associated with potash exploration has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system (see screening discussion for H21, H22, and H23). Potash exploration in the future is accounted for in disturbed performance scenarios through incorporation of the rate of future drilling as specified in 40 CFR 194.33.

FEP Text **Drilling**

Historical, Current, and Near-Future Human-Initiated EPs

Resource exploration and exploitation are the most common reasons for drilling in the Delaware Basin and are the most likely reasons for drilling in the near future. The WIPP location has been evaluated for the occurrence of natural resources in economic quantities. Powers et al. (1978) (Appendix GCR, Chapter 8) investigated the potential for exploitation of potash, hydrocarbons, caliche, gypsum, salt, uranium, sulfur, and lithium. Also, in 1995, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) performed a reevaluation of the mineral resources at and within 1 mile (1.6 kilometers) around the WIPP site.

Potash resources in the vicinity of the WIPP are discussed in CCA Section 2.3.1.1. Throughout the Carlsbad Potash District, commercial quantities of potash are restricted to the McNutt, which forms part of the Salado above the repository horizon. *Potash exploration* and evaluation boreholes have been drilled within and outside the controlled area. Such drilling will continue outside the WIPP land withdrawal boundary, but no longer occurs within the boundary due to transfer of rights and controls to the Department of Energy. Moreover, drilling for the evaluation of potash resources within the boundary will not occur throughout the time period of active institutional controls.

In summary, drilling associated with potash exploration has taken place and is expected to continue in the Delaware Basin. The potential effects of existing and possible near-future boreholes on fluid flow and radionuclide transport within the disposal system are discussed in FEPs discussions for FEPs H25 through H36 where low consequence screening arguments are provided.

Future Human-Initiated EPs

Criteria in 40 CFR § 194.33 require the DOE to examine the historical rate of drilling for resources in the Delaware Basin. Thus, consistent with 40 CFR § 194.33(b)(3)(i), the DOE has used the historical record of deep drilling associated with *oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, potash exploration,* and drilling associated with *other resources* (sulfur exploration), in the Delaware Basin in calculations to determine the rate of future deep drilling in the Delaware Basin (see CCA Appendix DEL, Section DEL.7.4).

EPA FEP Number(s): H3 & H5
FEP Title(s): Water Resources Exploration (H3)
Groundwater Exploitation (H5)

SCR Section Number: SCR.3.2.1.2
Screening Decision: SO-C (HCN)
SO-C (Future)

Summary:

In the screening of FEPs conducted for the CCA, FEP H3 and H5 were screened-out based on low consequence (SO-C) for the long-term performance of the WIPP. The CCA screening decision and argument applied to both the HCN and future time periods and remain valid for this current FEP re-assessment; however, the following discussion provides additional justification for the conclusions reached.

Italicized Text

The effects of historical, current, and near-future drilling associated with water resources exploration and groundwater exploitation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Historical shallow drilling associated with water resources exploration, and groundwater exploitation, is accounted for in calculations to determine the rate of future shallow drilling.

FEP Text

Drilling associated with water resources exploration and groundwater exploitation has taken place and is expected to continue in the Delaware Basin. For the most part, water resources in the vicinity of the WIPP are scarce. Elsewhere in the Delaware Basin, potable water occurs in places while some communities rely solely on groundwater sources for drinking water. Even though water resources exploration and groundwater exploitation occur in the Basin, all such exploration/exploitation is confined to shallow drilling that extends no deeper than the Rustler Formation and thus will not impact repository performance because of the limited drilling anticipated in the future and the sizeable thickness of low permeability Salado salt between the waste panels and the shallow groundwaters. Given the limited groundwater resources and minimal consequence of shallow drilling on performance, the effects of historical, current, near-future, and future drilling associated with water resources exploration and groundwater exploitation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Thus, the screening argument remains the same as given previously in the CCA.

Although shallow drilling for water resources exploration and groundwater exploitation have been eliminated from performance assessment calculations, the Delaware Basin Drilling Surveillance Program (DBDSP) continues to collect drilling data related to water resources, as well as other shallow drilling activities. As shown in the DBDSP 2002 Annual Report (DOE 2002), the total number of shallow water wells in the Delaware Basin is currently 2,296 compared to 2,331 shallow water wells reported in the CCA, a decrease of 35 wells (attributed primarily to the reclassification of water wells to other types of shallow boreholes). Based on these data, the shallow drilling rate for water resources exploration and groundwater exploitation is essentially the same as reported in the CCA. The distribution of groundwater wells in the Delaware Basin was included in Appendix USDW (Section USDW.3). Based on recent updates to USDW (DOE 2003), no modification to the CCA USDW determinations is warranted.

Historical, Current, and Near-Future Human-Initiated EPs

Water is currently extracted from formations above the Salado, as discussed in CCA Section 2.3.1.3. The distribution of groundwater wells in the Delaware Basin is included in Appendix USDW (Section USDW.3). *Water resources exploration* and *groundwater exploitation* are expected to continue in the Delaware Basin.

In summary, drilling associated with *water resources exploration, groundwater exploitation,* potash exploration, oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, and drilling to explore other resources has taken place and is expected to continue in the Delaware Basin. The potential effects of existing and possible near-future boreholes on fluid flow and radionuclide transport within the disposal system are discussed in Section SCR.3.3.1, where low consequence screening arguments are provided.

Future Human-Initiated EPs

Criteria in 40 CFR § 194.33 require that, to calculate the rates of future shallow and deep drilling in the Delaware Basin, the DOE should examine the historical rate of drilling for resources in the Delaware Basin.

Shallow drilling associated with water, potash, sulfur, oil, and gas extraction has taken place in the Delaware Basin over the past 100 years. However, of these resources, only water and potash are present at shallow depths (less than 2,150 feet [655 meters] below the surface) within the controlled area. Thus, consistent with 40 CFR § 194.33(b)(4), the DOE accounts for this drilling through the use of the historical record of shallow drilling associated with *water resources exploration*, potash exploration, and *groundwater exploitation*, in calculations to determine the rate of future shallow drilling in the Delaware Basin.

EPA FEP Number: **H4**
FEP Title: **Oil and Gas Exploitation**

SCR Section Number: **SCR.3.2.1**
Screening Decision: **SO-C (HCN)**
DP (Future)

Summary:

Regulations require that drilling for resources in the future be considered in performance assessment calculations. As such, deep drilling associated with oil and gas exploitation in the future is accounted for in the performance assessment in disturbed performance scenarios (DP) via the drilling rate as calculated by the method prescribed by the EPA. For historic, current, and near future (HCN) time frames, deep drilling for oil and gas exploitation has been screened out based on consequence. The screening decision of SO-C for HCN is largely based on the screening of FEPs H21 *Drilling Fluid Flow*, H22 *Drilling Fluid Loss*, and H23 *Blowouts*. Because oil and gas exploitation is currently taking place, and will not occur within the land withdrawal boundary during the current time period nor in the near future (due to active institutional controls), the only possible impact to the repository could be from drilling fluid flow, fluid loss, or blowout in boreholes outside the WIPP land withdrawal boundary. The specific effects are discussed in detail within the screening discussions for FEPs H21, H22, and H23.

No changes in exploration/exploitation techniques have been identified that would impact this FEP. Drilling rate is calculated on an annual basis and reported to the EPA via the 40 CFR 194.4 reports. Changes in drilling rate are accounted for in PA calculations. No substantive changes have been made to the screening argument and decision. Editorial changes have been made to separate this FEP from other FEPs grouped within the same section of CCA Appendix SCR for clarity.

Italicized Text

The effects of historical, current, and near-future drilling associated with oil and gas exploitation has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system (see screening discussion for H21, H22, and H23). Oil and gas exploitation in the future is accounted for in disturbed performance scenarios through incorporation of the rate of future drilling as specified in 40 CFR 194.33.

Historical, Current, and Near-Future Human-Initiated EPs

Resource exploration and exploitation are the most common reasons for drilling in the Delaware Basin and are the most likely reasons for drilling in the near future. The WIPP location has been evaluated for the occurrence of natural resources in economic quantities. Powers et al. (1978) (CCA Appendix GCR, Chapter 8) investigated the potential for exploitation of potash, hydrocarbons, caliche, gypsum, salt, uranium, sulfur, and lithium. Also, in 1995, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) performed a reevaluation of the mineral resources at and within 1 mile (1.6 kilometers) around the WIPP site.

Drilling associated with ***oil and gas exploitation*** currently takes place in the vicinity of the WIPP. For example, gas is extracted from reservoirs in the Morrow Formation, some 14,000 feet (4,200 meters) below the surface, and oil is extracted from shallower units within the Delaware Mountain Group, some 7,000 to 8,000 feet (2,150 to 2,450 meters) below the surface.

In summary, drilling associated with oil and gas exploitation has taken place and is expected to continue in the Delaware Basin. The potential effects of existing and possible near-future boreholes on fluid flow and radionuclide transport within the disposal system are discussed in FEPs discussions for H25 through H36, where low consequence screening arguments are provided.

Future Human-Initiated EPs

Criteria in 40 CFR § 194.33 require the DOE to examine the historical rate of drilling for resources in the Delaware Basin. Thus, consistent with 40 CFR § 194.33(b)(3)(i), the DOE has used the historical record of deep drilling associated with *oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, potash exploration,* and drilling associated with *other resources* (sulfur exploration), in the Delaware Basin in calculations to determine the rate of future deep drilling in the Delaware Basin (see CCA Appendix DEL, Section DEL.7.4).

EPA FEP Number: **H6**
FEP Title: **Archeology**

SCR Section Number: **SCR.3.2.1**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

The screening argument presented in CCA SCR 3.2.1 appears reasonable, however it is suggested that drilling for *archeology (H6),* geothermal energy production (H7), liquid waste disposal (H10), and hydrocarbon storage (H11) be separated from the other FEPs discussed in this section of CCA Appendix SCR. These FEPs share the same screening bases and classification and would be well suited to a joint screening discussion. Based on current Delaware Basin data, the regulatory exclusion based on the "future states assumption" continues to be valid; i.e., no drilling for geothermal, archeological, liquid waste disposal, or hydrocarbon storage has occurred.

Italicized Text

Drilling associated with archeology has been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Historic, Current, and Near-Future EPs

No drilling associated with ***archeology*** has taken place in the Delaware Basin. Consistent with the future states assumptions in 40 CFR § 194.25(a), such drilling activities have been eliminated from performance assessment calculations on regulatory grounds.

While numerous archeological sites exist at and near the WIPP site, drilling for archeological purposes has not occurred. Archeological investigations have only involved shallow surface disruptions, and do not required deeper investigation by any method, drilling or otherwise.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.33 and the future states assumptions in 40 CFR § 194.25(a), drilling for purposes other than resource recovery (such as WIPP site investigation), and drilling activities that have not taken place in the Delaware Basin over the past 100 years, need not be considered in determining future drilling rates. Thus, drilling associated with archeological investigations has been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: **H7**
FEP Title: **Geothermal**

SCR Section Number: **SCR.3.2.1**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

The screening argument presented in SCR 3.2.1 appears reasonable, however it is suggested that drilling for archeology (H6), *geothermal energy production (H7)*, liquid waste disposal (H10), and hydrocarbon storage (H11) be separated from the other FEPs discussed in this section of Appendix SCR. These FEPs share the same screening bases and classification and would be well suited to a joint screening discussion. Based on current Delaware Basin data, the regulatory exclusion based on the "future states assumption" continues to be valid; i.e., no drilling for geothermal, archeological, liquid waste disposal, or hydrocarbon storage has occurred.

Italicized Text

Drilling associated with geothermal energy production has been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Historic, Current, and Near-Future EPs

No drilling associated with *geothermal energy production* has taken place in the Delaware Basin. Consistent with the future states assumptions in 40 CFR § 194.25(a), such drilling activities have been eliminated from performance assessment calculations on regulatory grounds.

Geothermal energy is not considered to be a potentially exploitable resource because economically attractive geothermal conditions do not exist in the northern Delaware Basin.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.33 and the future states assumptions in 40 CFR § 194.25(a), drilling for purposes other than resource recovery (such as WIPP site investigation), and drilling activities that have not taken place in the Delaware Basin over the past 100 years, need not be considered in determining future drilling rates. Thus, drilling associated with geothermal energy production has been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: **H8**
FEP Title: **Other Resources (Drilling for)**

SCR Section Number **SCR.3.2.1**
Screening Decision: **SO-C (HCN)**
DP (Future)

Summary:

Regulations require that drilling for resources in the future be considered in performance assessment calculations. As such, deep drilling associated with oil and gas exploitation (or any other resource) in the future is accounted for in the performance assessment in disturbed performance scenarios (DP) via the drilling rate as calculated by the method prescribed by the EPA. For historic, current, and near future (HCN) time frames, deep drilling for oil, gas, or other resources has been screened out based on consequence. The screening decision of SO-C for HCN is largely based on the screening of FEPs H21 *Drilling Fluid Flow*, H22 *Drilling Fluid Loss*, and H23 *Blowouts*. Because drilling (for a variety of reasons) is currently taking place, and will not occur within the land withdrawal boundary during the current time period nor in the near future (due to active institutional controls), the only possible impact to the repository could be from drilling fluid flow, fluid loss, or blowout in boreholes outside the WIPP land withdrawal boundary. The specific effects are discussed in detail within the screening discussions for FEPs H21, H22, and H23.

No changes in drilling techniques have been identified that would impact this FEP. Drilling rate is calculated on an annual basis and reported to the EPA via the 40 CFR 194.4 reports and includes deep boreholes drilled for any purpose, not only those for oil and gas. Changes in drilling rate are accounted for in PA calculations. No substantive changes have been made to the screening argument and decision. Editorial changes have been made to separate this FEP from other FEPs grouped within the same section of Appendix SCR for clarity.

Italicized Text

The effects of historical, current, and near-future drilling associated with resources other than oil and gas have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system (see screening discussion for H21, H22, and H23). Drilling for other resources in the future is accounted for in disturbed performance scenarios through incorporation of the rate of future drilling as specified in 40 CFR 194.33.

FEP Text

This section discusses historical, current, and near-future drilling activities within and outside the controlled area and drilling activities that may take place within or outside the controlled area in the future. Drilling may occur within the controlled area in the future after the end of the period of active institutional control (100 years after disposal).

Historical, Current, and Near-Future Human-Initiated EPs

Resource exploration and exploitation are the most common reasons for drilling in the Delaware Basin and are the most likely reasons for drilling in the near future. The WIPP location has been evaluated for the occurrence of natural resources in economic quantities. Powers et al. (1978) (CCA Appendix GCR, Chapter 8) investigated the potential for exploitation of potash, hydrocarbons, caliche, gypsum, salt, uranium, sulfur, and lithium. Also, in 1995, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) performed a reevaluation of the mineral resources at and within 1 mile (1.6 kilometers) around the WIPP site. While some resources do exist at the WIPP site, for the historic, current, and near future timeframes, such drilling is assumed to only occur outside the WIPP site boundary. This assumption is based on current federal ownership and management of the WIPP during operations, and assumed effectiveness of institutional controls for the 100-year period immediately following site closure.

Drilling associated with the extraction of sulfur and brine production has taken place within the Delaware Basin. For example, sulfur extraction using the Frasch process began in 1969 and continued for three decades at the Culberson County Rustler Springs mine near Orla, Texas. Brine wells have been in operation in and about the Delaware Basin for at least as long. Solution mining processes for sulfur, salt (brine), potash, or any other mineral are not addressed in this FEP; only the drilling of the borehole is addressed. Resource extraction through solution mining and any potential effects are evaluated in H58, Solution Mining.

In summary, drilling for resources has taken place and is expected to continue in the Delaware Basin. The effects of such drilling are of low consequence to repository performance and are therefore not included in performance assessment calculations. Screening assessments for H21 *Drilling Fluid Flow*, H22 *Drilling Fluid Loss*, and H23 *Blowouts* provide additional bases for the exclusion of this FEP during the historic, current, and near future time periods.

Future Human-Initiated EPs

Criteria in 40 CFR § 194.33 require the DOE to examine the historical rate of drilling for resources in the Delaware Basin. Thus, consistent with 40 CFR § 194.33(b)(3)(i), the DOE has used the historical record of deep drilling associated with *oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, potash exploration,* and drilling associated with *other resources*, in the Delaware Basin in calculations to determine the rate of future deep drilling in the Delaware Basin (see CCA Appendix DEL, CRA Appendix DATA, and CRA Chapter 6.3.2).

EPA FEP Number: **H9**
FEP Title: **Enhanced Oil and Gas Recovery (Drilling for)**

SCR Section Number: **SCR.3.2.1**
Screening Decision: **SO-C (HCN)**
DP

Summary:

Regulations require that drilling be considered in performance assessment calculations. As such, deep drilling in the future is accounted for in the performance assessment in disturbed performance scenarios (DP) via the drilling rate as calculated by the method prescribed by the EPA. For this and other drilling-related FEPs, the reasons for drilling are unimportant; it is the actual drilling of the borehole itself that is of interest, and therefore the event that is ultimately accounted for in performance assessment calculations. For historic, current, and near future (HCN) timeframes, deep drilling for oil, gas, or other resources has been screened out based on consequence. Additionally, *drilling for the purposes of enhanced oil and gas recovery* has been screened out based on consequence because the process of drilling does not vary depending on the intended use of the borehole, be it for resource recovery, reservoir stimulation, or for other purposes such as geologic characterization and exploration. The screening decision of SO-C for HCN is largely based on the screening of FEPs H21 *Drilling Fluid Flow*, H22 *Drilling Fluid Loss*, and H23 *Blowouts*. Because drilling (for a variety of reasons) is currently taking place, and will not occur within the land withdrawal boundary during the current time period nor in the near future (due to active institutional controls), the only possible impact to the repository could be from drilling fluid flow, fluid loss, or blowout in boreholes outside the WIPP land withdrawal boundary. The specific effects are discussed in detail within the screening discussions for FEPs H21, H22, and H23.

EPA and stakeholders have been concerned with the effects of enhanced oil and gas recovery techniques on repository performance. The effects of enhanced oil and gas recovery are addressed in FEP H28, *Enhanced Oil and Gas Production.*

No changes in drilling techniques have been identified that would impact this FEP. Drilling rate is calculated on an annual basis and reported to the EPA via the 40 CFR 194.4 reports and includes deep boreholes drilled for any purpose, not only those intended for the reservoir stimulation processes such as waterflood or CO_2 injection. Changes in drilling rate are accounted for in PA calculations. No substantive changes have been made to the screening argument and decision. Editorial changes have been made to separate this FEP from other FEPs grouped within the same section of Appendix SCR for clarity.

Italicized Text

The effects of historical, current, and near-future drilling for enhanced oil and gas recovery have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system (see screening discussion for H21, H22, and H23). Drilling for enhanced oil and gas recovery in the future is accounted for in disturbed performance scenarios through incorporation of the rate of future drilling as specified in 40 CFR 194.33.

FEP Text

Historical, Current, and Near-Future Human-Initiated EPs

Resource exploration and exploitation are the most common reasons for drilling in the Delaware Basin and are the most likely reasons for drilling in the near future. The WIPP location has been evaluated for the occurrence of natural resources in economic quantities. Powers et al. (1978) (CCA Appendix GCR, Chapter 8) investigated the potential for exploitation of potash, hydrocarbons, caliche, gypsum, salt, uranium, sulfur, and lithium. Also, in 1995, the New Mexico Bureau of Mines and Mineral Resources (NMBMMR) performed a reevaluation of the mineral resources at and within 1 mile (1.6 kilometers) around the WIPP site. While some resources do exist at the WIPP site, for the historic, current, and near future timeframes, such drilling is assumed to only occur outside the WIPP site boundary. This assumption is based on current federal ownership and management of the WIPP during operations, and assumed effectiveness of institutional controls for the 100-year period immediately following site closure.

Drilling for the purposes of reservoir stimulation and subsequent enhanced recovery of oil and gas does take place within the Delaware Basin, although systematic, planned waterflooding has not taken place near the WIPP. Instead, injection near WIPP consists of single-point injectors, rather than broad, grid-type waterflood projects (Hall et al. 2003). In the vicinity of the WIPP, fluid injection usually takes place using boreholes initially drilled as producing wells. Therefore, regardless of the initial intent of a deep borehole, whether in search of petroleum reserves or as an injection point, the drilling event and associated processes are virtually the same. These drilling related processes are addressed more fully in H21 *Drilling Fluid Flow*, H22 *Drilling Fluid Loss*, and H23 *Blowouts*. Discussion on the effects subsequent to drilling a borehole for the purpose of enhancing oil and gas recovery is discussed in FEP H28, *Enhanced Oil and Gas Production.*

In summary, drilling for the purpose of enhanced oil and gas recovery has taken place and is expected to continue in the Delaware Basin. The effects of such drilling are of low consequence to repository performance and are therefore not included in performance assessment calculations.

Future Human-Initiated EPs

Criteria in 40 CFR § 194.33 require the DOE to examine the historical rate of drilling for resources in the Delaware Basin. Thus, consistent with 40 CFR § 194.33(b)(3)(i), the DOE has used the historical record of deep drilling associated with *oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, potash exploration,* and drilling associated with *other resources*, in the Delaware Basin in calculations to determine the rate of future deep drilling in the Delaware Basin (see CCA Appendix DEL, CRA Appendix DATA, and CRA Chapter 6.3.2).

EPA FEP Number: **H10**
FEP Title: **Liquid Waste Disposal**

SCR Section Number: **SCR.3.2.1**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

The screening argument presented in SCR 3.2.1 appears reasonable, however it is suggested that drilling for archeology (H6), geothermal energy production (H7), *liquid waste disposal (H10),* and hydrocarbon storage (H11) be separated from the other FEPs discussed in this section of Appendix SCR. These FEPs share the same screening bases and classification and would be well suited to a joint screening discussion. Based on current Delaware Basin data, the regulatory exclusion based on the "future states assumption" continues to be valid; i.e., no drilling for geothermal, archeological, liquid waste disposal, or hydrocarbon storage has occurred.

Revised Italicized

Drilling associated with liquid waste disposal has been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Historic, Current, and Near-Future EPs

No drilling associated with liquid waste *disposal* has taken place in the Delaware Basin. Consistent with the future states assumptions in 40 CFR § 194.25(a), such drilling activities have been eliminated from performance assessment calculations on regulatory grounds.

Oil and gas production byproducts are disposed of underground in the WIPP region, but such liquid waste disposal does not involve drilling of additional boreholes (see H27), therefore drilling of boreholes for the explicit purpose of disposal has not occurred.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.33 and the future states assumptions in 40 CFR § 194.25(a), drilling for purposes other than resource recovery (such as WIPP site investigation), and drilling activities that have not taken place in the Delaware Basin over the past 100 years, need not be considered in determining future drilling rates. Thus, drilling associated with liquid waste disposal has been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Title: **H11**
FEP Title: **Hydrocarbon Storage**

SCR Section Number: **SCR.3.2.1**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

The screening argument presented in SCR 3.2.1 appears reasonable, however it is suggested that drilling for archeology (H6), geothermal energy production (H7), liquid waste disposal (H10), and *hydrocarbon storage (H11)* be separated from the other FEPs discussed in this section of Appendix SCR. These FEPs share the same screening bases and classification and would be well suited to a joint screening discussion. Based on current Delaware Basin data, the regulatory exclusion based on the "future states assumption" continues to be valid; i.e., no drilling for geothermal, archeological, liquid waste disposal, or hydrocarbon storage has occurred.

Italicized Text

Drilling associated with hydrocarbon storage has been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Historic, Current, and Near-Future EPs

No drilling associated with *hydrocarbon storage* has taken place in the Delaware Basin. Consistent with the future states assumptions in 40 CFR § 194.25(a), such drilling activities have been eliminated from performance assessment calculations on regulatory grounds.

Hydrocarbon storage takes place in the Delaware Basin, but it involves gas injection through existing boreholes into depleted reservoirs (see, for example, Burton et al. 1993, 66-67). Therefore, drilling of boreholes for the explicit purpose of hydrocarbon storage has not occurred.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.33 and the future states assumptions in 40 CFR § 194.25(a), drilling for purposes other than resource recovery (such as WIPP site investigation), and drilling activities that have not taken place in the Delaware Basin over the past 100 years, need not be considered in determining future drilling rates. Thus, drilling associated with hydrocarbon storage has been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: H-12
FEP Title: Deliberate Drilling Intrusion

SCR Section Number: SCR.3.2.1
Screening Decision: SO-R (HCN)
SO-R (Future)

Summary:

The italicized text has been changed to more concisely present the screening argument for H-12, *Deliberate Drilling Intrusion.* Changes have been made to the FEP text to remove reference to other FEP descriptions, screening arguments and screening decisions. With regard to the validity of the screening argument (SO-R)/HCN (SO-R), changes have not occurred within the regulations since WIPP's certification, therefore the regulatory screening bases remain valid.

Italicized Text:

Consistent with 40 CFR § 194.33(b)(1), near-future human-initiated events and processes relating to deliberate drilling intrusion into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds. Furthermore, consistent with 40 CFR § 194.33(b)(1), future human-initiated events and processes relating to deliberate drilling intrusion into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

Historical, Current, and Near-Future Human-Initiated EPs

In summary, drilling associated with water resources exploration, groundwater exploitation, potash exploration, oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, and drilling to explore other resources has taken place and is expected to continue in the Delaware Basin. Consistent with 40 CFR § 194.33(b)(1), all near-future human-initiated EPs relating to *deliberate drilling intrusion* into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.33(b)(1), all future human-initiated EPs relating to *deliberate drilling intrusion* into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: **H13**
FEP Title: **Conventional Underground Potash Mining**

SCR Section Number: **SCR.3.2.2 Excavation Activities**
Screening Decision: **UP (HCN)**
DP (Future)

Summary:

The name of this FEP has been changed to more specifically identify the mining process. Previously, H13 was generically titled "Potash Mining," which broadly included all mining mechanisms and techniques such as conventional, strip or surface, and solution mining. EPA requested additional information regarding the prospects of solution mining the potash reserves near WIPP, while requiring specific treatment of mining in PA as specified in 40 CFR §194.32(b). For clarity, this FEP has been renamed to specifically identify the type of mining being addressed. Solution mining for potash is addressed in FEP H58, and solution mining for brine, other minerals, or for the creation of storage cavities is addressed in FEP H59.

Italicized Text:

As prescribed by 40 CFR § 194.32 (b), the effects of historical, current, near-future, and future conventional potash mining are accounted for in performance assessment calculations (See also FEP H37).

FEP Text

Potash is the only known economically viable resource in the vicinity of the WIPP that is recovered by underground mining (see Section 2.3.1). Potash is mined by conventional techniques extensively in the region east of Carlsbad and up to 1.5 miles (2.4 kilometers) from the boundaries of the controlled area of the WIPP. According to existing plans and leases (see CRA Chapter 2.0, Section 2.3.1.1), potash mining is expected to continue in the vicinity of the WIPP in the near future. The DOE assumes that all economically recoverable potash in the vicinity of the disposal system will be extracted in the near future, although there are no economical reserves above the WIPP waste panels (Griswold and Griswold 1999).

In summary, conventional underground potash mining is currently taking place and is expected to continue in the vicinity of the WIPP in the near future. The potential effects of historical, current, near-future, and future conventional underground potash mining are accounted for in performance assessment calculations as prescribed by 40 CFR § 194.32 (b), and as further described in the Supplementary Information to 40 CFR 194, Subpart C, "Compliance Certification and Recertification" and in the Compliance Application Guidance (CAG), Subpart C, § 194.32, Scope of Performance Assessments.

EPA FEP Number: H14
FEP Title: Other Resources

SCR Section Number: SCR.3.2.2
Screening Decision: SO-C (HCN)
SO-R (Future)

Summary:

The screening argument presented in CCA Appendix SCR section SCR 3.2.2 appears reasonable, however the description is somewhat confusing. It is unclear whether the *phrase "... other than for potash and archaeological excavations,"* is inclusive or exclusive of the phrase *"... and archaeological excavations."* Moreover, the screening argument is somewhat confusing regarding "other resources," although EPA concurred with the screening basis in their TSD. Since the CCA, no changes in the resources sought via mining have changed, therefore, the original description for this FEP and screening argument remain valid. Editorial changes for clarity are suggested, as well as separating the seven excavation FEPs into discrete arguments. No substantive changes have been made to the FEP description, screening argument or screening decision other than editorial changes for clarity.

Italicized Text

Historical, current, and near-future mining for other resources has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Future mining for resources has been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Other Resources

Potash is the only known economically viable resource in the vicinity of the WIPP that is recovered by underground mining. Potash is mined extensively in the region east of Carlsbad and up to 3.1 miles (5 kilometers) from the boundaries of the controlled area. According to existing plans and leases, *potash mining* is expected to continue in the vicinity of the WIPP in the near future. The DOE assumes that all economically recoverable potash in the vicinity of the disposal system will be extracted in the near future. Excavation for *other resources* does take place elsewhere in the Delaware Basin. In numerous areas, sand, gravel, and caliche are produced, but in all cases, these are surface quarries that are generally shallow (tens of feet).

EPA FEP Number: H15
FEP Title: Tunneling

SCR Section Number: SCR.3.2.2
Screening Decision: SO-R (HCN)
SO-R (Future)

Summary:

Tunneling has been eliminated from performance assessment calculations on regulatory grounds. With regard to the validity of the screening argument (SO-R)/HCN (SO-R), no changes have been made to 40 CFR 191 since WIPP's certification, therefore the regulatory requirements remain unchanged. This FEP has been screened out according to the regulatory criteria in 40 CFR 194.25 (a) (characteristics of the future remain what they are at the time the compliance application). Potash mining, which includes tunneling, has taken place in the Northern Delaware Basin and potash mining is accounted for in performance assessment calculations. Furthermore, consistent with 40 CFR § 194.33(b)(1), all future human-initiated EPs relating to deliberate mining intrusion into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds. The FEP description, screening argument or screening decision remain unchanged.

New information worthy of mention is the proposal to conduct underground scientific experiments using the WIPP tunnels and infrastructure. On April 26, 2001, the DOE formally requested approval the installation of the OMNISita astrophysics experiment in the core storage alcove of the WIPP underground. The purpose of the project is to develop a prototype neutrino detector to test proof of concept principles and measure background cosmic radiation levels within the WIPP underground. EPA approved the request on August 29, 2001. This project does not require additional tunneling or excavation. However, one proposal currently under consideration would be developed within the land withdrawal area, but may not be connected to existing WIPP tunnels, as the OMNISita project. This option may present a human tunneling activity not previously conducted. This option is by far the most expensive of those proposed, and is considered the least likely to progress beyond the conceptual stage. However, should any of these proposals actually become implemented, the information supporting the current screening decisions will need to be updated.

This FEP has been separated from the original grouping as provided in CCA Appendix SCR section SCR.3.2.2. The original grouping of FEPs is confusing and places several of the "excavation" FEPs within the same section of Appendix SCR. While most of these FEPs are screened out based on regulations, one is screened based on consequence. It is therefore more appropriate to separate these FEPs and describe each screening decision and basis separately.

With regard to the validity of the screening argument (SO-R)/HCN (SO-R), no changes have been made to the governing regulations for the WIPP, therefore a screening based on regulatory grounds continues to be valid.

Italicized Text

Consistent with 40 CFR § 194.33(b)(1), near-future human-initiated events and processes relating to tunneling into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds. Furthermore, consistent with 40 CFR § 194.33(b)(1), future human-initiated events and processes relating to tunneling into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Tunneling

No construction of underground facilities (for example, storage, disposal, accommodation [that is, dwellings]) or tunneling has taken place in the Delaware Basin. Mining for potash occurs (a form of tunneling), but is addressed specifically in FEP H-13. Gas storage does take place in the Delaware Basin, but it involves injection through boreholes into depleted reservoirs, and not excavation (see, for example, Burton et al. 1993, pp. 66-67).

On April 26, 2001, the DOE formally requested approval the installation of the OMNISita astrophysics experiment in the core storage alcove of the WIPP underground. The purpose of the project is to develop a prototype neutrino detector to test proof of concept principles and measure background cosmic radiation levels within the WIPP underground. EPA approved the request on August 29, 2001. This project does not require additional tunneling or excavation, and therefore does not impact the screening argument for this FEP.

Because tunneling and construction of underground facilities (other than WIPP) have not taken place in the Delaware Basin, and consistent with the future states assumptions in 40 CFR § 194.25(a), such excavation activities have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: **H16**
FEP Title: **Construction of Underground Facilities**

SCR Section Number: **SCR.3.2.2**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

Construction of underground facilities has been eliminated from performance assessment calculations on regulatory grounds. With regard to the validity of the screening argument (SO-R)/HCN (SO-R)/Future, no changes have been made to 40 CFR Part 191 since WIPP's certification, therefore a screening decision based on regulatory grounds will continue to be valid, provided that the basis of those regulatory assumptions continue to hold true as well. Consistent with the future states assumptions in 40 CFR § 194.25(a), excavation activities that have not taken place in the Delaware Basin over the past 100 years need not be included in consideration of future human activities. Thus, construction of underground facilities (for example, storage, disposal, accommodation) have been eliminated from performance assessment calculations on regulatory grounds. The FEP description, screening argument or screening decision remain unchanged.

New information worthy of mention is the proposal to conduct underground scientific experiments using the WIPP tunnels and infrastructure. On April 26, 2001, the DOE formally requested approval the installation of the OMNISita astrophysics experiment in the core storage alcove of the WIPP underground. The purpose of the project is to develop a prototype neutrino detector to test proof of concept principles and measure background cosmic radiation levels within the WIPP underground. EPA approved the request on August 29, 2001. This project does not require additional tunneling or excavation. However, one proposal currently under consideration would be developed within the land withdrawal area, but may not be connected to existing WIPP tunnels, as the OMNISita project. This option may present a human tunneling activity not previously conducted. This option is by far the most expensive of those proposed, and is considered the least likely to progress beyond the conceptual stage. However, should any of these proposals actually become implemented, the information supporting the current screening decisions will need to be updated.

This FEP has been separated from the original grouping as provided in CCA Appendix SCR section SCR.3.2.2. The original grouping of FEPs is confusing and places several of the "excavation" FEPs within the same section of Appendix SCR. While most of these FEPs are screened out based on regulations, one is screened out based on consequence. It is therefore more appropriate to separate these FEPs and describe each screening decision and basis separately.

Italicized Text

Consistent with 40 CFR § 194.33(b)(1), near-future human-initiated events and processes relating to construction of underground facilities at the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds. Furthermore, consistent with 40 CFR § 194.33(b)(1), future human-initiated events and processes relating to construction of underground facilities at the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Construction of Underground Facilities

No *construction of underground facilities* (for example, storage, disposal, accommodation [that is, dwellings]) has taken place in the Delaware Basin, with the obvious exception of the WIPP. Mining for potash occurs (a form of underground construction), but is addressed specifically in FEP H-2. Gas storage does take place in the Delaware Basin, but it involves injection through boreholes into depleted reservoirs, and not excavation (see, for example, Burton et al. 1993, pp. 66-67). Because construction of underground facilities has not taken place in the Delaware Basin, and consistent with the future states assumptions in 40 CFR § 194.25(a), such excavation activities have been eliminated from performance assessment calculations on regulatory grounds.

On April 26, 2001, the DOE formally requested approval the installation of the OMNISita astrophysics experiment in the core storage alcove of the WIPP underground. The purpose of the project is to develop a prototype neutrino detector to test proof of concept principles and measure background cosmic radiation levels within the WIPP underground. EPA approved the request on August 29, 2001. This project does not require additional tunneling or excavation, and therefore does not impact the screening argument for this FEP.

Because tunneling and construction of underground facilities (other than WIPP) have not taken place in the Delaware Basin, and consistent with the future states assumptions in 40 CFR § 194.25(a), such excavation activities have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: H17
FEP Title: Archeological Excavations

SCR Section Number: SCR.3.2.2
Screening Decision: SO-C (HCN)
SO-R (Future)

Summary:

The screening argument presented in SCR 3.2.2 appears reasonable, however the description is somewhat confusing. It is unclear whether the *phrase "... other than for potash and archaeological excavations,"* is inclusive or exclusive of the phrase *"... and archaeological excavations."* Because the evaluation of the effects of potash mining is required by 40 CFR 194, it is assumed that the statement should be exclusive of archeological excavations. This could be editorially remedied by making the phrase "other than for potash" a parenthetical phrase, thus disassociating archeological excavations from the exclusion. Based on this, the screening logic is that since archeological excavations have taken place or are currently taking place in the Delaware Basin and have not altered the geology of the controlled area, they may be screened out based on consequence for historic, current, and near-future archeological excavations.

Future archeological excavations have been eliminated from performance assessment calculations on regulatory grounds as provided in 40 CFR 194.32 (a). The original description for this FEP and screening argument remains valid. Editorial changes for clarity are suggested, as well as separating the seven excavation FEPs into discrete arguments. No substantive changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

Historical, current, and near-future archaeological excavations have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Future archaeological excavations into the disposal system have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

Archaeological Excavations

Archeological excavations have occurred at or near the WIPP, but involved only minor surface disturbances. These archeological excavations may continue into the foreseeable future as other archeological sites are discovered. These activities have not altered the geology of the controlled area significantly, and have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Also, consistent with 40 CFR § 194.32 (a) and § 194.33(b)(1), archeological excavations have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number **H18**
FEP Title: **Deliberate Mining Intrusion**

SCR Section Number: **SCR.3.2.2**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

This FEP has been separated from the original grouping as provided in CCA Appendix SCR section SCR.3.2.2. The original grouping of FEPs is confusing and places several of the "excavation" FEPs within the same section of Appendix SCR. While most of these FEPs are screened out based on regulations, one is screened out based on consequence. It is therefore more appropriate to separate these FEPs and describe each screening decision and basis separately.

With regard to the validity of the screening argument (SO-R)/HCN (SO-R), no changes have occurred that would impact this screening decision. Therefore, a screening based on regulatory grounds continues to be valid.

Italicized Text

Consistent with 40 CFR § 194.33(b)(1), near-future human-initiated events and processes relating to deliberate mining intrusion into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds. Furthermore, consistent with 40 CFR § 194.33(b)(1), future human-initiated events and processes relating to deliberate mining intrusion into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

Consistent with 40 CFR § 194.33(b)(1), all future human-initiated related EPs relating to *deliberate mining intrusion* into the WIPP excavation have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEPs Number: **H19**
FEP Title: **Explosions for Resource Recovery**

SCR Section Number: **SCR.3.2.3.1**
Screening Decision: **SO-C (HCN)**
SO-R (Future)

Summary:

The screening argument presented in CCA SCR 3.2.3.1 appears reasonable. The size of explosions used to fracture an oil- or gas-bearing unit is limited by the need to contain the damage within the unit being exploited. In the area surrounding the WIPP, the stratigraphic units with oil and gas resources are too deep for explosions to affect the performance of the disposal system. Thus, for historic, current, and near-future events, the effects of explosions for resource recovery have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal. Consistent with 40 CFR § 194.33(d), performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of a future borehole. Therefore, future underground explosions for resource recovery have been eliminated from performance assessment calculations on regulatory grounds.

Additional text is suggested to describe the past use of explosives in potash mining in the Delaware Basin. This additional information is provided for completeness, and does not affect the screening argument or decision.

Italicized Text

Historical underground explosions for resource recovery have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Future underground explosions for resource recovery have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Subsurface Explosions

This section discusses subsurface explosions associated with resource recovery that may result in pathways for fluid flow between hydraulically conductive horizons. The potential effects of explosions on the hydrological characteristics of the disposal system are discussed in H39

Historical, Current, and Near-Future Human-Initiated EPs

Neither small-scale nor regional-scale explosive techniques to enhance formation hydraulic conductivity form a part of current mainstream oil- and gas-production technology. Instead, controlled perforating and hydrofracturing are used to improve the performance of oil and gas boreholes in the Delaware Basin. However, small-scale explosions have been used in the past to fracture oil- and natural-gas-bearing units to enhance resource recovery. The size of explosion used to fracture an oil- or gas-bearing unit is limited by the need to contain the damage within the unit being exploited. In the area surrounding the WIPP, the stratigraphic units with oil and gas resources are too deep for explosions to affect the performance of the disposal system. Thus, the effects of *explosions for resource recovery* have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Potash mining is currently taking place and is expected to continue in the vicinity of the WIPP in the near future. Potash is mined extensively in the region east of Carlsbad and up to 1.3 miles (2.4 kilometers) from the boundaries of the controlled area. In earlier years conventional drill, blast, load, and rail-haulage methods were used. Today, continuous miners similar to those used in coal-mining have been adapted to fit the potash-salt formations. Hence, drilling and blasting technology is not used in the present day potash mines.

Thus, the effects of *explosions for resource recovery* have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEPs Number: **H20**
FEP Title: **Underground Nuclear Device Testing**

SCR Section Number: **SCR.3.2.3.2**
Screening Decision: **SO-C (HCN)**
SO-R (Future)

Summary:

This FEP was screened out due to low consequences for historic, current and near future activities and according to the regulatory criteria in 40 CFR 194.32(a) for future activities. Project Gnome (Rawson et al. 1965, pp. 5, 8, 35), took place in 1961 at a location approximately 8 miles (13 kilometers) southwest of the WIPP waste disposal region. A zone of increased permeability was observed to extend at least 150 feet (46 meters) laterally from, and 344 feet (105 meters) above, the point of the explosion. The test had no significant effects on the geological characteristics of the WIPP disposal system. Thus, historical underground nuclear device testing has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The criterion in 40 CFR § 194.32(a), relating to the scope of performance assessments, limits the consideration of future human actions to mining and drilling. Therefore, future underground nuclear device testing has been eliminated from performance assessment calculations on regulatory grounds. Future underground nuclear device testing has been eliminated from performance assessment calculations on regulatory grounds. There are no existing plans for underground nuclear device testing in the vicinity of the WIPP in the near future. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

Historical underground nuclear device testing has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Future underground nuclear device testing has been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Historical, Current, and Near-Future Human-Initiated EPs

The Delaware Basin has been used for an isolated nuclear test. This test, Project Gnome (Rawson et al. 1965, pp. 5, 8, 35), took place in 1961 at a location approximately 8 miles (13 kilometers) southwest of the WIPP waste disposal region. Project Gnome was decommissioned in 1979.

The primary objective of Project Gnome was to study the effects of an underground nuclear explosion in salt. The Gnome experiment involved the detonation of a 3.1 kiloton nuclear device at a depth of 1,190 feet (360 meters) in the bedded salt of the Salado. The explosion created an approximately spherical cavity of about 950,000 cubic feet (27,000 cubic meters) and caused surface displacements in a radius of 1,180 feet

(360 meters). No earth tremors perceptible to humans were reported at distances over 25 miles (40 kilometers) from the explosion. A zone of increased permeability was observed to extend at least 150 feet (46 meters) laterally from, and 344 feet (105 meters) above, the point of the explosion. The test had no significant effects on the geological characteristics of the WIPP disposal system. Thus, historical ***underground nuclear device testing*** has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. There are no existing plans for underground nuclear device testing in the vicinity of the WIPP in the near future.

Future Human-Initiated EPs

The criterion in 40 CFR § 194.32(a), relating to the scope of performance assessments, limits the consideration of future human actions to mining and drilling. Therefore, future underground nuclear device testing has been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: H21
FEP Title: Drilling Fluid Flow

SCR Section Number: SCR.3.3.1.1
Screening Decision: SO-C (HCN)
DP (Future)

Summary:

The original description for this FEP and screening argument remain valid. The text has been modified to remove reference to other FEPs. Drilling in the Delaware Basin is monitored by the Delaware Basin Drilling Surveillance Program conducted by Westinghouse TRU Solutions LLC. The program provides for active surveillance of drilling activities within the Delaware Basin. Information provided for the CRA falls between July 1, 1995 and September 30, 2002. Since the CCA, the drilling technology has remained the same. Therefore, no changes were made to the screening arguments.

Italicized Text

Drilling fluid flow associated with historical, current, near-future, and future boreholes that do not intersect the waste disposal region, has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The possibility of a future deep borehole penetrating a waste panel, such that drilling-induced flow results in transport of radionuclides to the land surface or to overlying hydraulically conductive units, is accounted for in performance assessment calculations. The possibility of a deep borehole penetrating both the waste disposal region and a Castile brine reservoir is accounted for in performance assessment calculations.

FEP Text

Borehole circulation fluid could be lost to thief zones encountered during drilling, or fluid could flow from pressurized zones through the borehole to the land surface (blowout) or to a thief zone. Such drilling-related EPs could influence groundwater flow and, potentially, radionuclide transport in the affected units. Future drilling within the controlled area could result in direct releases of radionuclides to the land surface or transport of radionuclides between hydraulically conductive units.

Movement of brine from a pressurized zone, through a borehole, into potential thief zones such as the Salado interbeds or the Culebra, could result in geochemical changes and altered radionuclide migration rates in these units.

Historical, Current, and Near-Future Human-Initiated EPs

Drilling fluid flow is a short-term event that can result in the flow of pressurized fluid from one geologic stratum to another. However, long-term flow through abandoned boreholes would have a greater hydrological impact in the Culebra than a short-term event like drilling-induced flow outside the controlled area. Wallace (1996a) analyzed the potential effects of flow through abandoned boreholes in the future within the controlled area, and concluded that interconnections between the Culebra and deep units could be eliminated from performance assessment calculations on the basis of low consequence. Thus, the historical, current, and near-future of drilling fluid flow associated with boreholes outside the controlled area has been screened out on the basis of low consequence to the performance of the disposal system.

As discussed in FEPs H25 through H36, drilling associated with water resources exploration, groundwater exploitation, potash exploration, oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, and drilling to explore other resources has taken place or is currently taking place outside the controlled area in the Delaware Basin. These drilling activities are expected to continue in the vicinity of the WIPP in the near future.

Future Human-Initiated EPs

For the future, drill holes may intersect the waste disposal region and their effects could be more profound. Thus, the possibility of a future borehole penetrating a waste panel, so that drilling fluid flow and, potentially, blowout, results in transport of radionuclides to the land surface or to overlying hydraulically conductive units, is accounted for in performance assessment calculations.

The units intersected by the borehole may provide sources for fluid flow (brine, oil, or gas) to the waste panel during drilling. In the vicinity of the WIPP, the Castile that underlies the Salado contains isolated volumes of brine at fluid pressures greater than hydrostatic. A future borehole that penetrates a Castile brine reservoir could provide a connection for brine flow from the reservoir to the waste panel, thus increasing fluid pressure and brine volume in the waste panel. The possibility of a deep borehole penetrating both a waste panel and a brine reservoir is accounted for in performance assessment calculations.

A future borehole that is drilled through a disposal room wall, but does not intersect waste, could penetrate a brine reservoir underlying the waste disposal region. Such an event would depressurize the brine reservoir to some extent, and thus would affect the consequences of any subsequent intersections of the reservoir. The possibility for a borehole to depressurize a brine reservoir underlying the waste disposal region is accounted for in performance assessment calculations.

Penetration of an underpressurized unit underlying the Salado could result in flow and radionuclide transport from the waste panel to the underlying unit during drilling, although drillers would minimize such fluid loss to a thief zone through the injection of materials to reduce permeability or through the use of casing and cementing. Also, the permeabilities of formations underlying the Salado are less than the permeability of the Culebra (Wallace 1996a). Thus, the consequences associated with radionuclide transport to an underpressurized unit below the waste panels during drilling will be less significant, in terms of disposal system performance, than the consequences associated with radionuclide transport to the land surface or to the Culebra during drilling. Through this comparison, drilling events that result in penetration of underpressurized units below the waste-disposal region have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

In evaluating the potential consequences of drilling fluid loss to a waste panel, two types of drilling events need to be considered - those that intercept pressurized fluid in underlying formations such as the Castile (defined in CCA Section 6.3.2.2 as E1 events) and those that do not (E2 events). A possible hydrological effect would be to make a greater volume of brine available for gas generation processes and thereby increase gas volumes at particular times in the future. As discussed in CCA Section 6.4.12.6, of boreholes that intersect a waste panel in the future, 8 percent are assumed to be E1 events and 92 percent are E2 events. For either type of drilling event, on the basis of current drilling practices, the driller is assumed to pass through the repository rapidly. Relatively small amounts of drilling fluid loss may not be noticed or may not give rise to concern. Larger fluid losses would lead to the driller injecting materials to reduce permeability, or to the borehole being cased and cemented, to limit the loss of drilling fluid.

For boreholes that intersect pressurized brine reservoirs, the volume of fluid available to flow up a borehole will be significantly greater than the volume of any drilling fluid that could be lost. This greater volume of brine is accounted for in performance assessment calculations, and is allowed to enter the disposal room (see CCA Section 6.4.7). Thus, the effects of drilling fluid loss will be small by comparison to the potential flow of brine from pressurized brine reservoirs. Therefore, the effects of drilling fluid loss for E1 drilling events have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

For boreholes that do not intersect pressurized brine reservoirs the treatment of the disposal room implicitly accounts for the potential for greater gas generation resulting from drilling fluid loss. Thus, the hydrological effects of drilling fluid loss for E2 drilling events are accounted for in performance assessment calculations within the conceptual model of the disposal room for drilling intrusions.

EPA FEP Number: **H22**
FEP Title: **Drilling Fluid Loss**

SCR Section Number: **SCR.3.3.1.1**
Screening Decision: **SO-C (HCN)**
DP (Future)

Summary:

The screening argument remains valid. Drilling fluid loss is a short-term event that can result in the flow of pressurized fluid from one geologic stratum to another. Large fluid losses would lead a driller to inject materials to reduce permeability, or it would lead to the borehole being cased and cemented to limit the loss of drilling fluid. Assuming such operations are successful, drilling fluid loss in the near future outside the controlled area will not affect the hydrology of the disposal system significantly. Thus, drilling fluid loss associated with historical, current, and near-future boreholes has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

The consequences of drilling fluid loss into waste panels in the future is accounted for in performance assessment calculations for E1 and E2 events.

Editorial changes for clarity are suggested, as well as separating the FEPs into discrete arguments. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

Drilling fluid loss associated with historical, current, near-future, and future boreholes that do not intersect the waste disposal region, has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The possibility of a future-drilling fluid loss into waste panels is accounted for in performance assessment calculations.

FEP Text

Borehole circulation fluid could be lost to thief zones encountered during drilling, or fluid could flow from pressurized zones through the borehole to the land surface (blowout) or to a thief zone. Such drilling-related EPs could influence groundwater flow and, potentially, radionuclide transport in the affected units. Future drilling within the controlled area could result in direct releases of radionuclides to the land surface or transport of radionuclides between hydraulically conductive units.

Movement of brine from a pressurized zone, through a borehole, into potential thief zones such as the Salado interbeds or the Culebra, could result in geochemical changes and altered radionuclide migration rates in these units.

Historical, Current, and Near-Future Human-Initiated EPs

Drilling fluid flow will not affect hydraulic conditions in the disposal system significantly unless there is substantial *drilling fluid loss* to a thief zone, such as the Culebra. Typically, zones into which significant borehole circulation fluid is lost are isolated through injection of materials to reduce permeability or through casing and cementing programs. Assuming such operations are successful, drilling fluid loss in the near future outside the controlled area will not affect the hydrology of the disposal system significantly and be of no consequence.

Future Human-Initiated EPs

The consequences of drilling within the controlled area in the future will primarily depend on the location of the borehole. Potentially, future deep drilling could penetrate the waste disposal region. Hydraulic and geochemical conditions in the waste panel could be affected as a result of *drilling fluid loss* to the panel.

Penetration of an under pressurized unit underlying the Salado could result in flow and radionuclide transport from the waste panel to the underlying unit during drilling, although drillers would minimize such fluid loss to a thief zone through the injection of materials to reduce permeability or through the use of casing and cementing. Also, the permeabilities of formations underlying the Salado are less than the permeability of the Culebra (Wallace 1996a). Thus, the consequences associated with radionuclide transport to an under pressurized unit below the waste panels during drilling will be less significant, in terms of disposal system performance, than the consequences associated with radionuclide transport to the land surface or to the Culebra during drilling. Through this comparison, drilling events that result in penetration of under pressurized units below the waste-disposal region have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

For boreholes that do not intersect pressurized brine reservoirs (but do penetrate the waste-disposal region) the treatment of the disposal room implicitly accounts for the potential for greater gas generation resulting from drilling fluid loss. Thus, the hydrological effects of drilling fluid loss for E2 drilling events are accounted for in performance assessment calculations within the conceptual model of the disposal room for drilling intrusions.

EPA FEP Number: **H23**
FEP Title: **Blowouts**

SCR Section Number: **SCR.3.3.1.1**
Screening Decision: **SO-C (HCN)**
DP (Future)

Summary:

The screening arguments remain valid. Blowouts are short-term events that can result in the flow of pressurized fluid from one geologic stratum to another. For the near future, a blowout may occur in the vicinity of the WIPP but is not likely to affect the disposal system because of the distance from the well to the waste panels, assuming that passive and active institutional controls are in place which restrict borehole installation to outside the LWA. Blowouts associated with historical, current, near-future, and future boreholes that do not intersect the waste disposal region, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. For the future, the drill holes may intersect the waste disposal region and these effects could be more profound. Thus, blowouts are included in the assessment of future activities.

The consequences of blowouts in the future are accounted for in performance assessment calculations.

Italicized Text

Blowouts associated with historical, current, near-future, and future boreholes that do not intersect the waste disposal region, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The possibility of a future deep borehole penetrating a waste panel, such that drilling-induced flow results in transport of radionuclides to the land surface or to overlying hydraulically conductive units, is accounted for in performance assessment calculations. The possibility of a deep borehole penetrating both the waste disposal region and a Castile brine reservoir is accounted for in performance assessment calculations.

FEP Text

Fluid could flow from pressurized zones through the borehole to the land surface (blowout) or to a thief zone. Such drilling-related EPs could influence groundwater flow and, potentially, radionuclide transport in the affected units. Movement of brine from a pressurized zone, through a borehole, into potential thief zones such as the Salado interbeds or the Culebra, could result in geochemical changes and altered radionuclide migration rates in these units.

Historical, Current, and Near-Future Human-Initiated EPs

Drilling associated with water resources exploration, groundwater exploitation, potash exploration, oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, and drilling to explore other resources has taken place or is currently taking place outside the controlled area in the Delaware Basin. These drilling activities are expected to continue in the vicinity of the WIPP in the near future.

Naturally occurring brine and gas pockets have been encountered during drilling in the Delaware Basin. Brine pockets have been intersected in the Castile (as discussed in CCA Section 2.2.1.3) and in the Salado above the WIPP horizon (CCA Section 2.2.1.2.2). Gas *blowouts* have occurred during drilling in the Salado. Usually, such events result in brief interruptions in drilling while the intersected fluid pocket is allowed to depressurize through flow to the surface (for a period lasting from a few hours to a few days). Drilling then restarts with an increased drilling mud weight. Under these conditions, blowouts in the near future will cause isolated hydraulic disturbances, but will not affect the hydrology of the disposal system significantly.

Potentially, the most significant disturbance to the disposal system could occur if an uncontrolled blowout during drilling resulted in substantial flow through the borehole from a pressurized zone to a thief zone. For example, if a borehole penetrates a brine reservoir in the Castile, brine could flow through the borehole to the Culebra, and, as a result, could affect hydraulic conditions in the Culebra. The potential effects of such an event can be compared to the effects of long-term fluid flow from deep overpressurized units to the Culebra through abandoned boreholes. Wallace (1996a) analyzed the potential effects of flow through abandoned boreholes in the future within the controlled area and concluded that interconnections between the Culebra and deep units could be eliminated from performance assessment calculations on the basis of low consequence. Long-term flow through abandoned boreholes would have a greater hydrological impact in the Culebra than short-term drilling-induced flow outside the controlled area. Thus, the effects of fluid flow during drilling in the near future have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

In summary, blowouts associated with historical, current, and near-future boreholes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs - Boreholes that Intersect the Waste Disposal Region

The consequences of drilling within the controlled area in the future will primarily depend on the location of the borehole. Potentially, future deep drilling could penetrate the waste disposal region. If the borehole intersects the waste in the disposal rooms, radionuclides could be transported as a result of drilling fluid flow: releases to the accessible environment may occur as material entrained in the circulating drilling fluid is brought to the surface. Also, during drilling, contaminated brine may flow up the borehole and reach the surface, depending on fluid pressure within the waste disposal panels; ***blowout*** conditions could prevail if the waste panel were sufficiently pressurized at the time of intrusion.

Hydraulic effects of drilling-induced flow

The possibility of a future borehole penetrating a waste panel, so that drilling fluid flow and, potentially, blowout, results in transport of radionuclides to the land surface or to overlying hydraulically conductive units, is accounted for in performance assessment calculations.

The units intersected by the borehole may provide sources for fluid flow (brine, oil, or gas) to the waste panel during drilling. In the vicinity of the WIPP, the Castile that underlies the Salado contains isolated volumes of brine at fluid pressures greater than hydrostatic. A future borehole that penetrates a Castile brine reservoir could provide a connection for brine flow from the reservoir to the waste panel, thus increasing fluid pressure and brine volume in the waste panel. The possibility of a deep borehole penetrating both a waste panel and a brine reservoir is accounted for in performance assessment calculations.

Future boreholes could affect the hydraulic conditions in the disposal system. Intersection of pockets of pressurized gas and brine would likely result in short-term, isolated hydraulic disturbances, and will not affect the hydrology of the disposal system significantly. Potentially, the most significant hydraulic disturbance to the disposal system could occur if an uncontrolled *blowout* during drilling resulted in substantial flow through the borehole from a pressurized zone to a thief zone. For example, if a borehole penetrates a brine reservoir in the Castile, brine could flow through the borehole to the Culebra, and, as a result, could affect hydraulic conditions in the Culebra. The potential effects of such an event can be compared to the effects of long-term fluid flow from deep overpressurized units to the Culebra through abandoned boreholes. Wallace (1996a) analyzed the potential effects of such interconnections in the future within the controlled area concluded that flow through abandoned boreholes between the Culebra and deep units could be eliminated from performance assessment calculations on the basis of low consequence

EPA FEP Number: H24
FEP Title: Drilling Induced Geochemical Changes

SCR Section Number: SCR.3.3.1.1
Screening Decision: UP (HCN)
DP (Future)

Summary:

Geochemical changes that occur within the controlled area as a result of historical, current, near-future, and future drilling-induced flow are accounted for in performance assessment calculations. Movement of brine from a pressurized reservoir in the Castile through a borehole into potential thief zones, such as the Salado interbeds or the Culebra, could cause drilling-induced geochemical changes resulting in altered radionuclide migration rates in these units through their effects on colloid transport and sorption (colloid transport may enhance radionuclide migration, while radionuclide migration may be retarded by sorption). This is included in performance assessment. The screening decision remains valid. The original FEP description has not been changed.

Italicized Text

Geochemical changes that occur within the controlled area as a result of historical, current, near-future, and future drilling-induced flow are accounted for in performance assessment calculations.

FEP Text

Borehole circulation fluid could be lost to thief zones encountered during drilling, or fluid could flow from pressurized zones through the borehole to the land surface (blowout) or to a thief zone. Such drilling-related EPs could influence groundwater flow and, potentially, radionuclide transport in the affected units. Future drilling within the controlled area could result in direct releases of radionuclides to the land surface or transport of radionuclides between hydraulically conductive units.

Movement of brine from a pressurized zone, through a borehole, into potential thief zones such as the Salado interbeds or the Culebra, could result in geochemical changes and altered radionuclide migration rates in these units.

Historical, Current, and Near-Future Human-Initiated EPs

As discussed in FEPs H25 through H36, drilling associated with water resources exploration, groundwater exploitation, potash exploration, oil and gas exploration, oil and gas exploitation, enhanced oil and gas recovery, and drilling to explore other resources has taken place or is currently taking place outside the controlled area in the Delaware Basin. These drilling activities are expected to continue in the vicinity of the WIPP in the near future.

Geochemical effects of drilling-induced flow

Radionuclide migration rates are governed by the coupled effects of hydrological and geochemical processes (See discussions in FEPs W77 through W100). Human-initiated EPs outside the controlled area could affect the geochemistry of units within the controlled area if they occur sufficiently close to the edge of the controlled area. Movement of brine from a pressurized reservoir in the Castile through a borehole into potential thief zones, such as the Salado interbeds or the Culebra, could cause *drilling-induced geochemical changes* resulting in altered radionuclide migration rates in these units through their effects on colloid transport and sorption (colloid transport may enhance radionuclide migration, while radionuclide migration may be retarded by sorption).

The treatment of colloids in performance assessment calculations is described in CCA Sections 6.4.3.6 and 6.4.6.2.2. The repository and its contents provide the main source of colloids in the disposal system. By comparison, Castile brines have relatively low total colloid concentrations. Therefore, changes in colloid transport in units within the controlled area as a result of historical, current, and near-future drilling-induced flow have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Sorption within the Culebra is accounted for in performance assessment calculations as discussed in CCA Section 6.4.6.2. The sorption model comprises an equilibrium, sorption isotherm approximation, employing distribution coefficients (Kds) applicable to dolomite in the Culebra (CCA Appendix MASS, Section MASS.15.2 and PAVT). The CDFs of distribution coefficients used are derived from a suite of experimental studies that include measurements of Kds for actinides in a range of chemical systems including Culebra and Castile brines, Culebra brines, and Salado brines. Therefore, any changes in sorption geochemistry in the Culebra within the controlled area as a result of historical, current, and near-future drilling-induced flow are accounted for in performance assessment calculations.

Sorption within the Dewey Lake is accounted for in performance assessment calculations, as discussed in CCA Section 6.4.6.6. It is assumed that the sorptive capacity of the Dewey Lake is sufficiently large to prevent any radionuclides that enter the Dewey Lake from being released over 10,000 years (Wallace et al. 1995). Sorption within other geological units of the disposal system has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system. The effects of changes in sorption in the Dewey Lake and other units within the controlled area as a result of historical, current, and near-future drilling-induced flow have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs - Boreholes that Intersect the Waste Disposal Region

The consequences of drilling within the controlled area in the future will primarily depend on the location of the borehole. Potentially, future deep drilling could penetrate the waste disposal region. If the borehole intersects the waste in the disposal rooms, radionuclides could be transported as a result of drilling fluid flow and geochemical conditions in the waste panel could be affected as a result of ***drilling-induced geochemical changes.***

Geochemical effects of drilling-induced flow

Drilling fluid loss to a waste panel could modify the chemistry of disposal room brines in a manner that would affect the solubility of radionuclides and the source term available for subsequent transport from the disposal room. The majority of drilling fluids used are likely to be locally derived, and their bulk chemistry will be similar to fluids currently present in the disposal system. In addition, the presence of the MgO chemical conditioner in the disposal rooms will buffer the chemistry across a range of fluid compositions, as discussed in detail in CCA Appendix SOTERM. Furthermore, for E1 drilling events, the volume of Castile brine that flows into the disposal room will be greater than that of any drilling fluids; Castile brine chemistry is accounted for in performance assessment calculations. Thus, the effects on radionuclide solubility of drilling fluid loss to the disposal room have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Movement of brine from a pressurized reservoir in the Castile through a borehole into thief zones, such as the Salado interbeds or the Culebra, could result in geochemical changes in the receiving units, and thus alter radionuclide migration rates in these units through their effects on colloid transport and sorption.

The repository and its contents provide the main source of colloids in the disposal system. Thus, colloid transport in the Culebra within the controlled area as a result of drilling-induced flow associated with boreholes that intersect the waste disposal region are accounted for in performance assessment calculations, as described in CCA Sections 6.4.3.6 and 6.4.6.2.1. The Culebra is the most transmissive unit in the disposal system and it is the most likely unit through which significant radionuclide transport could occur. Therefore, colloid transport in units other than the Culebra, as a result of drilling-induced flow associated with boreholes that intersect the waste disposal region, has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

As discussed in FEPs H21, H22 and H23, sorption within the Culebra is accounted for in performance assessment calculations. The sorption model used incorporates the effects of changes in sorption in the Culebra as a result of drilling-induced flow associated with boreholes that intersect the waste disposal region.

Consistent with the screening discussion in FEPs H21, H22 and H23, the effects of changes in sorption in the Dewey Lake inside the controlled area as a result of drilling-induced flow associated with boreholes that intersect the waste disposal region have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Sorption within other geological units of the disposal system has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

Future Human-Initiated EPs - Boreholes that do not Intersect the Waste Disposal Region

Future boreholes that do not intersect the waste disposal region could nevertheless encounter contaminated material by intersecting a region into which radionuclides have migrated from the disposal panels, or could affect hydrogeological conditions within the disposal system. Consistent with the containment requirements in 40 CFR § 191.13(a), performance assessments need not evaluate the effects of the intersection of contaminated material outside the controlled area.

Movement of brine from a pressurized reservoir in the Castile, through a borehole, into thief zones such as the Salado interbeds or the Culebra, could result in *drilling-induced geochemical changes* and altered radionuclide migration rates in these units.

Geochemical effects of drilling-induced flow

Movement of brine from a pressurized reservoir in the Castile through a borehole into thief zones, such as the Salado interbeds or the Culebra, could cause geochemical changes resulting in altered radionuclide migration rates in these units through their effects on colloid transport and sorption.

The contents of the waste disposal panels provide the main source of colloids in the disposal system. Thus, consistent with the discussion in FEPs H21, H22 and H23, colloid transport as a result of drilling-induced flow associated with future boreholes that do not intersect the waste disposal region has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. As discussed in FEPs H21, H22 and H23, sorption within the Culebra is accounted for in performance assessment calculations. The sorption model accounts for the effects of changes in sorption in the Culebra as a result of drilling-induced flow associated with boreholes that do not intersect the waste disposal region.

Consistent with the screening discussion in FEPs H21, H22 and H23, the effects of changes in sorption in the Dewey Lake within the controlled area as a result of drilling-induced flow associated with boreholes that do not intersect the waste disposal region have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Sorption within other geological units of the disposal system has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

In summary the effects of *drilling-induced geochemical changes* that occur within the controlled area as a result of historical, current, near-future, and future drilling-induced flow are accounted for in performance assessment calculations. Those that occur outside the controlled are have been eliminated from performance assessment calculations.

EPA FEP Number(s): **H25 & H26**
FEP Title(s): **Oil and Gas Extraction**
Groundwater Extraction

SCR Section Number: **SCR.3.3.1.2**
Screening Decision: **SO-C (HCN)**
SO-R (Future)

Summary:

The historical, current, and near-future extraction of extraction of groundwater and hydrocarbons from the WIPP area was screened out on the basis of low consequence. Extraction in the future was screened out on regulatory grounds. DOE considered the effects of both subsidence and altered pressure gradients in a system due to extraction of hydrocarbons, and concluded that the effects of subsidence and pressure gradients would be minimal, and would not affect the formations through which radionuclides could potentially be transported. For groundwater extraction, the only sources of freshwater that exist and are currently being exploited are the Dewey Lake and Culebra south of the WIPP site. DOE considered that increased hydraulic gradients in the Dewey Lake caused by extraction of water south of the WIPP site would be of no significance because the sorptive properties of the redbeds prevent migration of radionuclides to the accessible environment over the10,000-year regulatory period. DOE considered the effects of increased head gradients in the Culebra due to extraction, and concluded that these effects would represent an insignificant change to the existing gradients. No changes have been made to the FEP descriptions, screening arguments, or screening decisions.

Italicized Text

Historical, current, and near-future groundwater, oil, and gas extraction outside the controlled area has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Groundwater, oil, and gas extraction through future boreholes has been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

The extraction of fluid could alter fluid-flow patterns in the target horizons, or in overlying units as a result of a failed borehole casing. Also, the removal of confined fluid from oil- or gas-bearing units can cause compaction in some geologic settings, potentially resulting in subvertical fracturing and surface subsidence.

Historical, Current, and Near-Future Human-Initiated EPs

As discussed in FEPs H25 through H36, water, oil, and gas production are the only activities involving fluid extraction through boreholes that have taken place or are currently taking place in the vicinity of the WIPP. These activities are expected to continue in the vicinity of the WIPP in the near future.

Groundwater extraction outside the controlled area from formations above the Salado could affect groundwater flow. The Dewey Lake contains a productive zone of saturation south of the WIPP site. Several wells operated by the J.C. Mills Ranch south of the WIPP produce water from the Dewey Lake to supply livestock (see CCA Section 2.2.1.4.2.1). Also, water has been extracted from the Culebra at the Engle Well approximately 6 miles south of the controlled area to provide water for livestock. No water wells in other areas in the vicinity of the WIPP are expected to be drilled in the near future because of the high concentrations of total dissolved solids in the groundwater.

If contaminated water intersects a well while it is producing, then contaminants could be pumped to the surface. Consistent with the containment requirements in 40 CFR § 191.13(a), performance assessments need not evaluate radiation doses that might result from such an event. However, compliance assessments must include any such events in dose calculations for evaluating compliance with the individual protection requirements in 40 CFR § 191.15. As discussed in Chapter 8.0, under undisturbed conditions, there are no calculated radionuclide releases to units containing producing wells.

Pumping from wells at the J.C. Mills Ranch may have resulted in reductions in hydraulic head in the Dewey Lake within southern regions of the controlled area, leading to increased hydraulic head gradients. However, these changes in the groundwater flow conditions in the Dewey Lake will have no significant effects on the performance of the disposal system, primarily because of the sorptive capacity of the Dewey Lake (see CCA Section 6.4.6.6). Retardation of any radionuclides that enter the Dewey Lake will be such that no radionuclides will migrate through the Dewey Lake to the accessible environment within the 10,000-year regulatory period.

The effects of groundwater extraction from the Culebra from a well 6 miles south of the controlled area have been evaluated by Wallace (1996b), using an analytical solution for Darcian fluid flow in a continuous porous medium. Wallace (1996b) showed that such a well pumping at about 0.5 gallons per minute for 10,000 years will induce a hydraulic head gradient across the controlled area of about 4×10^{-5}. The hydraulic head gradient across the controlled area currently ranges from between 0.001 to 0.007. Therefore, pumping from the Engle Well will have only minor effects on the hydraulic head gradient within the controlled area even if pumping were to continue for 10,000 years. Thus, the effects of historical, current, and near-future groundwater extraction outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Oil and gas extraction outside the controlled area could affect the hydrology of the disposal system. However, the horizons that act as oil and gas reservoirs are sufficiently below the repository for changes in fluid-flow patterns to be of low consequence, unless there is fluid leakage through a failed borehole casing. Also, oil and gas production horizons in the Delaware Basin are well-lithified rigid strata, so oil and gas extraction is not likely to result in compaction and subsidence (Brausch et al. 1982, pp. 52, 61). Furthermore, the plasticity of the salt formations in the Delaware Basin will limit the extent of any fracturing caused by compaction of underlying units. Thus, neither the extraction of gas from reservoirs in the Morrow Formation (some 14,000 feet [4,200 meters] below the surface), nor extraction of oil from the shallower units within the Delaware Mountain Group (about 4,000 to 8,000 feet [1,250 to 2,450 meters] below the surface) will lead to compaction and subsidence. In summary, historical, current, and near-future oil and gas extraction outside the controlled area has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.33(d), performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of a future borehole. Therefore, *groundwater extraction* and *oil and gas extraction* through future boreholes have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number(s): H27, H28 & H29
FEP Title(s): Liquid Waste Disposal (H27)
Enhanced Oil and Gas Production (H28)
Hydrocarbon Storage (H29)

SCR Section Number SCR.3.3.1.3
Screening Decision: SO-C (HCN)
SO-C (Future)

Summary:

The historical, current, and near-future disposal of liquid waste (H27) in boreholes near the WIPP was screened out on the basis of low consequence. Liquid waste disposal in the future is also screened out on the basis of low consequence. No changes have been made to this FEP's description, although it was previously screened out on regulatory grounds for the future. The hydrological effects of historical, current, near-future, and future enhanced oil and gas production (H28) have been screened out on the basis of low consequence. Neither hydraulic fracturing nor waterflooding conducted in wells outside the controlled area have the potential to affect the disposal system in any significant way. Additional information was added to the screening argument to reference analyses that were performed after the CCA. The hydrological effects of historical, current, near-future, and future hydrocarbon storage (H29) have been screened out on the basis of low consequence. Only one hydrocarbon (gas) storage facility is operating in the Delaware Basin, and it is too far away to have any effect on groundwater at the WIPP under any circumstances. No changes have been made to the FEP description, although the screening decision for the future time period has been changed from SO-R to SO-C; the screening argument has been modified slightly to include citation of a recent survey.

Italicized Text

The hydrological effects of historical, current, and near-future fluid injection (liquid waste disposal, enhanced oil and gas production, and hydrocarbon storage) through boreholes outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Geochemical changes that occur inside the controlled area as a result of fluid flow associated with historical, current and near-future fluid injection are accounted for in performance assessment calculations. Liquid waste disposal, enhanced oil and gas production, and hydrocarbon storage in the future have been eliminated from performance assessment calculations based on low consequence.

FEP Text

The injection of fluids could alter fluid-flow patterns in the target horizons or, if there is accidental leakage through a borehole casing, in any other intersected hydraulically conductive zone. Injection of fluids through a leaking borehole could also result in geochemical changes and altered radionuclide migration rates in the thief units.

Historical, Current, and Near-Future Human-Initiated EPs

The only historical and current activities involving fluid injection through boreholes in the Delaware Basin are *enhanced oil and gas production* (waterflooding or CO_2 injection), *hydrocarbon storage* (gas reinjection), and *liquid waste disposal* (by-products from oil and gas production). These fluid injection activities are expected to continue in the vicinity of the WIPP in the near future.

Hydraulic fracturing of oil- or gas-bearing units is currently used to improve the performance of hydrocarbon reservoirs in the Delaware Basin. Fracturing is induced during a short period of high-pressure fluid injection, resulting in increased hydraulic conductivity near the borehole. Normally, this controlled fracturing is confined to the pay zone and is unlikely to affect overlying strata.

Secondary production techniques, such as waterflooding, that are used to maintain reservoir pressure and displace oil are currently employed in hydrocarbon reservoirs in the Delaware Basin (Brausch et al. 1982, pp. 29-30). Tertiary recovery techniques such as CO_2 miscible flooding have been implemented with limited success in the Delaware Basin, but CO_2 miscible flooding is not an attractive recovery method for reservoirs near WIPP (Melzer 2003). Even if CO_2 flooding were to occur the effects (if any) would be very similar to those associated with waterflooding. Reinjection of gas for storage currently takes place at one location in the Delaware Basin in a depleted gas field in the Morrow Formation at the Washington Ranch near Carlsbad Caverns (Burton et al. 1993, pp. 66-67; Kehrman 2002, Volume One, Delaware Basin, Underground Gas Storage Facilities in the Vicinity of the WIPP Site). This field is too far from the WIPP site to have any effect on WIPP groundwaters under any circumstances. Disposal of liquid by-products from oil and gas production involves injection of fluid into depleted reservoirs. Such fluid injection techniques result in repressurization of the depleted target reservoir and mitigates any effects of fluid withdrawal.

The most significant effects of fluid injection would arise from substantial and uncontrolled fluid leakage through a failed borehole casing. The highly saline environment of some units can promote rapid corrosion of well casings and may result in fluid loss from boreholes.

Hydraulic effects of leakage through injection boreholes

The Vacuum field (located in the Capitan Reef, some 20 miles [30 kilometers] northeast of the WIPP site) and the Rhodes-Yates field (located in the back reef of the Capitan, some 45 miles [70 kilometers] southeast of the WIPP site) have been waterflooded for 40 years with confirmed leaking wells, which have resulted in brine entering the Salado and other formations above the Salado (see, for example, Silva 1994, pp. 67-68). Currently, saltwater disposal takes place in the vicinity of the WIPP into formations below the Castile. However, leakages from saltwater disposal wells or waterflood wells in the near future in the vicinity of the WIPP are unlikely to occur because of the following:

- There are significant differences between the geology and lithology in the vicinity of the disposal system and that of the Vacuum and Rhodes-Yates Fields. The WIPP is located in the Delaware Basin in a fore reef environment, where a thick zone of anhydrite and halite (the Castile) exists. In the vicinity of the WIPP, oil is produced from the Brushy Canyon Formation at depths greater than 7,000 feet (2100 meters). By contrast, the Castile is not present at either the Vacuum or the Rhodes-Yates Field, which lie outside the Delaware Basin. Oil production at the Vacuum Field is from the San Andres and Grayburg Formations at depths of approximately 4,500 feet (1400 meters), and oil production at the Rhodes-Yates Field is from the Yates and Seven Rivers Formations at depths of approximately 3,000 feet (900 meters). Waterflooding at the Rhodes-Yates Field involves injection into a zone only 200 feet (60 meters) below the Salado. There are more potential thief zones below the Salado near the WIPP than at the Rhodes-Yates or Vacuum Fields; the Salado in the vicinity of the WIPP is therefore less likely to receive any fluid that leaks from an injection borehole. Additionally, the oil pools in the vicinity of the WIPP are characterized by channel sands with thin net pay zones, low permeabilities, high irreducible water saturations, and high residual oil saturations. Therefore, waterflooding of oil fields in the vicinity of the WIPP on the scale of that undertaken in the Vacuum or the Rhodes-Yates Field is unlikely.

- New Mexico state regulations require the emplacement of a salt isolation casing string for all wells drilled in the potash enclave, which includes the WIPP area, to reduce the possibility of petroleum wells leaking into the Salado. Also, injection pressures are not allowed to exceed the pressure at which the rocks fracture. The injection pressure gradient must be kept below 0.2 pounds per square inch per foot (4.5×10^3 pascals per meter) above hydrostatic if fracture pressures are unknown. Such controls on fluid injection pressures limit the potential magnitude of any leakages from injection boreholes.

- Recent improvements in well completion practices and reservoir operations management have reduced the occurrences of leakages from injection wells. For example, injection pressures during waterflooding are typically kept below about one pounds per square inch per foot (23×10^3 pascals per meter) to avoid fracture initiation. Also, wells are currently completed using cemented and perforated casing, rather than the open-hole completions used in the early Rhodes-Yates wells. A recent report (Hall et al. 2003) concludes that injection well operations near WIPP have a very low failure rate, and that failures, although rare, are remedied quickly.

Any injection well leakages that do occur in the vicinity of the WIPP in the near future are more likely to be associated with liquid waste disposal than waterflooding. Disposal typically involves fluid injection though old and potentially corroded well casings and does not include monitoring to the same extent as waterflooding. Such fluid injection could affect the performance of the disposal system if sufficient fluid leaked into the Salado interbeds to affect the rate of brine flow into the waste disposal panels.

Stoelzel and O'Brien (1996) evaluated the potential effects on the disposal system of leakage from a hypothetical salt water disposal borehole near the WIPP. Stoelzel and O'Brien (1996) used the two-dimensional BRAGFLO model (vertical north-south cross-section) to simulate saltwater disposal to the north and to the south of the disposal system. The disposal system model included the waste disposal region, the marker beds and anhydrite intervals near the excavation horizon, and the rock strata associated with local oil and gas developments. A worst case simulation was run using high values of borehole and anhydrite permeability and a low value of halite permeability to encourage flow to the disposal panels via the anhydrite. Also, the boreholes were assumed to be plugged immediately above the Salado (consistent with the plugging configurations described in CCA Section 6.4.7.2). Values of key parameters for this simulation are shown in CCA Appendix SCR Table SCR-4.

Saltwater disposal into the Upper Bell Canyon was simulated, with annular leakage through the Salado. A total of approximately 7×10^5 cubic meters of brine was injected through the boreholes during a 50-year simulated disposal period. In this time, approximately 50 cubic meters of brine entered the anhydrite interval at the horizon of the waste disposal region. For the next 200 years the boreholes were assumed to be abandoned (with open-hole permeabilities of 1×10^{-9} square meters). Cement plugs (of permeability 10^{-17} square meters) were assumed to be placed at the injection interval and at the top of the Salado. Subsequently, the boreholes were prescribed the permeability of silty sand (see CCA Section 6.4.7.2), and the simulation was continued until the end of the 10,000-year regulatory period. During this period, approximately 400 cubic meters of brine entered the waste disposal region from the anhydrite interval. This value of cumulative brine inflow is within the bounds of the values generated by performance assessment calculations for the undisturbed performance scenario. During the disposal well simulation, leakage from the injection boreholes would have had no significant effect on the inflow rate at the waste panels.

Stoelzel and Swift (1997) expanded on Stoelzel and O'Brien's (1996) work by considering injection for a longer period of time (up to 150 years) and into deeper horizons at higher pressures. They developed two computational models (a modified cross-sectional model and an axisymmetric radial model) that are alternatives to the cross-sectional model used by Stoelzel and O'Brien (1996). Rather than repeat the conservative and bounding approach used by Stoelzel and O'Brien (1996), Stoelzel and Swift (1997) focused on reasonable and realistic conditions for most aspects of the modeling, including setting parameters that were sampled in the CCA at their median values. Model results indicate that, for the cases considered, the largest volume of brine entering MB139 (the primary pathway to the WIPP) from the borehole is approximately 1,500 m^3, which is a small enough volume that it would not affect Stoelzel and O'Brien's (1996) conclusion even if it somehow all reached the WIPP. Other cases showed from 0 to 600 m^3 of brine entering MB139 from the injection well. In all cases, high-permeability fractures created in the Castile and Salado anhydrite layers by the modeled injection pressures were restricted to less than 400 m from the wellbore, and did not extend more than 250 m in MB138 and MB139.

No flow entered MB139, nor was fracturing of the unit calculated to occur away from the borehole, in cases in which leaks in the cement sheath had permeabilities of $10^{-12.5}$ m^2 (corresponding to the median value used to characterize fully degraded boreholes in the CCA) or lower. The cases modeled in which flow entered MB139 from the borehole and fracturing occurred away from the borehole required injection pressures conservatively higher than any currently in use near the WIPP and either 150 years of leakage through a fully degraded cement sheath or 10 years of simultaneous tubing and casing leaks from a waterflood operation. These conditions are not likely to occur in the future. If leaks like these do occur from brine injection near the WIPP, however, results of the Stoelzel and Swift (1997) modeling study indicate that they will not affect the performance of the repository.

Thus, the hydraulic effects of leakage through historical, current, and near-future boreholes outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Effects of density changes resulting from leakage through injection boreholes

Leakage through a failed borehole casing during a fluid injection operation in the vicinity of the WIPP could alter fluid density in the affected unit, which could result in changes in fluid flow rates and directions within the disposal system. Disposal of oil and gas production by-products through boreholes could increase fluid densities in transmissive units affected by leakage in the casing. Operations such as waterflooding use fluids derived from the target reservoir, or fluids with a similar composition, to avoid scaling and other reactions. Therefore, the effects of leakage from waterflood boreholes would be similar to leakage from disposal wells.

Denser fluids have a tendency to sink relative to less dense fluids, and, if the hydrogeological unit concerned has a dip, there will be a tendency for the dense fluid to travel in the downdip direction. If this direction is the same as the direction of the groundwater pressure gradient, there would be an increase in flow velocity, and conversely, if the downdip direction is opposed to the direction of the groundwater pressure gradient, there would be a decrease in flow velocity. In general terms, taking account of density-related flow will cause a rotation of the flow vector towards the downdip direction that is dependent on the density contrast and the dip.

Wilmot and Galson (1996) showed that brine density changes in the Culebra resulting from leakage through an injection borehole outside the controlled area will not affect fluid flow in the Culebra significantly. Potash mining activities assumed on the basis of regulatory criteria to occur in the near future outside the controlled area will have a more significant effect on modeled Culebra hydrology. The distribution of existing leases suggests that near-future mining will take place to the north, west, and south of the controlled area (see CCA Section 2.3.1.1). The effects of such potash mining are accounted for in calculations of undisturbed performance of the disposal system (through an increase in the transmissivity of the Culebra above the mined region, as discussed in

FEPs H37, H38 and H39). Groundwater modeling that accounts for potash mining shows a change in the fluid pressure distribution, and a consequent shift of flow directions towards the west in the Culebra within the controlled area (Wallace 1996c). A localized increase in fluid density in the Culebra resulting from leakage from an injection borehole would rotate the flow vector towards the downdip direction (towards the east).

Wilmot and Galson (1996) compared the relative magnitudes of the freshwater head gradient and the gravitational gradient and showed that the density effect is of low consequence to the performance of the disposal system. According to Darcy's Law, flow in an isotropic porous medium is governed by the gradient of fluid pressure and a gravitational term

$$\bar{v} = -\frac{k}{\mu}\left[\nabla p - \rho\bar{g}\right],$$

where

v	=	Darcy velocity vector	(m s^{-1})
k	=	intrinsic permeability	(m^2)
μ	=	fluid viscosity	(pa s)
∇p	=	gradient of fluid pressure	(pa m^{-1})
ρ	=	fluid density	(kg m^{-3})
g	=	gravitational acceleration vector	(m s^{-2})

The relationship between the gravity-driven flow component and the pressure-driven component can be shown by expressing the velocity vector in terms of a freshwater head gradient and a density-related elevation gradient

$$\bar{v} = -K\left[\nabla H_f + \frac{\Delta\rho}{\rho_f}\nabla E\right],$$

where

K	=	hydraulic conductivity	(m s^{-1})
∇H_f	=	gradient of freshwater head	
$\Delta\rho$	=	difference between actual fluid density and reference fluid density	(kg m^{-3})
ρ_f	=	density of freshwater	(kg m^{-3})
∇E	=	gradient of elevation	

Davies (1989, p. 28) defined a driving force ratio (DFR) to assess the potential significance of the density gradient

$$DFR = \frac{\Delta\rho \left| \nabla E \right|}{\rho_f \left| \nabla H_f \right|}$$

and concluded that a DFR of 0.5 can be considered an approximate threshold at which density-related gravity effects may become significant (Davies 1989, p. 28).

The dip of the Culebra in the vicinity of the WIPP is about 0.44° or 8 meters per kilometer to the east (Davies 1989, p. 42). According to Davies (1989, pp. 47 - 48), freshwater head gradients in the Culebra between the waste panels and the southwestern and western boundaries of the accessible environment range from 4 meters per kilometer to 7 meters per kilometer. Only small changes in gradient arise from the calculated effects of near-future mining. Culebra brines have densities ranging from 998 to 1,158 kilograms per cubic meter (Cauffman et al. 1990, Table E1.b). Assuming the density of fluid leaking from a waterflood borehole or a disposal well to be 1,215 kilograms per cubic meter (a conservative high value similar to the density of Castile brine [Popielak et al. 1983, Table C-2]), leads to a DFR of between 0.07 and 0.43. These values of the DFR show that density-related effects caused by leakage of brine into the Culebra during fluid injection operations are not significant.

In summary, the effects of historical, current, and near-future fluid injection (liquid waste disposal, enhanced oil and gas production, and hydrocarbon storage) through boreholes outside the controlled area have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Geochemical effects of leakage through injection boreholes

Injection of fluids through a leaking borehole could affect the geochemical conditions in thief zones, such as the Salado interbeds or the Culebra. Such *fluid injection-induced geochemical changes* could alter radionuclide migration rates within the disposal system in the affected units if they occur sufficiently close to the edge of the controlled area through their effects on colloid transport and sorption.

The majority of fluids injected (for example, during brine disposal) have been extracted locally during production activities. Because they have been derived locally, their compositions are similar to fluids currently present in the disposal system, and they will have low total colloid concentrations compared to those in the waste disposal panels (see FEPs discussion for H21 through H24). The repository will remain the main source of colloids in the disposal system. Therefore, colloid transport as a result of historical, current, and near-future fluid injection has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

As discussed in FEPs H21 through H24, sorption within the Culebra is accounted for in performance assessment calculations. The sorption model used accounts for the effects of any changes in sorption in the Culebra as a result of leakage through historical, current, and near-future injection boreholes.

Consistent with the screening discussion in FEPs H21 through H24, the effects of changes in sorption in the Dewey Lake within the controlled area as a result of leakage through historical, current, and near-future injection boreholes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Sorption within other geological units of the disposal system has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

Nonlocally derived fluids could be used during hydraulic fracturing operations. However, such fluid injection operations would be carefully controlled to minimize leakage to thief zones. Therefore, any potential geochemical effects of such leakages have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.33(d), performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of a future borehole within the site boundary. *Liquid waste disposal* (by-products from oil and gas production), *enhanced oil and gas production*, and *hydrocarbon storage* are techniques associated with resource recovery and are expected to continue into the future outside the site boundary. Analyses have shown that these activities have little consequence on repository performance (Stoelzel and Swift 1997). Therefore, activities such as *liquid waste disposal, enhanced oil and gas production*, and *hydrocarbon storage* have been eliminated from performance assessment calculations on the basis of low consequence.

EPA FEP Number: **H30**
FEP Title: **Fluid Injection-Induced Geochemical Changes**

SCR Section Number: **SCR.3.1.3**
Screening Decision: **UP (HCN)**
SO-R (Future)

Summary:

Geochemical changes that occur inside the controlled area as a result of fluid flow associated with historical, current and near-future fluid injection are accounted for in performance assessment calculations. The effects of fluid injection activities involving future boreholes have been screened out on the basis of regulatory requirements. Consistent with 40 CFR § 194.33(d), performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of a future borehole. Liquid waste disposal (by-products from oil and gas production), enhanced oil and gas production, and hydrocarbon storage are techniques associated with resource recovery. Therefore, the use of future boreholes for such activities and fluid injection-induced geochemical changes have been eliminated from performance assessment calculations on regulatory grounds. The screening decision remains valid. The original FEP description has not been changed.

Induced geochemistry changes due to injection activity was reported to be accounted for in the undisturbed case performance assessments during historical and anticipated operations. In the future, the FEP was screened out on the basis of regulatory requirements. In CCA Appendix SCR section SCR 3.3.1.3.1, the screening of geochemical effects of injection borehole leakage is discussed.

Italicized Text

Geochemical changes that occur inside the controlled area as a result of fluid flow associated with historical, current and near-future fluid injection are accounted for in performance assessment calculations. Liquid waste disposal, enhanced oil and gas production, and hydrocarbon storage involving future boreholes have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

The injection of fluids could alter fluid-flow patterns in the target horizons or, if there is accidental leakage through a borehole casing, in any other intersected hydraulically conductive zone. Injection of fluids through a leaking borehole could also result in geochemical changes and altered radionuclide migration rates in the thief units.

Geochemical effects of leakage through injection boreholes

Injection of fluids through a leaking borehole could affect the geochemical conditions in thief zones, such as the Salado interbeds or the Culebra. Such *fluid injection-induced geochemical changes* could alter radionuclide migration rates within the disposal system in the affected units if they occur sufficiently close to the edge of the controlled area through their effects on colloid transport and sorption.

The majority of fluids injected (for example, during brine disposal) have been extracted locally during production activities. Because they have been derived locally, their compositions are similar to fluids currently present in the disposal system, and they will have low total colloid concentrations compared to those in the waste disposal panels (see FEPs H21 through H24). The repository will remain the main source of colloids in the disposal system. Therefore, colloid transport as a result of historical, current, and near-future fluid injection has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

As discussed in FEPs H21 through H24, sorption within the Culebra is accounted for in performance assessment calculations. The sorption model used accounts for the effects of any changes in sorption in the Culebra as a result of leakage through historical, current, and near-future injection boreholes.

Consistent with the screening discussion in FEPs H21 through H24, the effects of changes in sorption in the Dewey Lake within the controlled area as a result of leakage through historical, current, and near-future injection boreholes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Sorption within other geological units of the disposal system has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

Non-locally derived fluids could be used during hydraulic fracturing operations. However, such fluid injection operations would be carefully controlled to minimize leakage to thief zones. Therefore, any potential geochemical effects of such leakages have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.33(d), performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of a future borehole. Liquid waste disposal (by-products from oil and gas production), enhanced oil and gas production, and hydrocarbon storage are techniques associated with resource recovery. Therefore, the use of future boreholes for such activities and fluid injection-induced geochemical changes have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: H31 & H33
FEP Title: Natural Borehole Fluid Flow (H31)
Flow Through Undetected Boreholes (H33)

SCR Section Number: SCR.3.3.1.4
Screening Decision: SO-C (HCN)
SO-C (Future, holes not penetrating waste panels)
DP (Future, holes through waste panels)

Summary:

FEPs H31 and H33 have been combined because knowledge of a borehole's existence has no impact on its effects. H33 has been deleted from the baseline and the description of H31 was changed to include unknown boreholes. The historic, current, and near-future effects of abandoned boreholes on flow through the Culebra have been screened out on the basis of low consequence. The future effects of abandoned boreholes that do not intersect waste panels have also been screened out on the basis of low consequence. The future effects of boreholes that intersect waste panels are included in PA calculations. Changes in fluid density caused by flow through abandoned boreholes at all times have been screened out on the basis of low consequence. The FEP screening arguments have been modified to simplify and improve clarity.

Italicized Text

The effects of natural fluid flow through existing or near-future abandoned boreholes, known or unknown, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Natural borehole flow through a future borehole that intersects a waste panel is accounted for in performance assessment calculations. The effects of natural borehole flow through a future borehole that does not intersect the waste-disposal region have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Abandoned boreholes could provide pathways for fluid flow and, potentially, contaminant transport between any intersected zones. For example, such boreholes could provide pathways for vertical flow between transmissive units in the Rustler, or between the Culebra and units below the Salado, which could affect fluid densities, flow rates, and flow directions.

Movement of fluids through abandoned boreholes could result in borehole-induced geochemical changes in the receiving units such as the Salado interbeds or Culebra, and thus alter radionuclide migration rates in these units.

Potentially, boreholes could provide pathways for surface-derived water or groundwater to percolate through low-permeability strata and into formations containing soluble minerals. Large-scale dissolution through this mechanism could lead to subsidence and to changes in groundwater flow patterns. Also, fluid flow between hydraulically conductive horizons through a borehole may result in changes in permeability in the affected units through mineral precipitation.

Historical, Current, and Near-Future Human-Initiated EPs

Abandoned water, potash, oil, and gas exploration and production boreholes exist within and outside the controlled area. Most of these boreholes have been plugged in some way, but some have simply been abandoned. Over time, even the boreholes that have been plugged may provide hydraulic connections among the units they penetrate as the plugs degrade. The DOE assumes that records of past and present drilling activities in New Mexico are largely accurate and that evidence of most boreholes would be included in these records. However, the potential effects of boreholes do not change depending on whether we know of their existence or not, hence *flow through abandoned boreholes (FEP H31)* and *flow through undetected boreholes (FEP H33)* can be evaluated together

Hydraulic effects of flow through abandoned boreholes

Fluid flow and radionuclide transport within the Culebra could be affected if deep boreholes result in hydraulic connections between the Culebra and deep overpressurized or underpressurized units, or if boreholes provide interconnections for flow between shallow units.

Connections Between the Culebra and Deeper Units

Fluid flow and radionuclide transport within the Culebra could be affected if deep boreholes result in hydraulic connections between the Culebra and deep overpressurized or underpressurized units. Over the past 80 years, a large number of deep boreholes have been drilled within and around the controlled area (see CCA Section 6.4.12.2). The effects on the performance of the disposal system of long-term hydraulic connections between the Culebra and deep units depends on the locations of the boreholes. In some cases, changes in the Culebra flow field caused by interconnections with deep units could decrease lateral radionuclide travel times to the accessible environment.

As part of an analysis to determine the impact of such interconnections, Wallace (1996a) gathered information on the pressures, permeabilities, and thicknesses of potential oil- or gas-bearing sedimentary units; such units exist to a depth of about 5,500 meters in the vicinity of the WIPP. Of these units, the Atoka, some 4,000 meters below the land surface, has the highest documented pressure of about 64×10^6 pascals (9,300 pounds per square inch), with permeability of about 2×10^{-14} square meters and thickness of about 210 meters. The Strawn, 3,900 meters below the land surface, has the lowest pressures (35×10^6 pascals [5,000 pounds per square inch], which is lower than hydrostatic) and highest permeability (10^{-13} square meters) of the deep units, with a thickness of about 90 meters.

Performance assessment calculations indicate that the shortest radionuclide travel times to the accessible environment through the Culebra occur when flow in the Culebra in the disposal system is from north to south. Wallace (1996a) ran the steady-state SECOFL2D model with the performance assessment data that generated the shortest radionuclide travel times (with and without mining in the controlled area) but perturbed the flow field by placing a borehole connecting the Atoka to the Culebra just north of the waste disposal panels and a borehole connecting the Culebra to the Strawn just south of the controlled area. The borehole locations were selected to coincide with the end points of the fastest flow paths modeled, which represents an unlikely worst-case condition. Although the Atoka is primarily a gas-bearing unit, Wallace (1996a) assumed that the unit is brine saturated. This assumption is conservative because it prevents two-phase flow from occurring in the Culebra, which would decrease the water permeability and thereby increase transport times. He further conservatively assumed that the pressure in the Atoka would not have been depleted by production before the well was plugged and abandoned. He also conservatively assumed that all flow from the Atoka would enter the Culebra and not intermediate or shallower units, and that flow from the Culebra could somehow enter the Strawn despite intermediate zones having higher pressures than the Culebra. The fluid flux through each borehole was determined using Darcy's Law, assuming a borehole hydraulic conductivity of 10^{-4} meter per second (for a permeability of about 10^{-11} square meters) representing silty sand, a borehole radius of 0.25 meters, and a fluid pressure in the Culebra of 0.88×10^{6} pascals (128 pounds per square inch) at a depth of about 200 meters (650 feet). With these parameters, the Atoka was calculated to transmit water to the Culebra at about 1.4×10^{-5} cubic meters per second (0.22 gallons per minute), and the Strawn was calculated to receive water from the Culebra at about 1.5×10^{-6} cubic meters per second (0.024 gallons per minute).

Travel times through the Culebra to the accessible environment were calculated using the SECOFL2D velocity fields for particles released to the Culebra above the waste panels, assuming no retardation by sorption or diffusion into the rock matrix. Mean Darcy velocities were then determined from the distance each radionuclide traveled, the time taken to reach the accessible environment, and the effective Culebra porosity. The results show that, at worst, interconnections between the Culebra and deep units under the unrealistically conservative assumptions listed above could cause less than a twofold increase in the largest mean Darcy velocity expected in the Culebra in the absence of such interconnections.

These effects can be compared to the potential effects of climate change on gradients and flow velocities through the Culebra. As discussed in Section 6.4.9 of the CCA (and Corbet and Knupp 1996), the maximum effect of a future wetter climate would be to raise the water table to the ground surface. This would raise heads and gradients in all units above the Salado. For the Culebra, the maximum change in gradient was estimated to be about a factor of 2.1. The effect of climate change is incorporated in compliance calculations through the Climate Index, which is used as a multiplier for Culebra groundwater velocities. The Climate Index has a bimodal distribution, with the range from 1.00 to 1.25 having a 75% probability, and the range from 1.50 to 2.25 having a 25% probability. Because implementation of the Climate Index leads to radionuclide releases through the Culebra that are orders of magnitude lower than the regulatory limits, the effects of flow between the Culebra and deeper units through abandoned boreholes can be screened out on the basis of low consequence.

Connections Between the Culebra and Shallower Units

Abandoned boreholes could also provide interconnections for long-term fluid flow between shallow units (overlying the Salado). Abandoned boreholes could provide pathways for downward flow of water from the Dewey Lake and/or Magenta to the Culebra because the Culebra hydraulic head is lower than the hydraulic heads of these units. Magenta freshwater heads are as much as 45 m higher than Culebra freshwater heads. Because the Culebra is generally at least one order of magnitude more transmissive than the Magenta at any location, a connection between the Magenta and Culebra would cause proportionally more drawdown in the Magenta head than rise in the Culebra head. For example, for a one order of magnitude difference in transmissivity and a 45-m difference in head, the Magenta head would decrease by approximately 40 m while the Culebra head increased by 5 m. This head increase in the Culebra would also be a localized effect, decreasing with radial distance from the leaking borehole. The primary flow direction in the Culebra across the WIPP site is from north to south, with the Culebra head decreasing by approximately 20 m across this distance. A 5-m increase in Culebra head at the northern WIPP boundary would, therefore, increase gradients by at most 25%.

The Dewey Lake freshwater head at the WQSP-6 pad is 55 m higher than the Culebra freshwater head. Leakage from the Dewey Lake could have a greater effect on Culebra head than leakage from the Magenta if the difference in transmissivity between the Dewey Lake and Culebra observed at the WQSP-6 pad, where the Dewey Lake is two orders of magnitude more transmissive than the Culebra (Beauheim and Ruskauff 1998), persists over a wide region. However, the saturated, highly transmissive zone in the Dewey Lake has only been observed south of the WIPP disposal panels. A connection between the Dewey Lake and the Culebra south of the panels would tend to decrease the north-south gradient in the Culebra across the site, not increase it.

In any case, leakage of water from overlying units into the Culebra could not increase Culebra heads and gradients as much as might result from climate change, discussed above. Because implementation of the Climate Index leads to radionuclide releases through the Culebra that are orders of magnitude lower than the regulatory limits, the effects of flow between the Culebra and shallower units through abandoned boreholes can be screened out on the basis of low consequence.

Changes in fluid density resulting from flow through abandoned boreholes

Leakage from historical, current, and near-future abandoned boreholes that penetrate pressurized brine pockets in the Castile could give rise to fluid density changes in affected units. Wilmot and Galson (1996) showed that brine density changes in the Culebra resulting from leakage through an abandoned borehole would not have a significant effect on the Culebra flow field. A localized increase in fluid density in the Culebra resulting from leakage from an abandoned borehole would rotate the flow vector towards the downdip direction (towards the east). A comparison of the relative magnitudes of the freshwater head gradient and the gravitational gradient, based on an analysis similar to that presented in CCA Appendix SCR Section SCR.3.3.1.3, shows that the density effect is of low consequence to the performance of the disposal system.

Geochemical effects of borehole flow—see H36

Borehole-induced solution and subsidence—see H-34

Borehole-induced mineralization—see H35

Future Human-Initiated EPs

The EPA provides criteria concerning analysis of the consequences of future drilling events in 40 CFR § 194.33(c). Consistent with these criteria, the DOE assumes that after drilling is complete, the borehole is plugged according to current practice in the Delaware Basin (see CCA Section 6.4.7.2). Degradation of casing and/or plugs may result in connections for fluid flow and, potentially, contaminant transport between connected hydraulically conductive zones. The long-term consequences of boreholes drilled and abandoned in the future will primarily depend on the location of the borehole and the borehole casing and plugging methods used.

Hydraulic effects of flow through abandoned boreholes

A future borehole that penetrates a Castile brine reservoir could provide a connection for brine flow from the reservoir to the waste panel, thus increasing fluid pressure and brine volume in the waste panel. Long-term ***natural borehole flow*** through such a borehole is accounted for in performance assessment calculations (see CCA Section 6.4.8).

Deep abandoned boreholes that intersect the Salado interbeds near the waste disposal panels could provide pathways for long-term radionuclide transport from the waste panels to the land surface or to overlying units. The potential significance of such events were assessed by WIPP PA Department (1991, B-26 to B-27), which examined single-phase flow and transport between the waste panels and a borehole intersecting MB139 outside the DRZ. The analysis assumed an in situ pressure of 11 megapascals in MB139, a borehole pressure of 6.5 megapascals (hydrostatic) at MB139, and a constant pressure of 18 megapascals as a source term in the waste panels representing gas generation. Also, MB139 was assigned a permeability of approximately 3×10^{-20} square meters and a porosity of 0.01 percent. The disturbed zone was assumed to exist in MB139 directly beneath the repository only and was assigned a permeability of 1.0×10^{-17} square meters and a porosity of 0.055 percent. Results showed that the rate of flow through a borehole located just 0.25 meters outside the DRZ would be more than two orders of magnitude less than the rate of flow through a borehole located within the DRZ because of the contrast in permeability. Thus, any releases of radionuclides to the accessible environment through deep boreholes that do not intersect waste panels would be insignificant compared to the releases that would result from transport through boreholes that intersect waste panels. Thus, radionuclide transport through deep boreholes that do not intersect waste panels has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Fluid flow and radionuclide transport within the Culebra could be affected if future boreholes result in hydraulic connections between the Culebra and either deeper or shallower units. Over the 10,000-year regulatory period, a large number of deep boreholes could be drilled within and around the controlled area (see CCA Section 6.4.12.2). The effects on the performance of the disposal system of long-term hydraulic connections between the Culebra and deeper or shallower units would be the same as those discussed above for historic, current, and near-future conditions. Thus, the effects of flow between the Culebra and deeper or shallower units through abandoned future boreholes can be screened out on the basis of low consequence.

Changes in fluid density resulting from flow through abandoned boreholes

A future borehole that intersects a pressurized brine reservoir in the Castile could also provide a source for brine flow to the Culebra in the event of borehole casing leakage, with a consequent localized increase in fluid density in the Culebra. The effect of such a change in fluid density would be to increase any density-driven component of groundwater flow. If the downdip direction, along which the density-driven component would be directed, is different from the direction of the groundwater pressure gradient, there would be a slight rotation of the flow vector towards the downdip direction. The groundwater modeling presented by Davies (1989, p. 50) indicates that a borehole that intersects a pressurized brine pocket and causes a localized increase in fluid density in the Culebra above the waste panels would result in a rotation of the flow vector slightly towards the east. However, the magnitude of this effect would be small in comparison to the magnitude of the pressure gradient (see CCA Appendix SCR Section SCR.3.3.1.3), and this effect can be screened out on the basis of low consequence.

Borehole-induced solution and subsidence—see H34

Borehole-induced mineralization—see H35

EPA FEP Number: **H32**
FEP Title: **Waste-Induced Borehole Flow**

SCR Section Number **SCR.3.3.1.4**
Screening Decision: **SO-R (HCN)**
DP (Future)

Summary:

No boreholes currently intersect the waste panels. Continued resource exploration and production in the near future will result in the occurrence of many more abandoned boreholes in the vicinity of the controlled area. Institutional controls will, however, prevent drilling (other than that associated with the WIPP development) from taking place within the controlled area in the near future. Therefore, no boreholes will intersect the waste disposal region in the near future, allowing *waste-induced borehole flow* in the near future to be screened out of performance assessment calculations on regulatory grounds. For simulations of the future after active and passive institutional control of the site has ceased, a borehole (or boreholes) is postulated to intersect a waste panel and allow flow of fluid and radioactivity to the overlying formations. The likelihood of such a borehole and its effects are included in the performance assessment. In accordance with the requirements of 40 CFR § 194.33(b)(1), the DOE models consequences of inadvertent and intermittent intrusion into the repository during drilling for natural resources as the most severe human-intrusion scenario that may affect long-term performance of the disposal system.

Italicized Text

Waste-induced flow through boreholes drilled in the near future has been eliminated from performance assessment calculations on regulatory grounds. Waste-induced borehole flow and natural borehole flow through a future borehole that intersects a waste panel are accounted for in performance assessment calculations.

FEP Text

Abandoned boreholes could provide pathways for fluid flow and, potentially, contaminant transport between any intersected zones. For example, such boreholes could provide pathways for vertical flow between transmissive units in the Rustler, or between the Culebra and units below the Salado, which could affect fluid densities, flow rates, and flow directions.

Continued resource exploration and production in the near future will result in the occurrence of many more abandoned boreholes in the vicinity of the controlled area. Institutional controls will prevent drilling (other than that associated with the WIPP development) from taking place within the controlled area in the near future. Therefore, no boreholes will intersect the waste disposal region in the near future, and *waste-induced* *borehole flow* in the near future has been eliminated from performance assessment calculations on regulatory grounds.

Future Human-Initiated EPs

The EPA provides criteria concerning analysis of the consequences of future drilling events in 40 CFR § 194.33(c). Consistent with these criteria, the DOE assumes that after drilling is complete the borehole is plugged according to current practice in the Delaware Basin (see CCA Section 6.4.7.2). Degradation of casing and/or plugs may result in connections for fluid flow and, potentially, contaminant transport between connected hydraulically conductive zones. The long-term consequences of boreholes drilled and abandoned in the future will primarily depend on the location of the borehole and the borehole casing and plugging methods used.

Hydraulic effects of flow through abandoned boreholes

An abandoned future borehole that intersects a waste panel could provide a connection for contaminant transport away from the repository horizon. If the borehole has degraded casing and/or plugs, and the fluid pressure within the waste panel is sufficient, radionuclides could be transported to the land surface. Additionally, if brine flows through the borehole to overlying units, such as the Culebra, it may carry dissolved and colloidal actinides that can be transported laterally to the accessible environment by natural groundwater flow in the overlying units. Long-term *waste-induced borehole flow* is accounted for in performance assessment calculations (see CCA Section 6.4.7.2).

EPA FEP Number: **H33**
FEP Title: **Flow Through Undetected Boreholes**

SCR Section Number: **SCR.3.3.1.4**
Screening Decision: **NA**

Summary:

FEPs H31 and H33 have been combined because knowledge of a borehole's existence has no impact on its effects. H33 has been deleted from the baseline and the description of H31 changed to include unknown boreholes. The historic, current, and near-future effects of abandoned boreholes on flow through the Culebra have been screened out on the basis of low consequence. The future effects of abandoned boreholes that do not intersect waste panels have also been screened out on the basis of low consequence. The future effects of boreholes that intersect waste panels are included in PA calculations. Changes in fluid density caused by flow through abandoned boreholes at all times have been screened out on the basis of low consequence. The FEP screening arguments have been modified to simplify and improve clarity.

EPA FEP Number: **H34**
FEP Title: **Borehole Induced Solution and Subsidence**

SCR Section Number: **SCR.3.3.1.4**
Screening Decision: **SO-C (HCN)**
SO-C (Future)

Summary:

The original description and screening arguments for *borehole-induced solution and subsidence* around existing and future boreholes remain unchanged and valid. The change in hydraulic conductivity within the Culebra from *borehole-induced solution and subsidence* along the flow path will have no significant affect on the long-term performance of the disposal system. The effects have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The FEP description and screening arguments have been revised, but the screening decision remains unchanged.

Italicized Text

The effects of borehole-induced solution and subsidence associated with existing, near-future, and future abandoned boreholes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Flow Through Abandoned Boreholes

Abandoned boreholes could provide pathways for fluid flow and, potentially, contaminant transport between any intersected zones. For example, such boreholes could provide pathways for vertical flow between transmissive units in the Rustler, or between the Culebra and units below the Salado, which could affect fluid densities, flow rates, and flow directions.

Movement of fluids through abandoned boreholes could result in borehole-induced geochemical changes in the receiving units such as the Salado interbeds or Culebra, and thus alter radionuclide migration rates in these units.

Potentially, boreholes could provide pathways for surface-derived water or groundwater to percolate through low-permeability strata and into formations containing soluble minerals. Large-scale dissolution through this mechanism could lead to subsidence and to changes in groundwater flow patterns. Also, fluid flow between hydraulically conductive horizons through a borehole may result in changes in permeability in the affected units through mineral precipitation.

Historical, Current, and Near-Future Human-Initiated EPs

Borehole-induced solution and subsidence

During the period covered by historical, current, and near-future FEPs, drilling within the land withdrawn for the WIPP will be controlled, and boreholes will be plugged according to existing regulations. Under these circumstances and during this time period, borehole-induced solution and subsidence at WIPP is eliminated from performance assessment calculations on the basis of no consequence to the disposal system.

Outside the area withdrawn for the WIPP, drilling has been regulated, but conditions of historical and existing boreholes are highly variable. Borehole-induced solution and subsidence may occur in these areas, although it is expected to be limited and should not affect the disposal system, as discussed in the following paragraphs.

Three features are required for significant *borehole-induced solution and subsidence* to occur: a borehole, an energy gradient to drive unsaturated (with respect to halite) water through the evaporite-bearing formations, and a conduit to allow migration of brine away from the site of dissolution. Without these features, minor amounts of halite might be dissolved in the immediate vicinity of a borehole, but percolating water would become saturated with respect to halite and stagnant in the bottom of the drillhole, preventing further dissolution.

At, and in the vicinity of, the WIPP site, drillholes penetrating into, but not through, the evaporite-bearing formations have little potential for dissolution. Brines coming from the Salado and Castile, for example, have high total dissolved solids (TDS) and are likely to precipitate halite, not dissolve more halite during passage through the borehole. Water infiltrating from the surface or near-surface units may not be saturated with halite. For drillholes with a total depth in halite-bearing formations, there is little potential for dissolution because the halite-bearing units have very low permeability and provide little outlet for the brine created as the infiltrating water fills the drillhole. ERDA 9 is the deepest drillhole in the immediate vicinity of the waste panels at WIPP; the bottom of the drillhole is in the uppermost Castile Formation, with no known outlet for brine at the bottom.

Drillholes penetrating through the evaporite-bearing formations provide possible pathways for circulation of water. Underlying units in the vicinity of the WIPP site with sufficient potentiometric levels or pressures to reach or move upward through the halite units generally have one of two characteristics: 1) high-salinity brines, which limit or eliminate the potential for dissolution of evaporites, or 2) are gas-producers. Wallace et al. (1982) analyzed natural processes of dissolution of the evaporites by water from the underlying Bell Canyon Formation. They concluded that brine removal in the Bell Canyon is slow, limiting the movement of dissolution fronts or the creation of natural collapse features. Existing drillholes that are within the boundaries of the withdrawn land and also penetrate through the evaporites are not located in the immediate vicinity of the waste panels or WIPP workings.

There are three examples in the region that appear to demonstrate the process for *borehole-induced solution and subsidence*, but the geohydrologic setting and drillhole completions differ from those at or near the WIPP.

An example of *borehole-induced solution and subsidence* occurred in 1980 about 100 miles (160 kilometers) southeast of the WIPP site (outside the Delaware Basin) at the Wink Sink (Baumgardner et al. 1982; Johnson 1989); percolation of shallow groundwater through abandoned boreholes, dissolution of the Salado, and subsidence of overlying units led to a surface collapse feature 360 feet (110 meters) in width and 110 feet (34 meters) deep. At Wink Sink, the Salado is underlain by the Tansill, Yates, and Capitan Formations, which contain vugs and solution cavities through which brine could migrate. Also, the hydraulic head of the Santa Rosa (the uppermost aquifer) is greater than those of the deep aquifers (Tansill, Yates, and Capitan Formations), suggesting downward flow if a connection were established. A second sink ("Wink Sink 2") formed in May, 2002, near the earlier sink (Johnson et al., in press). Its origin is similar to the earlier sink. By February, 2003, "Wink Sink 2" had enlarged by surface collapse to a length of about 1000 ft and a width of about 650 ft.

A similar, though smaller, surface collapse occurred in 1998 northwest of Jal, NM (Powers 2000). The most likely cause of collapse appears to be dissolution of Rustler, and possibly Salado, halite as relatively low salinity water from the Capitan reef circulated through breaks in the casing of a deep water supply well. Much of the annulus behind the casing through the evaporite section was uncemented, and work in the well at one time indicated bent and ruptured casing. The surface collapse occurred quickly, and the sink was initially about 75 ft across and a little more than 100 ft deep. By 2001, the surface diameter was about 120 ft, and the sink was filled with collapse debris to about 60 feet below the ground level (Powers, in press).

The sinkholes near Wink, TX, and Jal, NM, occurred above the Capitan reef (which is by definition outside the Delaware Basin), and the low salinity water and relatively high potentiometric levels of the Capitan reef appear to be integral parts of the process that formed these sinkholes. They are reviewed as examples of the process of evaporite dissolution and subsidence related to circulation in drillholes. Nevertheless, the factors of significant low salinity water and high potentiometric levels in units below the evaporites do not appear to apply at the WIPP site.

Beauheim (1986) considered the direction of natural fluid flow through boreholes in the vicinity of the WIPP. Beauheim (1986, p. 72) examined hydraulic heads measured using drill stem tests in the Bell Canyon and the Culebra at well DOE-2 and concluded that the direction of flow in a cased borehole open only to the Bell Canyon and the Culebra would be upward. Bell Canyon waters in the vicinity of the WIPP site are saline brines (e.g., Lambert 1978; Beauheim et al. 1983; Mercer et al. 1987), limiting the potential for dissolution of the overlying evaporites. However, dissolution of halite in the Castile and the Salado would increase the relative density of the fluid in an open borehole, causing a reduction in the rate of upward flow. Potentially, the direction of borehole fluid flow could reverse, but such a flow could be sustained only if sufficient driving pressure, porosity, and permeability exist for fluid to flow laterally within the Bell Canyon. A further potential sink for Salado-derived brine is the Capitan Limestone. However, the subsurface extent of the Capitan Reef is approximately 10 miles (16 kilometers) from the WIPP at its closest point, and this unit will not provide a sink for brine derived from boreholes in the vicinity of the controlled area. A similar screening argument is made for natural deep dissolution in the vicinity of the WIPP (see N16, N17 and N18).

The effects of *borehole-induced solution and subsidence* through a waste panel are considered below. The principal effects of *borehole-induced solution and subsidence* in the remaining parts of the disposal system should be to change the hydraulic properties of the Culebra and other rocks in the system. The features are local (limited lateral dimensions) and commonly nearly circular. If subsidence occurs along the expected travel path and the transmissivity of the Culebra is increased, as in the calculations conducted by Wallace (1996c), the travel times should increase. If the transmissivity along the expected flow path decreased locally due to such a feature, the flow path should be lengthened by travel around the feature. Thus, the effects of borehole-induced solution and subsidence around existing abandoned boreholes, and boreholes drilled and abandoned in the near-future, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs

The EPA provides criteria concerning analysis of the consequences of future drilling events in 40 CFR § 194.33(c). Consistent with these criteria, the DOE assumes that after drilling is complete the borehole is plugged according to current practice in the Delaware Basin (see CCA Section 6.4.7.2). Degradation of casing and/or plugs may result in connections for fluid flow and, potentially, contaminant transport between connected hydraulically conductive zones. The long-term consequences of boreholes drilled and abandoned in the future will primarily depend on the location of the borehole and the borehole casing and plugging methods used.

Borehole-induced solution and subsidence

Future boreholes that do not intersect the WIPP excavation do not differ in long-term behavior or consequences from existing boreholes, and they can be eliminated from performance assessment on the basis of low consequence to the performance of the disposal system.

The condition of more apparent concern is a future borehole that intersects the WIPP excavation. Seals and casings are assumed to degrade, connecting the excavation to various units. For a drillhole intersecting the excavation, but not connecting to a brine reservoir or to formations below the evaporites, downward flow is limited by the open volume of the disposal room(s), which is dependent with time, gas generation, or brine inflow to the disposal system from the Salado.

Maximum dissolution, and maximum increase in borehole diameter, will occur at the top of the Salado; dissolution will decrease with depth as the percolating water becomes salt saturated. Eventually, degraded casing and concrete plug products, clays, and other materials will fill the borehole. Long-term flow through a borehole that intersects a waste panel is accounted for in disturbed performance calculations by assuming that the borehole is eventually filled by such materials, which have the properties of a silty sand (see CCA Section 6.4.7.2). However, these calculations assume that the borehole diameter does not increase with time. Under the conditions assumed in the SCR for the CCA for an E2 drilling event at 1,000 years, about 1,000 m^3 would be dissolved from the lower Rustler and upper Salado Formations. If the dissolved area is approximately cylindrical or conical around the borehole, and the collapse/subsidence propagates upward as occurred in breccia pipes (e.g., Snyder and Gard 1982), the diameter of the collapsed or subsided area through the Culebra and other units would be a few tens of meters across. Changes in hydraulic parameters for this small zone should slow travel times for any hypothesized radionuclide release, as discussed for HCN occurrences. This does not change the argument for low consequence due to *borehole induced solution and subsidence* for these circumstances.

If a drillhole through a waste panel and into deeper evaporites intercepts a Castile brine reservoir, the brine has little or no capability of dissolving additional halite. The Castile brine flow is considered elsewhere as part of disturbed performance. There is, however, no *borehole induced solution and subsidence* under this circumstance, and therefore there is no effect on performance due to this EP.

If a borehole intercepts a waste panel and also interconnects with formations below the evaporite section, fluid flow up or down is determined by several conditions and may change over a period of time (e.g., as dissolution increases the fluid density in the borehole. Fluid flow downward is not a concern for performance, as fluid velocities in units such as the Bell Canyon are slow and should not be of concern for performance (e.g., II-G-12, 3.12.3.3.). For dissolution at the top of the evaporite section (as with boreholes considered under HCN), the process can develop a localized area around the borehole in which the hydraulic parameters for the Culebra and other units are altered. As with boreholes considered for HCN, the local change in hydraulic parameters, if it occurs along the expected flow path, would be expected to cause little change in travel time and should increase the travel time.

In summary, the effects of *borehole-induced solution and subsidence* around future abandoned boreholes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **H35**
FEP Title: **Borehole Induced Mineralization**

SCR Section Number: **SCR.3.3.1**
Screening Decision: **SO-C (HCN)**
SO-C (Future)

Summary:

Abandoned boreholes could provide pathways for fluid flow and, potentially, contaminant transport between any intersected zones. Movement of compositionally different groundwater into the Culebra may lead to mineral precipitation, potentially changing porosity and permeability within the unit, and affecting contaminant transport. The potential effects of borehole-induced brine movement into the Culebra dolomite and mineral precipitation/dissolution are discussed in FEPs H31 through H36. The screening decision remains valid. The original FEP description was slightly modified to include an evaluation of the effects of mineral precipitation on matrix diffusion.

Italicized Text

The effects of borehole-induced mineralization, associated with existing, near-future, and future abandoned boreholes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP text

Abandoned boreholes could provide pathways for fluid flow and, potentially, contaminant transport between any intersected zones. For example, such boreholes could provide pathways for vertical flow between transmissive units in the Rustler, or between the Culebra and units below the Salado, which could affect fluid densities, flow rates, and flow directions.

Movement of fluids through abandoned boreholes could result in borehole-induced geochemical changes in the receiving units such as the Salado interbeds or Culebra, and thus alter radionuclide migration rates in these units.

Potentially, boreholes could provide pathways for surface-derived water or groundwater to percolate through low-permeability strata and into formations containing soluble minerals. Large-scale dissolution through this mechanism could lead to subsidence and to changes in groundwater flow patterns. Also, fluid flow between hydraulically conductive horizons through a borehole may result in changes in permeability in the affected units through mineral precipitation.

Borehole-induced mineralization

Fluid flow between hydraulically conductive horizons through a borehole may result in changes in permeability in the affected units through mineral precipitation. For example:

- Limited calcite precipitation may occur as the waters mix in the Culebra immediately surrounding the borehole, and calcite dissolution may occur as the brines migrate away from the borehole due to variations in water chemistry along the flow path.

- Gypsum may be dissolved as the waters mix in the Culebra immediately surrounding the borehole but may precipitate as the waters migrate through the Culebra.

The effects of these mass transfer processes on groundwater flow depend on the original permeability structure of the Culebra rocks and the location of the mass transfer. The volumes of minerals that may precipitate and/or dissolve in the Culebra as a result of the injection of Castile or Salado brine through a borehole will not affect the existing spatial variability in the permeability field significantly.

Predicted radionuclide transport rates in the Culebra assume that the dolomite matrix is diffusively accessed by the contaminants. The possible inhibition of matrix diffusion by secondary mineral precipitation on fracture walls, due to mixing between brines and Culebra porewater, was addressed by Wang (1998). Wang showed that the volume of secondary minerals precipitated due to this mechanism was too small to significantly affect matrix porosity and accessibility.

Consequently, the effects of *borehole-induced mineralization* on permeability and groundwater flow within the Culebra, as a result of brines introduced via any existing abandoned boreholes, and boreholes drilled and abandoned in the near-future, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs

The EPA provides criteria concerning analysis of the consequences of future drilling events in 40 CFR § 194.33(c). Consistent with these criteria, the DOE assumes that after drilling is complete the borehole is plugged according to current practice in the Delaware Basin (see CCA Section 6.4.7.2). Degradation of casing and/or plugs may result in connections for fluid flow and, potentially, contaminant transport between connected hydraulically conductive zones. The long-term consequences of boreholes drilled and abandoned in the future will primarily depend on the location of the borehole and the borehole casing and plugging methods used.

Borehole-induced mineralization

Fluid flow between hydraulically conductive horizons through a future borehole may result in changes in permeability in the affected units through mineral precipitation. However, the effects of mineral precipitation as a result of flow through a future borehole in the controlled area will be similar to the effects of mineral precipitation as a result of flow through an existing or near-future borehole (see FEP H32 and H33). Thus, *borehole-induced mineralization* associated with flow through a future borehole has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: H36
FEP Title: Borehole-Induced Geochemical Changes

SCR Section Number: SCR.3.3.1
Screening Decision: UP (HCN)
DP (Future)
SO-C for units other than the Culebra

Summary:

Movement of fluids through abandoned boreholes could result in *borehole-induced geochemical changes* in the receiving units such as the Salado interbeds or Culebra. Such geochemical changes could alter radionuclide migration rates within the disposal system in the affected units if they occur sufficiently close to the edge of the controlled area, or if they occur as a result of flow through existing boreholes within the controlled area through their effects on colloid transport and sorption.

The contents of the waste disposal panels provide the main source of colloids in the disposal system. Colloid transport within the Culebra as a result of long-term flow associated with future abandoned boreholes that intersect the waste disposal region is accounted for in performance assessment calculations. Colloid transport as a result of flow through future abandoned boreholes that do not intersect the waste disposal region has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. For units other than the Culebra, the effects of changes in colloid transport or sorption as a result of flow through existing, near-future, and future abandoned boreholes has been eliminated from performance assessment calculations, on the basis of either beneficial consequence or low consequence to the performance of the disposal system.

Sorption within the Culebra is accounted for in performance assessment calculations. The sorption model used accounts for the effects of changes in sorption in the Culebra as a result of flow through existing, near-future, and future abandoned boreholes.

The screening argument remains valid. Fluids could migrate through boreholes to receiving units such as the Salado interbeds or the Culebra. These effects are included in the modeling. The original FEP description has not been changed.

Italicized Text

Geochemical changes that occur inside the controlled area as a result of long-term flow associated with historical, current, near-future, and future abandoned boreholes are accounted for in performance assessment calculations.

FEP Text

Abandoned boreholes could provide pathways for fluid flow and, potentially, contaminant transport between any intersected zones. For example, such boreholes could provide pathways for vertical flow between transmissive units in the Rustler, or between the Culebra and units below the Salado, which could affect fluid densities, flow rates, and flow directions.

Movement of fluids through abandoned boreholes could result in borehole-induced geochemical changes in the receiving units such as the Salado interbeds or Culebra, and thus alter radionuclide migration rates in these units.

Geochemical effects of borehole flow

Movement of fluids through abandoned boreholes could result in *borehole-induced geochemical changes* in the receiving units such as the Salado interbeds or Culebra. Such geochemical changes could alter radionuclide migration rates within the disposal system in the affected units if they occur sufficiently close to the edge of the controlled area, or if they occur as a result of flow through existing boreholes within the controlled area through their effects on colloid transport and sorption.

The contents of the waste disposal panels provide the main source of colloids in the disposal system. Thus, consistent with the discussion for FEP H24, colloid transport as a result of flow through existing and near-future abandoned boreholes has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

As discussed in H24, sorption within the Culebra is accounted for in performance assessment calculations. The sorption model used accounts for the effects of changes in sorption in the Culebra as a result of flow through existing and near-future abandoned boreholes.

Consistent with the screening discussion in H24, the effects of changes in sorption in the Dewey Lake inside the controlled area as a result of flow through existing and near-future abandoned boreholes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Sorption within other geological units of the disposal system has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

Future Human-Initiated EPs

The EPA provides criteria concerning analysis of the consequences of future drilling events in 40 CFR § 194.33(c). Consistent with these criteria, the DOE assumes that after drilling is complete the borehole is plugged according to current practice in the Delaware Basin (see CCA Section 6.4.7.2). Degradation of casing and/or plugs may result in connections for fluid flow and, potentially, contaminant transport between connected hydraulically conductive zones. The long-term consequences of boreholes drilled and abandoned in the future will primarily depend on the location of the borehole and the borehole casing and plugging methods used.

Geochemical effects of flow through abandoned boreholes

Movement of fluids through abandoned boreholes could result in *borehole-induced geochemical changes* in the receiving units, such as the Salado interbeds or Culebra. Such geochemical changes could alter radionuclide migration rates within the disposal system in the affected units through their effects on colloid transport and sorption.

The waste disposal panels provide the main source of colloids in the disposal system. Colloid transport within the Culebra as a result of long-term flow associated with future abandoned boreholes that intersect the waste disposal region are accounted for in performance assessment calculations, as described in CCA Sections 6.4.3.6 and 6.4.6.2.1. Consistent with the discussion in H24, colloid transport as a result of flow through future abandoned boreholes that do not intersect the waste disposal region has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The Culebra is the most transmissive unit in the disposal system and it is the most likely unit through which significant radionuclide transport could occur. Therefore, colloid transport in units other than the Culebra, as a result of flow through future abandoned boreholes, has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

As discussed in H24, sorption within the Culebra is accounted for in performance assessment calculations. The sorption model accounts for the effects of changes in sorption in the Culebra as a result of flow through future abandoned boreholes.

Consistent with the screening discussion in H24, the effects of changes in sorption in the Dewey Lake within the controlled area as a result of flow through future abandoned boreholes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Sorption within other geological units of the disposal system has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

EPA FEP Number: **H37**
FEP Title: **Changes in Groundwater Flow due to Mining**

SCR Section Number: **SCR.3.3.2**
Screening Decision: **UP (HCN)**
DP (Future)

Summary:

Changes in groundwater flow due to historical, current, near-future, and future mining are included in PA calculations of groundwater flow and transport through the Culebra. The FEP description and screening argument have been modified slightly to reflect recent activities, but the screening decision is unchanged.

Existing Italicized Text from SCR

Changes in groundwater flow due to historical, current, near-future, and future potash mining are accounted for in performance assessment calculations

FEP Text

Excavation activities may result in hydrological disturbances of the disposal system. Subsidence associated with excavations may affect groundwater flow patterns through increased hydraulic conductivity within and between units. Fluid flow associated with excavation activities may also result in changes in brine density and geochemistry in the disposal system.

Historical, Current, and Near-Future Human-Initiated EPs

As discussed in CCA Appendix SCR Section SCR.3.2.2, potash mining is the only excavation activity currently taking place in the vicinity of the WIPP that could affect hydrogeological or geochemical conditions in the disposal system. Potash is mined in the region east of Carlsbad and up to 3.1 miles (5 kilometers) from the boundaries of the controlled area. Mining of the McNutt in the Salado is expected to continue in the vicinity of the WIPP (see CCA Section 2.3.1.1): the DOE assumes that all economically recoverable potash in the vicinity of the WIPP (outside the controlled area) will be extracted in the near future.

Hydrogeological effects of mining

Potash mining in the Delaware Basin typically involves constructing vertical shafts to the elevation of the ore zone and then extracting the minerals in an excavation that follows the trend of the ore body. Potash has been extracted using conventional room and pillar mining, secondary mining where pillars are removed, and modified long-wall mining methods. Mining techniques used include drilling and blasting (used for mining langbeinite) and continuous mining (commonly used for mining sylvite). The DOE

(Westinghouse 1994, pp. 2-17 to 2-19) reported investigations of subsidence associated with potash mining operations located near the WIPP. The reported maximum total subsidence at potash mines is about 5 feet (1.5 meters), representing up to 66 percent of initial excavation height, with an observed angle of draw from the vertical at the edge of the excavation of 58 degrees. The DOE (Westinghouse 1994 pp. 2-22 to 2-23) found no evidence that subsidence over local potash mines had caused fracturing sufficient to connect the mining horizon to water-bearing units or the surface. However, subsidence and fracturing associated with mining in the McNutt in the vicinity of the WIPP may allow increased recharge to the Rustler units and affect the lateral hydraulic conductivity of overlying units, such as the Culebra, which could influence the direction and magnitude of fluid flow within the disposal system. Such *changes in groundwater flow due to mining* are accounted for in calculations of undisturbed performance of the disposal system. The effects of any increased recharge that may be occurring are in effect included by using heads measured in 2000 (which should reflect that recharge) to calibrate Culebra transmissivity fields and calculate transport through those fields (Beauheim 2002). Changes (increases) in Culebra transmissivity are incorporated directly in the modeling of flow and transport in the Culebra (see CCA Section 6.4.6.2.3).

Potash mining, and the associated processing outside the controlled area, have changed fluid densities within the Culebra, as demonstrated by the areas of higher densities around boreholes WIPP-27 and WIPP-29 (Davies 1989, p. 43). Transient groundwater flow calculations (Davies 1989, pp. 77 - 81) show that brine density variations to the west of the WIPP site caused by historical and current potash processing operations will not persist because the rate of groundwater flow in this area is fast enough to flush the high density groundwaters to the Pecos River. These calculations also show that accounting for the existing brine density variations in the region east of the WIPP site, where hydraulic conductivities are low, would have little effect on the direction or rate of groundwater flow. Therefore, changes in fluid densities from historical and current human-initiated EPs have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

The distribution of existing leases and potash grades suggests that near-future mining will take place to the north, west, and south of the controlled area (see CCA Appendix DEL). A localized increase in fluid density in the Culebra, in the mined region or elsewhere outside the controlled area, would rotate the flow vector towards the downdip direction (towards the east). A comparison of the relative magnitudes of the pressure gradient and the density gradient (based on an analysis identical to that presented for fluid leakage to the Culebra through boreholes) shows that the density effect is of low consequence to the performance of the disposal system.

Geochemical effects of mining—see H38

Future Human-Initiated EPs

Consistent with 40 CFR § 194.32(b), consideration of future mining may be limited to potash mining within the disposal system (see CCA Section 3.3.2). Within the controlled area, the McNutt provides the only potash of appropriate quality. The extent of possible future potash mining within the controlled area is discussed in CCA Section 2.3.1.1. Criteria concerning the consequence modeling of future mining are provided in 40 CFR § 194.32(b): the effects of future mining may be limited to changes in the hydraulic conductivity of the hydrogeologic units of the disposal system. Thus, consistent with 40 CFR § 194.32(b), *changes in groundwater flow due to mining* within the controlled area are accounted for in calculations of the disturbed performance of the disposal system (see CCA Section 6.4.6.2.3).

EPA FEP Number: H38
FEP Title: **Changes in Geochemistry Due to Mining**

SCR Section Number: SCR.3.3.2
Screening Decision: SO-C (HCN)
SO-R (Future)

Summary:

The only natural resource being mined underground currently near WIPP is potash in the McNutt, and it is the only mineral considered for future mining. Potash mining is also the only excavation activity currently taking place in the vicinity of the WIPP that could affect hydrogeological or geochemical conditions in the disposal system. It appears unlikely that underground mining will impact the site geochemistry during the time of passive institutional controls, and a conclusion of no near-term consequence is screened from future events as per 40 CFR § 194.25. Changes have been made to the screening argument. However, the screening decision remains the same.

Italicized text

Changes in geochemistry due to historical, current, and near-future potash mining have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Changes in geochemistry due to future mining have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

Fluid flow associated with excavation activities may also result in changes in brine density and geochemistry in the disposal system.

Historical, Current, and Near-Future Human-Initiated EPs

As discussed in CCA Section SCR.3.2.2, potash mining is the only excavation activity currently taking place in the vicinity of the WIPP that could affect hydrogeological or geochemical conditions in the disposal system. Potash is mined in the region east of Carlsbad and up to 1.5 miles (5 kilometers) from the boundaries of the controlled area. Mining of the McNutt in the Salado is expected to continue in the vicinity of the WIPP (see CCA Section 2.3.1.1): the DOE assumes that all economically recoverable potash in the vicinity of the WIPP (outside the controlled area) will be extracted in the near future.

Geochemical effects of mining

Fluid flow associated with excavation activities may result in geochemical disturbances of the disposal system. Some waters from the Culebra reflect the influence of current potash mining, having elevated potassium to sodium ratios. However, potash mining has had no significant effect on the geochemical characteristics of the disposal system. Solution mining, which involves the injection of freshwater to dissolve the ore body, can be used for extracting sylvite. The impact on the WIPP of neighboring potash mines was examined in greater detail by D'Appolonia in 1982 (D'Appolonia 1982). D'Appolonia noted that attempts to solution mine sylvite in the Delaware Basin failed due to low ore grade, thinness of the ore beds, and problems with heating and pumping injection water. See discussion for potash mining FEP H13. Thus, changes in geochemistry due to mining (historical, current, and near-future) have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs

Consistent with 40 CFR § 194.32(b), consideration of future mining may be limited to potash mining within the disposal system (see CCA Section 3.3.2). Within the controlled area, the McNutt provides the only potash of appropriate quality. The extent of possible future potash mining within the controlled area is discussed in Section 2.3.1.1. Criteria concerning the consequence modeling of future mining are provided in 40 CFR § 194.32(b): the effects of future mining may be limited to changes in the hydraulic conductivity of the hydrogeologic units of the disposal system. Thus, consistent with 40 CFR § 194.32(b), changes in groundwater flow due to mining within the controlled area are accounted for in calculations of the disturbed performance of the disposal system (see CCA Section 6.4.6.2.3). Other potential effects, such as changes in geochemistry due to mining, have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: H39
FEPs Title: Changes in Groundwater Flow due to Explosions

SCR Section Number: SCR.3.3.3
Screening Decision: SO-C (HCN)
SO-R (Future)

Summary:

The original description and screening argument remains valid. Historical, current, and near-future effects on groundwater flow due to explosions have been screened out on the basis of low consequence. The original regulatory screening argument for future explosions was based on 40 CFR § 194.32(a). The EPA's criteria relating to future human activities in 40 CFR § 194.32(a), that limit the scope of consideration of future human actions in performance assessments to mining and drilling, have not been modified. No changes have been made to the FEP description, screening argument, or screening decision.

Italicized Text

Changes in groundwater flow due to historical explosions have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Changes in groundwater flow due to future explosions have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

This section discusses the potential hydrological disturbances of the disposal system that may occur as a result of explosions.

Historical, Current, and Near-Future Human-Initiated EPs

The small-scale explosions that have been used in the Delaware Basin to fracture oil- and natural-gas-bearing units to enhance resource recovery have been too deep to have disturbed the hydrology of the disposal system (see FEP H19).

Also, as discussed in FEP H20, the Delaware Basin has been used for an isolated nuclear test (Project Gnome), approximately 8 miles (13 kilometers) southwest of the WIPP waste disposal region. An induced zone of increased permeability was observed to extend 150 feet (46 meters) laterally from the point of the explosion. The increase in permeability was primarily associated with motions and separations along bedding planes, the major pre-existing weaknesses in the rock. This region of increased permeability is too far from the WIPP site to have had a significant effect on the hydrological characteristics of the disposal system. Thus, changes in groundwater flow due to explosions in the past have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs

The criterion in 40 CFR § 194.32(a), relating to the scope of performance assessments, limits the consideration of future human actions to mining and drilling. Also, consistent with 40 CFR § 194.33(d), performance assessments need not analyze the effects of techniques used for resource recovery subsequent to the drilling of a future borehole. Therefore, *changes in groundwater flow due to explosions* in the future have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: **H40**
FEP Title: **Land Use Changes**

SCR Section Number: **SCR.3.4.1**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

The Delaware Basin monitoring program monitors land use activities in the WIPP vicinity. This program has not identified new planned uses for land in the vicinity of the WIPP (DOE 2002). Criteria relating to future human activities in 40 CFR § 194.32(a) limit the scope of consideration of future human actions in performance assessments to mining and drilling. Consistent with the future state assumption at 40 CFR § 194.25, *land use changes* in the vicinity of the WIPP have been eliminated from performance assessment calculations on regulatory grounds.

Italicized Text

Land use changes have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

This section discusses surface activities that could affect the geomorphological characteristics of the disposal system and result in changes in infiltration and recharge conditions. The potential effects of water use and control on disposal system performance are discussed in FEPs H42 through H46.

Historical, Current, and Near-Future Human-Initiated Eps

Surface activities that take place at present in the vicinity of the WIPP site include those associated with potash mining, oil and gas reservoir development, water extraction, and grazing. Additionally, a number of archeological investigations have taken place within the controlled area that were aimed at protecting and preserving cultural resources. Elsewhere in the Delaware Basin, sand, gravel, and caliche are produced through surface quarrying. The only surface activity that has the potential to affect the disposal system is potash tailings and effluent disposal. Potash tailings ponds may act as sources of focused recharge to the Dewey Lake and Rustler units.

Three potash tailings piles/ponds are in operation that might be influencing groundwater flow at the WIPP site. These are the Mississippi Potash Inc. (MPI) East tailings pile, approximately six miles due north of the WIPP, the MPI West tailings pile in the northwest arm of Nash Draw, and the IMC Kalium tailings pile, approximately six miles due west of the WIPP in Nash Draw. These tailings piles have been in operation for decades—disposal at the MPI East site, the youngest of the piles, began in 1965. Brine disposal at these locations affects Rustler groundwaters in Nash Draw, as shown by the hydrochemical facies D waters described by Siegel et al. (1991, p. 2-61). Brine disposal also affects heads in Nash Draw, and these head effects likely propagate to the WIPP site as well. These effects, however, predate water-level monitoring for the WIPP and have been implicitly included when defining boundary heads for Culebra flow models. The Culebra transmissivity fields developed for the CRA used water levels measured in 2000 to define model boundary conditions. Thus, the effects of brine disposal at the tailings piles can be considered to be included in PA calculations. These effects are expected to continue in the near future.

The Delaware Basin monitoring program monitors land use activities in the WIPP vicinity. This program has not identified new planned uses for land in the vicinity of the WIPP (DOE 2002). Therefore, consistent with the criteria in 40 CFR § 194.32(c) and 40 CFR § 194.54(b), *land use changes* in the near future in the vicinity of the WIPP have been eliminated from performance assessment calculations on regulatory grounds.

Future Human-Initiated EPs

The criterion in 40 CFR § 194.25(a), concerned with predictions of the future states of society, requires that compliance assessments and performance assessments "shall assume that characteristics of the future remain what they are at the time the compliance application is prepared, provided that such characteristics are not related to hydrogeologic, geologic or climatic conditions." Therefore, no future *land use changes* need be considered in the vicinity of the WIPP, and they have been eliminated from performance assessment calculations on regulatory grounds.

Future *surface disruptions* not affecting hydrogeologic or geologic conditions have been eliminated from performance assessment calculations on regulatory grounds. Future tailings ponds, if situated in Nash Draw, are expected to change Culebra (and Magenta) heads, similar to existing ones. Future tailings ponds outside of Nash Draw would not be expected to alter Culebra heads because leakage from the ponds would not be able to propagate through the low-permeability lower Dewey Lake clastics and Rustler anhydrites overlying the Culebra during the 100 years or less that such a pond might be in operation. Because performance assessment calculations already include the present-day effects of tailings ponds in Nash Draw on heads, as well as the effects of future potash mining on the permeability of the Culebra (which has much greater potential to alter flow than changes in head), future potash tailings ponds may be screened out on the basis of low consequence.

EPA FEP Number: **H41**
FEP Title: **Surface Disruptions**

SCR Section Number: **SCR.3.4.1**
Screening Decision: **UP (HCN)**
SO-R (Future)

Summary:

The screening argument for Surface Disruptions has changed. Per the original screening decision, surface activities in the vicinity of the WIPP site have disrupted the surface, but most surface activities have no potential to affect the disposal system and are, therefore, screened out on the basis of low consequence. However, the effects of the activity capable of altering the disposal system (disposal of potash effluent) are included in our modeling of current conditions (i.e., heads) at and around the site. Therefore, the screening decision has been changed from SO-C to UP for HCN. There are no planned changes to land use in the vicinity of the WIPP in the near future, and future events that might disrupt the surface at the WIPP site are screened out on the basis of regulatory criteria.

Italicized Text

The effects of historical, current, and near-future surface disruptions have been screened out on the basis of low consequence if they have no potential to affect the disposal system, or are implicitly included in performance assessment calculations when they might affect the disposal system. The effects of future surface disruptions have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

This section discusses surface activities that could affect the geomorphological characteristics of the disposal system and result in changes in infiltration and recharge conditions. The potential effects of water use and control on disposal system performance are discussed in FEPs H42 through H46.

Historical, Current, and Near-Future Human-Initiated EPs

Surface activities that take place at present in the vicinity of the WIPP site include those associated with potash mining, oil and gas reservoir development, water extraction, and grazing. Additionally, a number of archeological investigations have taken place within the controlled area that were aimed at protecting and preserving cultural resources. Elsewhere in the Delaware Basin, sand, gravel, and caliche are produced through surface quarrying. The only surface activity that has the potential to affect the disposal system is potash tailings and effluent disposal. Potash tailings ponds may act as sources of focused recharge to the Dewey Lake and Rustler units.

Three potash tailings piles/ponds are in operation that might be influencing groundwater flow at the WIPP site. These are the Mississippi Potash Inc. (MPI) East tailings pile, approximately six miles due north of the WIPP, the MPI West tailings pile in the northwest arm of Nash Draw, and the IMC Kalium tailings pile, approximately six miles due west of the WIPP in Nash Draw. These tailings piles have been in operation for decades—disposal at the MPI East site, the youngest of the piles, began in 1965. Brine disposal at these locations affects Rustler groundwaters in Nash Draw, as shown by the hydrochemical facies D waters described by Siegel et al. (1991, p. 2-61). Brine disposal also affects heads in Nash Draw, and these head effects likely propagate to the WIPP site as well. These effects, however, predate water-level monitoring for the WIPP and have been implicitly included when defining boundary heads for Culebra flow models. The Culebra transmissivity fields developed for the CRA used water levels measured in 2000 to define model boundary conditions. Thus, the effects of brine disposal at the tailings piles can be considered to be included in PA calculations. These effects are expected to continue in the near future.

The Delaware Basin monitoring program monitors land use activities in the WIPP vicinity. This program has not identified new planned uses for land in the vicinity of the WIPP (DOE 2002). Therefore, consistent with the criteria in 40 CFR § 194.32(c) and 40 CFR § 194.54(b), *land use changes* in the near future in the vicinity of the WIPP have been eliminated from performance assessment calculations on regulatory grounds.

Future Human-Initiated EPs

The criterion in 40 CFR § 194.25(a), concerned with predictions of the future states of society, requires that compliance assessments and performance assessments "shall assume that characteristics of the future remain what they are at the time the compliance application is prepared, provided that such characteristics are not related to hydrogeologic, geologic or climatic conditions." Therefore, no future *land use changes* need be considered in the vicinity of the WIPP, and they have been eliminated from performance assessment calculations on regulatory grounds.

Future *surface disruptions* not affecting hydrogeologic or geologic conditions have been eliminated from performance assessment calculations on regulatory grounds. Future tailings ponds, if situated in Nash Draw, are expected to change Culebra (and Magenta) heads, similar to existing ones. Future tailings ponds outside of Nash Draw would not be expected to alter Culebra heads because leakage from the ponds would not be able to propagate through the low-permeability lower Dewey Lake clastics and Rustler anhydrites overlying the Culebra during the 100 years or less that such a pond might be in operation. Because performance assessment calculations already include the present-day effects of tailings ponds in Nash Draw on heads, as well as the effects of future potash mining on the permeability of the Culebra (which has much greater potential to alter flow than changes in head), future potash tailings ponds may be screened out on the basis of low consequence.

EPA FEP Number(s): **H42, H43 & H44**
FEP Title(s): **Damming of Streams and Rivers (H42)**
Reservoirs (H43)
Irrigation (H44)

SCR Section Number: **SCR.3.5.1**
Screening Decision: **SO-C (HCN)**
SO-R (Future)

Summary:

The existing screening argument and description for Reservoirs, Damming of Streams and Rivers and Irrigation remain valid. The EPA's criteria relating to future human activities that limit the scope for consideration of future human actions in performance assessments have not changed. Changes have been made to the FEP text to remove reference to other FEP descriptions, screening arguments and screening decisions.

Italicized Text

The effects of historical, current, and near-future damming of streams and rivers, reservoirs and irrigation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Future damming of streams and rivers, reservoirs and irrigation have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

Irrigation and damming, as well as other forms of water control and use, could lead to localized changes in recharge, possibly leading to increased heads locally, thereby affecting flow directions and velocities in the Rustler and Dewey Lake.

Historical, Current, and Near-Future Human-Initiated EPs

In the WIPP area, two topographically low features, the Pecos River and Nash Draw, are sufficiently large to warrant consideration for damming. Dams and reservoirs already exist along the Pecos River. However, the Pecos River is far enough from the waste panels (12 miles [19 kilometers]) that the effects of *damming of streams and rivers* and *reservoirs* can be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Nash Draw is not currently dammed, and based on current hydrological and climatic conditions, there is no reason to believe it will be dammed in the near future.

Irrigation uses water from rivers, lakes, impoundments, and wells to supplement the rainfall in an area to grow crops. Irrigation in arid environments needs to be efficient and involves the spreading of a relatively thin layer of water for uptake by plants, so little water would be expected to infiltrate beyond the root zone. However, some water added to the surface may infiltrate and reach the water table, affecting groundwater flow patterns. Irrigation currently takes place on a small scale within the Delaware Basin but not in the vicinity of the WIPP, and the extent of irrigation is not expected to change in the near future. Such irrigation has no significant effect on the characteristics of the disposal system. Thus, the effects of irrigation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Future Human-Initiated EPs

The EPA has provided criteria relating to future human activities in 40 CFR § 194.32(a), that limit the scope of consideration of future human actions in performance assessments to mining and drilling. Therefore, the effects of future *damming of streams and rivers, reservoirs* and *irrigation* have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: **H45**
FEP Title: **Lake Usage**

SCR Section Number: **SCR.3.5.1**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

The original description and screening argument remains valid. The original regulatory screening argument was based on 40 CFR § 194.32(a). The EPA's criteria relating to future human activities in 40 CFR § 194.32(a), that limit the scope of consideration of future human actions in performance assessments to mining and drilling have not been modified. Changes have been made to the FEP text to remove reference to other FEP descriptions, screening arguments and screening decisions.

Italicized Text

The effects of lake usage have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

Irrigation and damming, as well as other forms of water control and use, could lead to localized changes in recharge, possibly leading to increased heads locally, thereby affecting flow directions and velocities in the Rustler and Dewey Lake. Surface activities, such as those associated with potash mining, could also affect soil and surface water chemistry. Note that the potential effects of geomorphological changes through land use are discussed in H40 and H41.

Historical, Current, and Near-Future Human-Initiated EPs

As discussed in CCA section 2.2.2, there are no major natural lakes or ponds within 5 miles (8 kilometers) of the site. To the northwest, west, and southwest, Red Lake, Lindsey Lake, and Laguna Grande de la Sal are more than 5 miles (8 kilometers) from the site, at elevations of 3,000 to 3,300 feet (914 to 1,006 meters). Laguna Gatuña, Laguna Tonto, Laguna Plata, and Laguna Toston are playas more than 10 miles (16 kilometers) north and are at elevations of 3,450 feet (1,050 meters) or higher. Waters from these lakes are of limited use. Therefore human activities associated with lakes have been screened out of performance assessment calculations based on regulatory grounds supported by 194.32(c) and 194.54(b).

Future Human-Initiated EPs

The EPA has provided criteria relating to future human activities in 40 CFR § 194.32(a), that limit the scope of consideration of future human actions in performance assessments to mining and drilling. Therefore, the effects of future *lake usage* have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: **H46**
FEP Title: **Altered Soil or Surface Water Chemistry by Human Activities**

SCR Section Number: **SCR.3.5.1**
Screening Decision: **SO-C (HCN)**
SO-R (Future)

Summary:

It is stated in the CCA that the effluent from potash mines and the runoff from oil fields alters soil or surface water chemistry. The disposal system design consists of multiple barriers, both natural and man-made, located in a geologic salt deposit, 2,150 feet (655.3 meters) below ground that help to isolate the repository from any effect that altered soil or surface water chemistry would exert on the performance of the disposal system. These barriers were selected because of their ability to permanently isolate the waste from the accessible environment as required to comply with subparts B and C of 40 CFR 191. As a part of the assurance requirements, 40 CFR §191.14 requires that barriers of different types be used to isolate the waste. The WIPP design uses both a geologic (natural) and engineered barriers for waste isolation as specified by these regulations. Thus, the performance of the disposal system will not be sensitive to the effect of potash mining effluent and runoff from oil fields because of a combination of natural and engineered barriers. Therefore, altered soil or surface water chemistry by human activities has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening argument remains valid.

The EPA has provided criteria relating to future human activities in 40 CFR § 194.32(a), that limit the scope of consideration of future human actions in performance assessments to mining and drilling. Therefore, the effects of altered soil or surface water chemistry by human activities have been eliminated from performance assessment calculations on regulatory grounds. These conclusions appear reasonable. The original description and screening arguments as presented remain valid. Editorial changes for clarity have been made, as well as separating the four FEPs into discrete arguments.

Italicized Text

The effects of historical, current, and near-future altered soil or surface water chemistry by human activities have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Future altered soil or surface water chemistry by human activities have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

Irrigation and damming, as well as other forms of water control and use, could lead to localized changes in recharge, possibly leading to increased heads locally, thereby affecting flow directions and velocities in the Rustler and Dewey Lake. Surface activities, such as those associated with potash mining, could also affect soil and surface water chemistry.

Historical, Current, and Near-Future Human-Initiated EPs

Potash mining effluent and runoff from oil fields have altered soil and surface water chemistry in the vicinity of the WIPP. However, the performance of the disposal will not be sensitive to soil and surface water chemistry. Therefore, *altered soil or surface water chemistry by human activities* has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The effects of effluent from potash processing on groundwater flow are discussed in H37.

Future Human-Initiated EPs

The EPA has provided criteria relating to future human activities in 40 CFR § 194.32(a), that limit the scope of consideration of future human actions in performance assessments to mining and drilling. Therefore, the effects of future *altered soil and surface water chemistry by human activities* have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: H47, H48 & H49
FEP Title: Greenhouse Gas Effects (H47)
Acid Rain (H48)
Damage to the Ozone (N49)

SCR Section Number: SCR.3.6.1
Screening Decision: SO-R (HCN)
SO-R (Future)

Summary:

The original descriptions and screening arguments remains valid. The original regulatory screening argument was based on 40 CFR § 194.25. The EPA's criteria relating to climate conditions and future states in 40 CFR § 194.25, that limit the scope of consideration of the future in performance assessments have not been modified. The anthropogenic effects in the future are to be assumed to remain as they are today. No changes have been made to the FEP descriptions, screening arguments or screening decisions. Discussions not pertaining to human activities or supportive to the FEP argument and screening decision have been removed from the original text.

Italicized Text

The effects of anthropogenic climate change (acid rain, greenhouse gas effects, and damage to the ozone layer) have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text Anthropogenic Climate Change

The effects of the current climate and natural climatic change are accounted for in performance assessment calculations, as discussed in CCA Section 6.4.9. However, human activities may also affect the future climate and thereby influence groundwater recharge in the WIPP region. The effects of anthropogenic climate change may be on a local to regional scale (*acid rain (H48)*) or on a regional to global scale (*greenhouse gas effects (H47)* and *damage to the ozone layer (H49)*). Of these anthropogenic effects, only the greenhouse gas effect could influence groundwater recharge in the WIPP region. However, consistent with the future states assumptions in 40 CFR § 194.25, compliance assessments and performance assessments need not consider indirect anthropogenic effects on disposal system performance. Therefore, the effects of anthropogenic climate change have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number(s): **H50, H51 & H52**
FEP Title(s): **Costal Water Use (H50)**
Sea Water Use (H51)
Estuarine Water (H52)

SCR Section Number: **SCR.3.7.1**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

The WIPP site is over 480 miles (800 kilometers) from the nearest seas. Hydrological conditions in the vicinity of the WIPP have not been affected by coastal water use. Consistent with the criteria in 40 CFR § 194.32(c) and 40 CFR § 194.54(b), consideration of historical, current, and near-future human activities is limited to those activities that have occurred or are expected to occur in the vicinity of the disposal system. The criteria provided in 40 CFR § 194.32(a) limits the scope of consideration of future human actions in performance assessments to mining and drilling. Therefore, the effects of a marine activity such as water use, historical, current, or in the future, has been eliminated from performance assessment calculations on regulatory grounds. This argument appears technically reasonable. The original FEP description and screening decision have not changed.

Italicized Text

Historical, current, near-future, and future coastal water use, seawater use, and estuarine water use have been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

This section discusses the potential for human-initiated EPs related to marine activities to affect infiltration and recharge conditions in the vicinity of the WIPP.

Historical, Current, and Near-Future Human-Initiated EPs

The WIPP site is more than 480 miles (800 kilometers) from the nearest seas, and hydrological conditions in the vicinity of the WIPP have not been affected by marine activities. Furthermore, consistent with the criteria in 40 CFR § 194.32(c) and 40 CFR § 194.54(b), consideration of historical, current, and near-future human activities is limited to those activities that have occurred or are expected to occur in the vicinity of the disposal system. Therefore, human-initiated EPs related to marine activities (such as *coastal water use (H50), seawater use (H51), and estuarine water use (H52)*) have been eliminated from performance assessment calculations on regulatory grounds.

Future Human-Initiated EPs

The EPA has provided criteria relating to future human activities in 40 CFR § 194.32(a) that limit the scope of consideration of future human actions in performance assessments to mining and drilling. Therefore, the effects of future marine activities (such as *coastal water use, seawater use,* and *estuarine water use)* have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number(s): H53, H54 & H55
FEP Title(s): Arable Farming (H53)
Ranching (H54)
Fish Farming (H55)

SCR Section Number: SCR.3.8.1
Screening Decision: SO-C (HCN)
SO-R (Future)

Summary:

The historical, current, and near-future effects of Arable Farming and Ranching have been eliminated from the performance assessment calculations on the basis of low consequence to the performance of the disposal system. The CCA states that although crop production has had some influence on the vegetation at the WIPP site this activity is unlikely to have affected subsurface hydrological or geochemical conditions. The climate, soil quality, and lack of suitable water sources all mitigate against agricultural development of the region in the near future. Future human initiated effects from arable farming and ranching have been eliminated from the performance assessment calculations based upon regulatory grounds. This screening evaluation is supported by the criteria outlined in 40 CFR §194.32(a) and (c) and §194.54 (b). The original description and screening argument remains valid. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

The effects of historical, current, and near-future ranching and arable farming have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The effects of changes in future ranching and arable farming practices have been eliminated from performance assessment calculations on regulatory grounds. Fish farming has been eliminated from performance assessment calculations on regulatory grounds.

FEP Text

Agricultural activities could affect infiltration and recharge conditions in the vicinity of the WIPP. Also, application of acids, oxidants, and nitrates during agricultural practice could alter groundwater geochemistry.

Historical, Current, and Near-Future Human-Initiated Eps

Grazing leases exist for all land sections immediately surrounding the WIPP and grazing occurs within the controlled area (see CCA Section 2.3.2.2). Although grazing and related crop production have had some control on the vegetation at the WIPP site, these activities are unlikely to have affected subsurface hydrological or geochemical conditions. The climate, soil quality, and lack of suitable water sources all mitigate against agricultural development of the region in the near future. Therefore, the effects of historical, current, and near-future *ranching* and *arable farming* have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Consistent with the criteria in 40 CFR § 194.32(c) and 40 CFR § 194.54(b), agricultural activities, such as *fish farming*, that have not taken place and are not expected to take place in the near future in the vicinity of the WIPP have been eliminated from performance assessment calculations on regulatory grounds.

Future Human-Initiated Eps

The EPA has provided criteria relating to future human activities in 40 CFR § 194.32(a), that limit the scope of consideration of future human activities in performance assessments to mining and drilling. Also, the criterion in 40 CFR § 194.25(a), concerned with predictions of the future states of society, requires that compliance assessments and performance assessments "shall assume that characteristics of the future remain what they are at the time the compliance application is prepared." Therefore, the effects of changes in future agricultural practices (such as *ranching, arable farming,* and *fish farming*) have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: **H56**
FEP Title: **Demographic Change and Urban Development**

SCR Section Number: **SCR.3.8.2**
Screening Decision: **SO-R (HCN)**
SO-R (Future)

Summary:

The DOE has stated that near-future and future demographic change and urban development have been eliminated from the performance assessment calculations based upon regulatory grounds. The original description and screening argument remain valid. The EPA's regulations concerning the future state assumptions have not been modified. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

Demographic change and urban development in the near future and in the future have been eliminated from performance assessment calculations on regulatory grounds

FEP Text

Social and technological changes in the future could result in the development of new communities and new activities in the vicinity of the WIPP that could have an impact on the performance of the disposal system.

Demography in the WIPP vicinity is discussed in CCA Section 2.3.2.1. The community nearest to the WIPP site is the town of Loving, 18 miles (29 kilometers) west-southwest of the site center. There are no existing plans for urban developments in the vicinity of the WIPP in the near future. Furthermore, the criterion in 40 CFR § 194.25(a), concerned with predictions of the future states of society, requires that compliance assessments and performance assessments "shall assume that characteristics of the future remain what they are at the time the compliance application is prepared." Therefore, *demographic change and urban development* in the vicinity of the WIPP and technological developments have been eliminated from performance assessment calculations on regulatory grounds.

EPA FEP Number: H57
FEP Title: Loss of Records

SCR Section Number: SCR.3.8.2
Screening Decision: NA (HCN)
DP (Future)

Summary:

The existing screening argument and description for Loss of Records remain valid. The FEP has been updated to include reference to the EPA's removal of credit for Passive Institutional Controls, which occurred during the original WIPP certification. Changes have been made to the FEP text to remove reference to other FEP descriptions, screening arguments and screening decisions.

Italicized Text

Loss of records in the future is accounted for in performance assessment calculations.

FEP Text

Human activities will be prevented from occurring within the controlled area in the near future. However, performance assessments must consider the potential effects of human activities that might take place within the controlled area at a time when institutional controls cannot be assumed to eliminate completely the possibility of human intrusion. Consistent with 40 CFR § 194.41(b), the DOE assumes no credit for active institutional controls for more than 100 years after disposal. Also, consistent with 40 CFR § 194.43(c), the DOE originally assumed in the CCA that passive institutional controls do not eliminate the likelihood of future human intrusion entirely. The provisions at 40 CFR 194.43(c) allow credit for passive institutional controls by reducing the likelihood of human intrusions for several hundred years. In the CCA, the DOE took credit for these controls that include records retention by reducing the probability of intrusion for the first 600 years after active controls cease. EPA disallowed this credit during the original certification (EPA 1998a). DOE no longer takes credit for passive institutional controls in PA, effectively assuming that all public records and archives relating to the repository are lost 100 years after closure. Therefore, DOE continues to include *the loss of records* FEP within PA and does not include credit for passive institutional controls.

EPA FEP Number **H58**
FEP Title: **Solution Mining for Potash**

SCR Section Number **SCR.3.2.2**
Screening Decision: **SO-R (HCN)**
SO-R (future)

Summary:

In the CCA, *solution mining of potash* was not identified as a separate FEP, although all components of the solution mining process were accounted for in FEPs screening, albeit in a piecemeal fashion. For example, the drilling of the borehole necessary for solution injection or effluent recovery is addressed in FEP H8, *Drilling For Other Resources,* mainly because the physical and mechanical effects of the drilling activity do not vary based on the type of resource being sought, nor on the final intended use of the borehole; e.g., disposal well, injection well, solution mining, or oil and gas extraction. The removal of an ore as a result of solution mining is ultimately the same as if conventional mining processes had removed the ore. Potash mining using conventional methods is addressed in FEP H13, *Conventional Underground Potash Mining*. The ultimate effect of such ore body removal is believed to be the eventual subsidence of the overlying units and the associated impact upon hydraulic conductivity. This has been demonstrated to have a negligible effect on performance of the WIPP (DOE 1996a), and is in fact accounted for in PA by EPA's requisite treatment of potash mining above the waste area.

Although the original FEP baseline considered different types of mineral and petroleum resource exploration/exploitation, it did not initially consider the possibility of brine mining (solution mining), even though this has occurred in the Delaware Basin. EPA noted this oversight in their March 1997 letter requesting additional information regarding the CCA (EPA 1997). In response to this request, the DOE submitted two memos (Hicks 1997a, b) that addressed both solution mining for potash and solution mining for brine. In EPA's TSD for §194.32, "Scope of Performance Assessments," EPA noted that these memos adequately supported the screening decisions presented in the CCA.

For the CRA, solution mining has been explicitly represented within the FEPs baseline through the additions of FEP H58, *Solution Mining for Potash* and FEP H59, *Solution Mining for Other Resources.* The reassessment of these EPs confirms that no significant developments have occurred since the CCA, and the arguments used by Hicks remain valid. The creation of these FEPs will aid in clarifying and separating the activities related to solution mining from conventional mining for potash as addressed in FEP H13.

Italicized Text

Historical, current, near-future, and future solution mining for potash has been eliminated from performance assessment calculations on regulatory grounds. Historical, current, near-future, and future solution mining for other resources have been eliminated *from performance assessment calculations on the basis of low consequence to the performance of the disposal system.*

FEP Text

Currently, no solution mining for potash occurs in the Carlsbad Potash District (CPD). The prospect of using solution-mining techniques for extracting potash has been identified in the region, but has not been implemented. A pilot plant for secondary solution mining of sylvite in the Clayton Basin, just north of the Delaware Basin was permitted, and concept planning took place during the mid-nineteen nineties and was noted by the EPA in their Response to Comments to the CCA (EPA 1998b). Five years later, this pilot project has yet to begin. Therefore, it is premature to consider this an operational solution mining activity. More importantly, the proposed site is outside the Delaware Basin.

The potash reserves evaluated by Griswold and Griswold (1999) and NMBMMR (1995) at WIPP are of economic importance in only two ore zones; the 4th and the 10th and contain two minerals of economic importance, langbeinite and sylvite. The ore in the 10th ore zone is primarily sylvite with some langbeinite and the ore in the 4th zone is langbeinite with some sylvite. Langbeinite falls between gypsum and polyhalite in solubility and dissolves at a rate 1000 times slower than sylvite (Heyn 1997). Halite, the predominate gangue mineral present, is much more soluble than the langbeinite. Due to the insolubility of langbeinite, sylvite is the only ore that could be mined using a solution mining process. Mining for sylvite by solutioning would cause the langbeinite to be lost because conventional mining could not be done in conjunction with a solution mining process.

Communiqués with IMC Global (Heyn 1997 & Prichard 2003), indicate that rock temperature is critical to the success of a solution-mining endeavor. IMC Global's solution mines in Michigan and Saskatchewan are at depths around 3000 feet or greater, at which rock temperatures are higher. The ore zones at WIPP are shallow, at depths of 1500 to 1800 feet, with fairly cool rock temperatures. David Prichard of IMC Global states that solution mining is energy intensive and the cool temperature of the rock would add to the energy costs. In addition, variable concentrations of confounding minerals (such as kainite and leonite) will cause problems with the brine chemistry.

Typically, solution mining is used for potash:

- when deposits are at depths in excess of 3000 feet and rock temperatures are high or are geologically too complex to mine profitably using conventional underground mining techniques,
- to recover the potash pillars at the end of a mine's life,
- or when a mine is unintentionally flooded with waters from underlying or overlying rock strata and conventional mining is no longer feasible.

Douglas W. Heyn (chief chemist of IMC Kalium) provided written testimony to EPA related to the Agency's rulemaking activities on the DOE Compliance Certification

Application for WIPP. Heyn concluded that "the rational choice for extracting WIPP potash ore reserves would be by conventional room and pillar mechanical means" (Heyn 1997). It is the opinion of IMC Global that no company will ever attempt solution mining of the ores in or near the WIPP (Heyn 1997 & Prichard 2003).

The impact on the WIPP of neighboring potash mines was examined in detail by D'Appolonia in 1982 (D'Appolonia 1982) and evaluated the possible effects of solution mining for potash or other evaporite minerals. According to D'Appolonia, and in agreement with Heyn (1997) of IMC Global Inc, solution mining of langbeinite is not technically feasible because the ore is less soluble than the surrounding evaporite minerals. Solution mining of sylvite was unsuccessfully attempted in the past by the Potash Company of America and Continental Potash, both ore bodies currently owned by Mississippi Chemical. Failure of solution mining was attributed to low ore grade, thinness of the ore beds, and problems with heating and pumping injection water. Unavailability of water in the area would also impede implementation of this technique. For these reasons, solution mining is not currently used in the Carlsbad Potash District.

Serious technical and economic obstacles exist that render solution mining for potash very unlikely in the vicinity of the WIPP. Expectedly, no operational example of this technology exists in the CPD; that is, solution mining for potash in not considered a current practice in the area. For this reason, consideration of solution mining on the disposal system in the future may be excluded on regulatory grounds. For example, the EPA stated in their Response to Comments, Section 8, Issue GG (EPA 1998b):

> "...However, the Agency emphasizes that, in accordance with the WIPP compliance criteria, solution mining does not need to be included in the PA. As previously discussed, potash solution mining is not an ongoing activity in the Delaware Basin. Section 194.32(b) of the rule limits assessment of mining effects to excavation mining. Thus the solution mining scenarios proposed are excluded on regulatory grounds after repository closure. Prior to or soon after disposal, solution mining is an activity that could be considered under Section 194.32(c). However, DOE found that potash solution mining is not an ongoing activity in the Delaware Basin; and one pilot project examining solution mining in the Basin is not substantive evidence that such mining is expected to occur in the near future. (Even if mining were assumed to occur in the near future, the proposed scenarios would not be possible because, even though solution mining might occur, there would be no intruding borehole to provide a pathway into the repository: active institutional controls would preclude such drilling during the first 100 years after disposal.) Furthermore, Section 194.33(d) states that PA need not analyze the effects of techniques used for resource recovery (e.g. solution mining) after a borehole is drilled in the future."

No new data or information has become available that compromise, reduce, or invalidate the project's position on whether solution mining for potash should be included in the performance assessment calculations. Therefore, conventional mining activities will continue to be incorporated into the WIPP performance assessment as directed by the EPA Compliance Application Guidance (CAG) (EPA 1996c). It remains to be seen if a viable potash solution mining project (or others like it) ever progress beyond the planning phase. Construction of a facility for solution mining is an expensive undertaking, and its use as a final recovery method implies that marginal (residual) ore quantities are available. Because the Carlsbad Potash District mines are in their mature stages (declining) of production, the significant financing required for a solution mining facility may not become available. Nonetheless, at the time of this FEP reassessment, this technology is not being employed. Therefore, a screening based on the future states assumption at 40 CFR §194.25 (a) is appropriate for this mining technique. Further, the proposed site is outside the Delaware Basin making it outside the scope of consideration.

EPA FEP Number **H59**
FEP Title: **Solution Mining for Other Resources**

SCR Section Number **SCR.3.2.2 Excavation Activities**
Screening Decision: **SO-C (HCN)**
SO-C (future)

Summary:

In the CCA, *solution mining* was not identified as a separate FEP, although different components of the solution mining process were accounted for in FEPs screening, albeit in a piecemeal fashion. For example, the *drilling* of the borehole necessary is addressed in FEP H8, *Drilling For Other Resources,* mainly because the physical and mechanical effects of the drilling activity do not vary based on the type of resource being sought, nor on the final intended use of the borehole; e.g., disposal well, injection well, solution mining, or oil and gas extraction. The *removal* of an ore body as a result of solution mining is ultimately the same as if conventional mining processes had removed the ore. Ore removal is addressed in FEP H13, *Conventional Underground Potash Mining* and has been demonstrated to have a negligible effect on performance (DOE 1996a).

Although the original FEP baseline considered different types of mineral and petroleum resource exploration/exploitation, it did not initially consider the possibility of brine mining (solution mining), even though this has occurred in the Delaware Basin. EPA noted this oversight in their March 1997 letter requesting additional information regarding the CCA (EPA 1997). In response to this request, the DOE submitted two memos (Hicks 1997a,b) that addressed both solution mining for potash and solution mining for brine. In EPA's TSD for §194.32, "Scope of Performance Assessments," EPA noted that these memos adequately supported the screening decisions presented in the CCA.

For the CRA, solution mining has been explicitly represented within the FEPs baseline through the additions of FEP H58, *Solution Mining for Potash* and FEP H59, *Solution Mining for Other Resources.* The reassessment of these EPs confirms that no significant developments or changes in the implementation of the technology have occurred since the CCA, therefore the arguments used by Hicks remain valid. The creation of these FEPs will aid in clarifying and separating the activities related to solution mining from conventional underground mining for potash as addressed in FEP H13.

Italicized Text

Historical, current, near-future, and future solution mining for potash has been eliminated from performance assessment calculations on regulatory grounds. Historical, current, near-future, and future solution mining for other resources have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Brine wells (solution mining for brine) exist within the Delaware Basin, although none within the vicinity of the WIPP. Sulfur extraction using the Frasch process began in 1969 and continued for three decades at the Culberson County Rustler Springs mine near Orla, Texas. Solution mining for the purposes of creating a storage cavity has not occurred within the New Mexico portion of the Delaware Basin.

Solution Mining for Brine

Oil and gas reserves in the Delaware Basin are located in structures within the Delaware Mountain Group and lower stratigraphic units. Boreholes drilled to reach these horizons pass through the Salado and Castile Formations that comprise thick halite and other evaporite units. To avoid dissolution of the halite units during drilling and prior to casing of the borehole, the fluid used for lubrication, rotating the drilling-bit cutters, and transporting cuttings (drilling mud) must be saturated with respect to halite. Most oil- and gas-field drilling operations in the Delaware Basin therefore use saturated brine (10 to 10.5 pounds per gallon) as a drilling fluid until reaching the Bell Canyon Formation, where intermediate casing is set.

One method of providing saturated brine for drilling operations is solution mining, whereby fresh water is pumped into the Salado Formation, allowed to reach saturation with respect to halite and then recovered. This manufactured brine is then transported to the drilling site by water tanker.

Two principal techniques are used for solution mining; single-borehole operations, and doublet or two-borehole operations.

In single-borehole operations, a borehole is drilled into the upper part of the halite unit. After casing and cementing this portion of the borehole, the borehole is extended, uncased into the halite formation. An inner pipe is installed from the surface to the base of this uncased portion of the borehole. During operation, fresh water is pumped down the annulus of the borehole. This dissolves halite over the uncased portion of the borehole, and saturated brine is forced up the inner tube to the surface.

In doublet operations, a pair of boreholes are drilled, cased and cemented into the upper part of the halite unit. The base of the production well is set some feet below the base of the injection well. In the absence of natural fractures or other connections between the boreholes, hydrofracturing is used to induce fractures around the injection well. During operation, fresh water is pumped down the injection well. This initially dissolves halite from the walls of the fractures and the resulting brine is then pumped from the production well. After a period of operation a cavity develops between the boreholes as the halite between fractures is removed. Because of its lower density, fresh water injected into this cavity will rise to the top and dissolve halite from the roof of the cavity. As the brine density increases it sinks within the cavern and saturated brine is extracted from the production well.

Current brine wells within the vicinity of WIPP

Brine wells are classified as Class II injection wells. In the Delaware Basin, the process includes injecting fresh water into a salt formation to create a saturated brine solution which is then extracted and utilized as a drilling agent. These wells are tracked by the Delaware Basin Drilling Surveillance Program on a continuing basis. Supplemental information provided to the EPA in 1997 showed 11 brine wells in the Delaware Basin. Since that time, additional information has shown that there are 15 brine wells within the Delaware basin, of which four are plugged and abandoned. This results in 11 currently active brine wells. Table H59 provides information on these wells.

Table H59
Delaware Basin Brine Well Status

County	Location	API No.	Well Name and No.	Operator	Status
Eddy	22S-26E-36	3001521842	City of Carlsbad #WS-1	Key Energy Services	Brine Well
Eddy	22S-27E-03	3001520331	Tracy #3	Ray Westall	Plugged Brine Well
Eddy	22S-27E-17	3001522574	Eugenie #WS-1	I & W Inc	Brine Well
Eddy	22S-27E-17	3001523031	Eugenie #WS-2	I & W Inc	Plugged Brine Well
Loving	Blk 29-03	4230110142	Lineberry Brine Station #1	Chance Properties	Brine Well
Loving	Blk 01-82	4230130680	Chapman Ford #BR1	Herricks & Son Co.	Plugged Brine Well
Loving	Blk 33-80	4230180318	Mentone Brine Station #1D	Basic Energy Services	Brine Well
Loving	Blk 29-28	4230180319	East Mentone Brine Station #1	Permian Brine Sales, Inc.	Plugged Brine Well
Loving	Blk 01-83	4230180320	North Mentone #1	Chance Properties	Brine Well
Reeves	Blk 56-30	4238900408	Orla Brine Station #1D	Mesquite SWD Inc.	Brine Well
Reeves	Blk 04-08	4238920100	North Pecos Brine Station #WD-1	Chance Properties	Brine Well
Reeves	Blk 07-21	4238980476	Coyanosa Brine Station #1	Chance Properties	Brine Well
Ward	Blk 17-20	4247531742	Pyote Brine Station #WD-1	Chance Properties	Brine Well
Ward	Blk 01-13	4247534514	Quito West Unit #207	Seaboard Oil Co.	Brine Well
Ward	Blk 34-174	4247582265	Barstow Brine Station #1	Chance Properties	Brine Well

While these wells are within the Delaware Basin, none are within the vicinity of the WIPP. The nearest brine well to the WIPP is the Eugenie #WS-1, located within the city limits of Carlsbad, New Mexico. This well is approximately 30 miles from the WIPP site.

Solution Mining for Other Minerals

Currently, there are no ongoing solution mining activities within the vicinity of WIPP. The Rustler Springs sulfur mine located in Culberson County, Texas began operations in 1969 and continued until it was officially closed in 1999. This mine used the Frasch process to extract molten sulfur (Cunningham 1999).

Solution Mining for Gas Storage

No gas storage cavities have been solution mined within the New Mexico portion of the Delaware Basin. Five gas storage facilities exist within the general vicinity of the WIPP, however only one is within the Delaware basin. This one New Mexico Delaware Basin facility uses a depleted gas reservoir for storage and containment; it was not solution mined (CRA Appendix DATA).

Solution Mining for Disposal

Solution mining can be used to create a disposal cavity in bedded salt. Such disposal cavities can be used for the disposal of NORM or other wastes. No such cavities have been mined or operated within the vicinity of the WIPP.

Effects of Solution Mining

Subsidence

Regardless of whether the single-borehole or two-borehole technique is used for solution mining, the result is a sub-surface cavity which could collapse and lead to subsidence of overlying strata. Gray (1991) quoted earlier analyses that show cavity stability is relatively high if the cavity has at least 50 feet of overburden per million cubic feet of cavity volume (26.9 meters per fifty thousand cubic meters). There are two studies - discussed below - of the size of solution mining cavities in the Carlsbad region. These studies concern the Carlsbad Eugenie Brine Wells and the Carlsbad Brine Well and show that neither of these cavities are currently close to this critical ratio, but that subsidence in the future, given continued brine extraction, is a possibility.

Hickerson (1991) considered the potential for subsidence resulting from operation of the Carlsbad Eugenie Brine wells, where fresh water is injected into a salt section at a depth of 583 feet (178 meters) and brine is recovered through a borehole at a depth of 587 feet (179 meters). The boreholes are 327 feet (100 meters) apart. Hickerson noted that the fresh water, being less dense than brine, tends to move upwards, causing the dissolution cavern to grow preferentially upwards. Thus, the dissolution cavern at the Carlsbad Eugenie Brine wells is approximately triangular in cross-section, being bounded by the top of the salt section and larger near the injection well. Hickerson estimated that brine production from 1979 until 1991 had created a cavern of about 3.4×10^6 cubic feet (9.6×10^4 cubic meters). The size of this cavern was estimated as 350 feet (107 meters) by 153 feet (47 meters) at the upper surface of the cavern with a depth of 127 feet (39 meters). Gray (1991) investigated the potential for collapse and subsidence at the Carlsbad Brine Well. Based on estimated production rates between 1976 and 1991, approximately 3.4 x

10^6 cubic feet (9.6 x 10^4 cubic meters) of salt has been dissolved at this site. The well depth is 710 feet (216 meters) and thus there are about 210 feet of overburden per million cubic feet of capacity (112 meters of overburden per fifty thousand cubic meters of capacity).

Gray (1991) also estimated the time required for the cavity at the Carlsbad Brine Well to reach the critical ratio. At an average cavity growth rate of 2.25 x 10^5 cubic feet per year (6.4 x 10^3 cubic meters per year), a further 50 years of operation would be required before cavity stability was reduced to levels of concern. A similar calculation for the Carlsbad Eugenie Brine well, based on an overburden of 460 feet (140 meters) and an estimated average cavity growth rate of 2.8 x 10^5 cubic feet per year (7.9 x 10^3 cubic meters per year), shows that a further 15 years of operation is required before the cavity reaches the critical ratio.

Hydrogeological effects

In regions where solution mining takes place, the hydrogeology could be affected in a number ways:

- Subsidence above a large dissolution cavity could change the vertical and lateral hydraulic conductivity of overlying units.
- Extraction of fresh water from aquifers for solution mining could cause local changes in pressure gradients.
- Loss of injected fresh water or extracted brine to overlying units could cause local changes in pressure gradients.

The potential for subsidence to take place above solution mining operations in the region of Carlsbad is discussed above. Some subsidence could occur in the future if brine operations continue at existing wells. Resulting fracturing may change permeabilities locally in overlying formations. However, because of the restricted scale of the solution mining at a particular site, and the distances between such wells, such fracturing will have no significant effect on hydrogeology near the WIPP.

Solution mining operations in the Delaware Basin extract water from shallow aquifers so that, even if large drawdowns are permitted, the effects on the hydrogeology will be limited to a relatively small area around the operation. Since all the active operations are more than 20 miles from the WIPP, there will be no significant effects on the hydrogeology near the WIPP.

Discharge plans for solution mining operations typically include provision for annual mechanical integrity tests at one and one-half the normal operating pressure for four hours (OCD 1994). Thus, the potential for loss of integrity and consequent leakage of freshwater or brine to overlying formations is low. If, despite these annual tests, large water losses did take place, from either injection or production wells, the result would be low brine yields and remedial actions would most likely be taken by the operators.

Geochemical effects

Solution mining operations could affect the geochemistry of surface or sub-surface water near the operation if there were brine leakage from storage tanks or production wells. Discharge plans for solution mining operations specify the measures to be taken to prevent leakage and to mitigate the effects of any that do take place. These measures include berms around tanks and annual mechanical integrity testing of wells (OCD 1994). The potential for changes in geochemistry is therefore low, and any brine losses that did take place would be limited by remedial actions taken by the operator. In the event of leakage from a production well, the effect on geochemistry of overlying formation waters would be localized and, given the distance of such wells from the WIPP site, such leakage would have no significant effect on geochemistry near the WIPP.

Conclusion of Low Consequence

Brine production through solution mining takes place in the Delaware Basin, and the DOE assumes it will continue in the near future.

Despite oil and gas exploration and production taking place in the vicinity of the WIPP site, the nearest operating solution mine is more than 20 miles from the WIPP site. These locations are too far from the WIPP site for any changes in hydrogeology or geochemistry, from subsidence or fresh water or brine leakage, to affect the performance of the disposal system. Thus, the effects of historical, current, near-future, and future solution mining in the Delaware Basin can be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

7. WASTE AND REPOSITORY-INDUCED FEPS

Of the 108 Waste and Repository Induced FEPs, 51 were screened from further investigation and identified as Element 1 FEPs. Table 4-1 provides details regarding the FEPs reassessment. Of the 108 Waste and Repository Induced FEPs, 61 remain unchanged, 43 were updated with new information or were edited for clarity and completeness, three screening decisions were changed, and one FEP was deleted from the baseline by combining with other more appropriate FEPs. The remainder of this section provides details and results of those 57 waste- and repository-induced FEPs that underwent Element 2 of this reassessment.

EPA FEP Number: **W4**
FEP Title: **Container Form**

SCR Section Number **SCR.2.1.3**
Screening Decision: **SO-C**

Summary :

The inventories of container materials (i.e., steel and plastic liners) are included in WIPP long-term performance assessments as input parameters of the gas generation model (Wang and Brush 1996). The container form has been eliminated from performance assessment calculations on the basis of its beneficial effect on retarding radionuclide release. The performance assessments assume instantaneous container failure and waste dissolution according to the source-term model. The screening decision remains valid.

Italicized Text

The container form has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

As in the CCA (Helton et al. 1998), the CRA calculations show that a significant fraction of steel and other Fe-base materials will remain undegraded over 10,000 years. For all undisturbed cases, at least 30% of the steels will remain uncorroded at the end of 10,000 years. In addition, it is assumed in both CCA and CRA calculations that there is no microbial degradation of plastic container materials in 75% of PA realizations (Wang and Brush 1996). All these undegraded container materials will (1) prevent the contact between brine and radionuclides; (2) decrease the rate and extent of radionuclide transport due to high tortuosity along the flow pathways and, as a result, increase opportunities for metallic Fe and corrosion products to beneficially reduce radionuclides to lower oxidation states. Therefore the container form can be eliminated on the basis of its beneficial effect on retarding radionculide transport. Both CCA and CRA assume instantaneous container failure and waste dissolution according to the source-term model. In the CCA Appendix WCL, a minimum quantity of metallic Fe was specified to ensure sufficient reactants to reduce radionuclides to lower and less soluble oxidation states. This requirement is met as long as there are no substantial changes in container materials. Secondly, the density of steel in container materials increases from 139 to 230 kg/m^3 and plastic liners decreases from 26 to 21 kg/m^3 in the new BIR data (Crawford 2003a; DOE 1996b).

EPA FEPs Number: **W8**
FEP Title: **Seal Chemical Composition**

SCR Section Number: **SCR.2.1.4**
Screening Decision: **SO-C Beneficial**

Summary:

The screening argument remains valid. Seal chemical composition was screened out on the basis of predicted beneficial consequences, which are not credited in performance assessment calculations. Recent publications provide support for the screening argument that chemical interactions between the cement seals and the brine will be of beneficial consequence to the performance of the disposal system, through sorption and sequestration of radionuclides. Ignoring adsorption simplifies the PA calculations, and is expected to produce somewhat more conservative results. However, because little or no upward flow is predicted to occur through the seals, the overall effect on PA results may not be significant.

The screening decision remains valid. The original FEP description has been modified slightly to include supporting evidence for the argument that chemical interactions between the cement seals and the brine will be of beneficial consequence to the performance of the disposal system.

Italicized Text

The seal chemical composition has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

FEP Text

Seal (shaft seals, panel closures, and drift closures) characteristics, including seal geometry and seal physical properties, are described in CCA Chapter 3.0 and are accounted for in performance assessment calculations through the representation of the seal system in BRAGFLO and the permeabilities assigned to the seal materials. The effect of shaft seal chemical composition on actinide speciation and mobility has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

Repository Seals

Certain repository materials have the potential to interact with groundwater and significantly alter the chemical speciation of any radionuclides present. In particular, extensive use of cementitious materials in the seals may have the capacity to buffer groundwaters to extremely high pH (for example, Bennett et al. 1992 pp. 315 - 325). At high pH values, the speciation and adsorption behavior of many radionuclides is such that their dissolved concentrations are reduced in comparison with near-neutral waters. This effect reduces the migration of radionuclides in dissolved form.

Several recent publications describe strong actinide (or actinide analog) sorption by cement (Altenheinhaese et al. 1994; Wierczinski et al. 1998; Pointeau et al. 2001), or sequestration by incorporation into cement alteration phases (Gougar et al. 1996, Dickson and Glasser 2000). These provide support for the screening argument that chemical interactions between the cement seals and the brine will be of beneficial consequence to the performance of the disposal system.

The effects of cementitious seals on groundwater chemistry have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

EPA FEP Number: **W9**
FEP Title: **Backfill Physical Properties**

SCR Section Number: **SCR.2.1.5**
Screening Decision: **SO-C**

Summary:

The screening argument appears valid. Appendix SCR, Section 2.1.5 (page SCR-39), of the CCA indicates that backfill physical properties have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. No changes have been made to the FEP description, screening argument or screening decision. Editorial changes were made to include references to the EPA FEP numbering scheme.

Italicized Text

Backfill physical properties have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

A chemical backfill is being added to the disposal room to buffer the chemical environment. The backfill characteristics were previously described in CCA Appendix BACK with additional information contained in CRA Appendix BARRIERS. The mechanical and thermal effects of backfill are discussed in W35 and W72 respectively, where they have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Backfill will result in an initial permeability for the disposal room lower than that of an empty cavity, so neglecting the hydrological effects of backfill is a conservative assumption with regard to brine inflow and radionuclide migration. Thus, backfill physical properties have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The chemical effects of backfill are discussed in W57 and the backfill chemical composition is accounted for in performance assessment calculations in deriving the dissolved and colloidal actinide source terms.

EPA FEPs Number: **W11**
FEP Title: **Post-closure Monitoring**

SCR Section Number: **SCR.2.1.6**
Screening Decision: **SO-C**

Summary:

The text of this FEP has been modified to include reference to 40 CFR 194.42(d). Compliance with this requirement ensures that post-closure monitoring is not detrimental to the performance of the repository. No changes have been proposed to the post-closure monitoring program as presented in the CCA. The pre-closure monitoring program has not identified a condition relating to the act of monitoring that would be detrimental to the performance of the repository after closure (Annual Site Environmental Reports and Annual Compliance Monitoring Parameter Assessments). No changes have been made to the FEP description, screening argument or screening decision.

Italicised Text

The potential effects of post-closure monitoring have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Post-closure monitoring is required by 40 CFR § 191.14(b) as an assurance requirement to "detect substantial and detrimental deviations from expected performance." The DOE has designed the monitoring program (see CCA Appendix MON) so that the monitoring methods employed are not detrimental to the performance of the disposal system (40 CFR 194.42(d)). Non-intrusive monitoring techniques are used such that post-closure monitoring would not impact containment or require remedial activities. In summary, the effects of monitoring have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: W13
FEP Title: Heat From Radioactive Decay

SCR Section Number: SCR.2.2.2
Screening Decision: SO-C

Summary:

The screening argument appears reasonable because the waste acceptance criteria for the WIPP does not allow the thermal load of the WIPP to exceed 10 kilowatts per acre. The waste acceptance criteria restricts the thermal load from RH-TRU waste containers to no more than 300 watts per container. However, the limit on the surface dose equivalent rate of the RH-TRU containers (1,000 rem/hr) is more restrictive and equates to a thermal load of only about 60 watts per container. Based on the thermal loads permitted, the maximum temperature rise in the repository from radioactive decay heat should be less than two degrees Celsius. The FY2002 update to the TWBIR (Crawford 2003c) has indicated that the radionuclide inventory is lower than previously estimated. Thus, all Compliance Recertification Application (CRA) radioactive decay heating screening arguments are bounded by the previous CCA screening arguments.

Italicized Text

The effects of temperature increases as a result of radioactive decay have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Radioactive decay of the waste emplaced in the repository will generate heat. The importance of *heat from radioactive decay* depends on the effects that the induced temperature changes would have on mechanics (W29-W31), fluid flow (W40 and W41), and geochemical processes (W44 through W75). For example, extreme temperature increases could result in thermally induced fracturing, regional uplift, or thermally driven flow of gas and brine in the vicinity of the repository.

According to the Waste Acceptance Criteria (WAC) (see CRA Chapter 4.0), the design basis for the WIPP requires that the thermal loading does not exceed 10 kilowatts per acre. The WAC also require that the thermal power generated by waste in an RH-TRU container shall not exceed 300 watts, but the WAC do not limit the thermal power of CH-TRU waste containers.

A numerical study to calculate induced temperature distributions and regional uplift is reported in DOE (1980 pp. 9-149 to 9-150). This study involved estimation of the thermal power of CH-TRU waste containers. The DOE (1980 pp. 9-149) analysis assumed the following:

- All CH-TRU waste drums and boxes contain the maximum permissible quantity of plutonium. According to the WAC, the fissionable radionuclide content for CH-TRU waste containers shall be no greater than 200 grams per 0.21 cubic meter drum and 350 grams per 1.8 cubic meter standard waste box (^{239}Pu fissile gram equivalents).

- The plutonium in CH-TRU waste containers is weapons grade material producing heat at 0.0024 watts per gram. Thus, the thermal power of a drum is approximately 0.5 watts and that of a box is approximately 0.8 watts.

- Approximately 3.7 x 10^5 cubic meters of CH-TRU waste are distributed within a repository enclosing an area of 7.3 x 10^5 square meters. This is a conservative assumption in terms of quantity and density of waste within the repository, because the maximum capacity of the WIPP is 1.756 x 10^5 cubic meters for all waste (as specified by the Land Withdrawal Act [LWA]) to be placed in an enclosed area of approximately x 10^5 square meters.

- Half of the CH-TRU waste volume is placed in drums and half in boxes so that the repository will contain approximately 9 x10^5 drums and 105 boxes. Thus, a calculated thermal power of 2.8 kilowatts per acre (0.7 watts per square meter) of heat is generated by the CH-TRU waste.

- Insufficient RH-TRU waste is emplaced in the repository to influence the total thermal load.

Under these assumptions, Thorne and Rudeen (1981) estimated the long-term temperature response of the disposal system to waste emplacement. Calculations assumed a uniform initial power density of 2.8 kilowatts per acre (0.7 watts per square meter) which decreases over time. Thorne and Rudeen (1981) attributed this thermal load to RH-TRU waste, but the DOE (1980), more appropriately, attributed this thermal load to CH-TRU waste based on the assumptions listed above. Thorne and Rudeen (1981) estimated the maximum rise in temperature at the center of a repository to be 1.6°C at 80 years after waste emplacement.

Sanchez and Trellue (1996) estimated the maximum thermal power of an RH-TRU waste container. The Sanchez and Trellue (1996) analysis involved inverse shielding calculations to evaluate the thermal power of an RH-TRU container corresponding to the maximum permissible surface dose; according to the WAC, the maximum allowable surface dose equivalent for RH-TRU containers is 1000 rem per hour. The following calculational steps were taken in the Sanchez and Trellue (1996) analysis:

- Calculate the absorbed dose rate for gamma radiation corresponding to the maximum surface dose equivalent rate of 1000 rem per hour. Beta and alpha radiation are not included in this calculation because such particles will not penetrate the waste matrix or the container in significant quantities. Neutrons are not included in the analysis because, according to the WAC, the maximum dose rate from neutrons is 270 millirem per hour, and the corresponding neutron heating rate will be insignificant.

- Calculate the exposure rate for gamma radiation corresponding to the absorbed dose rate for gamma radiation.

- Calculate the gamma flux density at the surface of a RH-TRU container corresponding to the exposure rate for gamma radiation. Assuming the gamma energy is 1.0 megaelectron volts, the maximum allowable gamma flux density at the surface of a RH-TRU container is about 5.8×10^8 gamma rays per square centimeter per second.

- Determine the distributed gamma source strength, or gamma activity, in an RH-TRU container from the surface gamma flux density. The source is assumed to be shielded such that the gamma flux is attenuated by the container and by absorbing material in the container. The level of shielding depends on the matrix density. Scattering of the gamma flux, with loss of energy, is also accounted for in this calculation through inclusion of a gamma buildup factor. The distributed gamma source strength is determined assuming a uniform source in a right cylindrical container. The maximum total gamma source (gamma curies) is then calculated for a RH-TRU container containing 0.89 cubic meters of waste. For the waste of greatest expected density (about 6,000 kilograms per cubic meter), the gamma source is about 2×10^4 curies per cubic meter.

- Calculate the total curie load of a RH-TRU container (including alpha and beta radiation) from the gamma load. The ratio of the total curie load to the gamma curie load was estimated through examination of the radionuclide inventory presented in Appendix BIR. The gamma curie load and the total curie load for each radionuclide listed in the WIPP BIR were summed. Based on these summed loads the ratio of total curie load to gamma curie load of RH-TRU waste was calculated to be 1.01.

- Calculate the thermal load of a RH-TRU container from the total curie load. The ratio of thermal load to curie load was estimated through examination of the radionuclide inventory presented in Appendix BIR. The thermal load and the total curie load for each radionuclide listed in the WIPP BIR were summed. Based on these summed loads the ratio of thermal load to curie load of RH-TRU waste was calculated to be about 0.0037 watts per curie. For a gamma source of 2×10^4 curies per cubic meter, the maximum permissible thermal load of a RH-TRU container is about 70 watts per cubic meter. Thus, the maximum thermal load of a RH-TRU container is about 60 watts, and the WAC upper limit of 300 watts will not be achieved.

Note that Sanchez and Trellue (1996) calculated the average thermal load for a RH-TRU container to be less than 1 watt. Also, the total RH-TRU heat load is less than 10 percent of the total heat load in the WIPP. Thus, the total thermal load of the RH-TRU waste will not significantly affect the average rise in temperature in the repository resulting from decay of CH-TRU waste.

Temperature increases will be greater at locations where the thermal power of an RH-TRU container is 60 watts, if any such containers are emplaced. Sanchez and Trellue (1996) estimated the temperature increase at the surface of a 60 watt RH-TRU waste container. Their analysis involved solution of a steady-state thermal conduction problem with a constant heat source term of 70 watts per cubic meter. These conditions represent conservative assumptions because the thermal load will decrease with time as the radioactive waste decays. The temperature increase at the surface of the container was calculated to be about 3°C.

In summary, analysis has shown that the average temperature increase in the WIPP repository, due to radioactive decay of the emplaced CH- and RH-TRU waste, will be less than 2°C. Temperature increases of about 3°C may occur in the vicinity of RH-TRU containers with the highest allowable thermal load of about 60 watts (based on the maximum allowable surface dose equivalent for RH-TRU containers). Potential heat generation from nuclear criticality is discussed in W14 and exothermic reactions and the effects of repository temperature changes on mechanics are discussed in the set of FEPs grouped as W29, W30, W31, W72, and W73. These FEPs have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

The previous FEPs screening arguments for the CCA used a bounding radioactivity heat load of 0.5 watts/drum for the CH-TRU waste containers. With a total CH-TRU volume of 168,500 m^3, this corresponds to approximately 810,000 55-gallon drum equivalents with a corresponding heat load of > 400 kilowatts used for the CCA FEPs screening arguments. From Sanchez and Trellue 1996, it can be seen that a realistic assessment of the heat load, based on radionuclide inventory data in the Transuranic Waste Baseline Inventory Report (TWBIR) is less than 100 kilowatts. Thus, the CCA FEPs incorporate a factor of safety of at least four. Also, since the FY2002 update to the TWBIR (Crawford 2003c) has indicated that the radionuclide inventory is lower than previously estimated. Thus, all CRA radioactive decay heating screening arguments are bounded by the previous CCA screening arguments.

EPA FEPs Number: W14
FEPs Title: Nuclear Criticality: Heat

SCR Section Number: SCR.2.2.3
Screening Decision: SO-P

Summary:

Heat generated via nuclear criticality was screened out based on the low probability that a criticality event would occur. The updated information for the WIPP disposal inventory of fissile material (Crawford 2003c and Leigh 2003a) indicates that the expected WIPP-scale quantity is 35% lower than previously estimated in TWBIR Rev 3 (DOE 1996b). Thus, all CRA criticality screening arguments are conservatively bounded by the previous CCA screening arguments (Rechard et al. 1996, 2000, and 2001).

Italicized Text

Nuclear criticality has been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text

Nuclear criticality refers to a sustained fission reaction that may occur if fissile radionuclides reach both a sufficiently high concentration and total mass (where the latter parameter includes the influence of enrichment of the fissile radionuclides). In the subsurface, the primary effect of a nuclear reaction is the production of *heat*.

Nuclear criticality (near and far field) was eliminated from performance assessment calculations for the WIPP for waste contaminated with TRU radionuclides. The probability for criticality within the repository is low (there are no mechanisms for concentrating fissile radionuclides dispersed amongst the waste). Possible mechanisms for concentration in the waste disposal region include high solubility, compaction, sorption, and precipitation. First, the maximum solubility of ^{239}Pu in the WIPP repository, the most abundant fissile radionuclide, is orders of magnitude lower than necessary to create a critical solution. The same is true for ^{235}U, the other primary fissile radionuclide. Second, the waste is assumed to be compacted by repository processes to one fourth its original volume. This compaction is still an order of magnitude too disperse (many orders of magnitude too disperse if neutron absorbers that prevent criticality (for example, ^{238}U) are included). Third, any potential sorbents in the waste would be fairly uniformly distributed throughout the waste disposal region; consequently, concentration of fissile radionuclides in localized areas through sorption is improbable. Fourth, precipitation requires significant localized changes in brine chemistry; small local variations are insufficient to separate substantial amounts of ^{239}Pu from other actinides in the waste disposal region (for example, 11 times more ^{238}U is present than ^{239}Pu).

Criticality away from the repository (following an inadvertent human intrusion) has a low probability because (1) the amount of fissile material transported from the repository is small, (2) host rock media have small porosities (insufficient for generation of sizable precipitation zone), and (3) no credible mechanism for the concentrating fissile material during transport (the natural tendency is for transported to be dispersed). As discussed in CCA Section 6.4.6.2 and CCA Appendix MASS Section 15, the dolomite porosity consists of intergranular porosity, vugs, microscopic fractures, and macroscopic fractures. As discussed in CCA Section 6.4.5.2, porosity in the marker beds consists of partially healed fractures that may dilate as pressure increases. Advective flow in both units occurs mostly through macroscopic fractures. Consequently, any potential deposition through precipitation or sorption is constrained by the depth to which precipitation and sorption occur away from fractures. This geometry is not favorable for fission reactions and eliminates the possibility of a criticality. Thus, nuclear criticality has been eliminated from performance assessment calculations on the basis of low probability of occurrence.

Screening arguments made in Rechard et al. (1996) are represented in greater detail in Rechard et al. (2000 and 2001). A major finding among the analysis results in the screening arguments is the determination that fissile material would need to be reconcentrated by three orders of magnitude in order to be considered in a criticality scenario. These previous arguments were based on radionuclide information from Revision 3 of the Transuranic Waste Baseline Inventory Report (TWBIR, DOE 1996b). Of the 135 radionuclides presented in that TWBIR database, only 17 are possible contributors to fissile material. Table W14-A identifies these nuclides along with their conversion factors for specific activity and ^{239}Pu fissile gram equivalents (^{239}Pu FGE per ANSI/ANS- 18.5).

Radioactivity inventories for the fissile radionuclides used in the 1996 WIPP Compliance Certification Application (CCA) and the current Compliance Recertification Application (CRA) are presented in Table W14-B. Also shown in Table W14-B are the corresponding FGE inventories. Key, amongst the information presented in this table is the identification that updated information for the WIPP disposal inventory of fissile material(Crawford 2003c and Leigh 2003a) indicates that the expected WIPP-scale quantity is 35% lower than previously estimated in TWBIR Rev3. Thus, all CRA criticality screening arguments are conservatively bounded by the previous CCA screening arguments (Rechard et al. 1996, 2000, and 2001).

Table W14-A. Properties of Fissile Radionuclides in the Actinide Series

Nuclide ID	Atomic Number	Atomic Number	Half-Life [a] (sec)	Mass Excess Value [b] (MeV)	Atomic Weight [c] (gm/mole)	Specific Activity [d] (Ci/gm)	Fissile Gram Equivalent Factor [e] (Pu-239)
U233	92	233	5.0020E+12	36.914	233.040	9.6763E-03	1.00E+00
U235	92	235	2.2210E+16	40.916	235.044	2.1611E-06	1.00E+00
Np237	93	237	6.7530E+13	44.868	237.048	7.0476E-04	1.50E-02
Pu238	94	238	2.7690E+09	46.160	238.050	1.7115E+01	1.13E-01
Pu239	94	239	7.5940E+11	48.585	239.052	6.2146E-02	1.00E+00
Pu240	94	240	2.0630E+11	50.122	240.054	2.2781E-01	2.25E-02

Table W14-A. Properties of Fissile Radionuclides in the Actinide Series							
Nuclide ID	Atomic Number	Atomic Number	Half-Life [(a)] (sec)	Mass Excess Value [(b)] (MeV)	Atomic Weight [(c)] (gm/mole)	Specific Activity [(d)] (Ci/gm)	Fissile Gram Equivalent Factor [(e)] (Pu-239)
Pu241	94	241	4.5440E+08	52.952	241.057	1.0300E+02	2.25E+00
Pu242	94	242	1.2210E+13	54.714	242.059	3.8171E-03	7.50E-03
Am241	95	241	1.3640E+10	52.931	241.057	3.4312E+00	1.87E-02
Am242m	95	242	4.7970E+09	55.513	242.060	9.7159E+00	3.46E+01
Am243	95	243	2.3290E+11	57.171	243.061	1.9929E-01	1.29E-02
Cm243	96	243	8.9940E+08	57.177	243.061	5.1607E+01	5.00E+00
Cm244	96	244	5.7150E+08	58.449	244.063	8.0883E+01	9.00E-02
Cm245	96	245	2.6820E+11	60.998	245.065	1.7165E-01	1.50E+01
Cm247	96	247	4.9230E+14	65.528	247.070	9.2752E-05	5.00E-01
Cf249	98	249	1.1060E+10	69.718	249.075	4.0953E+00	4.50E+01
Cf251	98	251	2.8340E+10	74.128	251.080	1.5855E+00	9.00E+01

(a) Half-life data originally taken from ORIGEN2 decay library (Croff 1980). Data values presented in Ref. Sanchez 1996 (WIPP WPO# 037404).

(b) Mass excess values originally taken from Nuclear Wallet Cards (Tuli 1985). Data values presented in Ref. Sanchez 1996 (WIPP WPO# 037404).

(c) Atomic weight calculated from: ATWT (AMU) = AN (atomic mass number) – ME (mass difference in MeV, ME of C^{12} = 0) / 931.4943 (MeV per AMU, Ref. Parrington et al. 1996, pg. 58)

(d) Specific Activity calculated from: A'= (Na ln(2))/(ATWT half-life), Ref. Turner 1992, pg. 64 and A (Ci/gm) = A'(Bq/gm) / 3.7E+10 (Bq/Ci), Ref. Turner 1992, pg. 43, where Na = Avogadro's number = 6.02213676E+23 (atom/mole, Parrington, pg.59).

(e) FGE (Pu-239 based) data values from NuPac 1989 (TRUPACT-II SAR/Table 10.1/pg. 1.3.7-51 (data originally from Ref. ANSI/ANS-8.15 1981).

Table W14-B. Fissile Equivalents of Radionuclides in the Actinide Series								
Nuclide ID	Radioactivity Inventory [(a)] (Ci)				Nuclide Fissile Mass [(b)] (FGE-Pu239)			
	TWBIR 3 (1995)	TWBIR 3 (2033)	2002 UpDate (2002)	2002 UpDate (2033)	TWBIR 3 (1995)	TWBIR 3 (2033)	2002 UpDate (2002)	2002 UpDate (2033)
U233	1.95E+03	1.95E+03	1.47E+03	3.88E+02	2.02E+05	2.02E+05	1.52E+05	4.00E+04
U235	1.74E+01	1.75E+01	2.33E+00	2.36E+00	8.05E+06	8.10E+06	1.08E+06	1.09E+06
Np237	5.90E+01	6.49E+01	7.08E+00	1.23E+01	1.26E+03	1.38E+03	1.51E+02	2.62E+02
Pu238	2.61E+06	1.94E+06	1.96E+06	1.53E+06	1.72E+04	1.28E+04	1.29E+04	1.01E+04
Pu239	7.96E+05	7.95E+05	7.84E+05	7.83E+05	1.28E+07	1.28E+07	1.26E+07	1.26E+07
Pu240	2.15E+05	2.14E+05	1.34E+05	1.34E+05	2.12E+04	2.11E+04	1.32E+04	1.32E+04
Pu241	2.45E+06	3.94E+05	3.11E+06	6.66E+05	5.35E+04	8.61E+03	6.79E+04	1.45E+04
Pu242	1.17E+03	1.17E+03	3.32E+01	3.32E+01	2.30E+03	2.30E+03	6.52E+01	6.52E+01
Am241	4.48E+05	4.88E+05	4.62E+05	5.18E+05	2.44E+03	2.66E+03	2.52E+03	2.82E+03
Am242m	1.75E+00	1.47E+00	2.49E-01	2.15E-01	6.23E+00	5.23E+00	8.87E-01	7.66E-01
Am243	3.26E+01	3.25E+01	3.42E+01	3.42E+01	2.11E+00	2.10E+00	2.21E+00	2.21E+00
Cm243	5.23E+01	2.07E+01	9.00E-01	4.13E-01	5.07E+00	2.01E+00	8.72E-02	4.00E-02
Cm244	3.18E+04	7.44E+03	1.68E+04	4.93E+03	3.54E+01	8.28E+00	1.87E+01	5.48E+00
Cm245	1.15E-02	1.15E-02	2.46E-02	2.48E-02	1.00E+00	1.00E+00	2.15E+00	2.17E+00
Cm247	3.21E-09	9.51E-09	1.34E+01	1.34E+01	1.73E-05	5.13E-05	7.22E+04	7.22E+04
Cf249	6.87E-02	6.38E-02	1.18E-01	1.11E-01	7.55E-01	7.01E-01	1.30E+00	1.22E+00
Cf251	3.78E-03	3.67E-03	8.18E-04	7.97E-04	2.15E-01	2.08E-01	4.64E-02	4.52E-02
				Σ	2.11E+07	2.12E+07	1.40E+07	1.38E+07

(a) TWBIR Rev. 3 data values originally from Ref. DOE 1996b. Data values presented in Ref. Sanchez 1997, pp. 27-30. TWBIR 2002 Update 2002 (beginning of calendar year) data from Crawford 2003c. TWBIR 2002 Update 2033 (end of calendar year) data from Leigh 2003.

(b) Pu-239 Fissile Gram Equivalents calculated from: FGE(Pu-239) = Inventory (Ci) * FGE Factor (from Table 1) / A'(Ci/gm, from Table 1).

EPA FEP Number: W15
FEP Title: Radiological Effects on Waste

SCR Section Number SCR.2.2.4
Screening Decision: SO-C

Summary

Radiological effects on the properties of the wastes have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening decision remains valid. The FEP description has been updated.

Italicized Text

Radiological effects on the properties of the waste, container, and seals, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Ionizing radiation can change the physical properties of many materials. Strong radiation fields could lead to damage of waste matrices, and brittleness of the metal containers. The low level of activity of the waste in the WIPP is unlikely to generate a strong radiation field. According to the new BIR data, the total radionuclide inventory increases from 7.44×10^6 (DOE 1996b) to 7.84×10^6 curies (Crawford 2003c), about a 6% increase. As a matter of fact, the radionuclide inventory in the contact handle waste, which accounts for the most volume of WIPP wastes, even decreases from 6.42×10^6 (DOE 1996b) to 5.89×10^6 curies (Crawford 2003c). Such a small increase will not change the original screening argument. In addition, performance assessment calculations assume instantaneous container failure and waste dissolution according to the source-term model (see Section 6.4.3.4, 6.4.3.5, and 6.4.3.6 of the CCA) (DOE 1996a). Therefore, radiological effects on the properties of the waste have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **W16**
FEP Title: **Radiological Effects on Containers**

SCR Section Number: **SCR.2.2.4**
Screening Decision: **SO-C**

Summary

Radiological effects on the properties of containers have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening decision remains valid. The FEP description has been updated.

Existing Italicized Text from SCR

Radiological effects on the properties of the waste, container, and seals, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Discussion

Ionizing radiation can change the physical properties of many materials. Strong radiation fields could lead to brittleness of the metal containers. According to the new BIR data, the total radionuclide inventory increases from 7.44 x 10^6 (DOE 1996b) to 7.84 x 10^6 (Crawford 2003b) curies, about a 6% increase. As a matter of fact, the radionuclide inventory in the contact handle waste, which accounts for the most volume of WIPP wastes, even decreases from 6.42 x 10^6 (DOE 1996b) to 5.89 x 10^6 curies (Crawford 2003b). Such a small increase will not change the original screening argument. The low level of activity of the waste in the WIPP is unlikely to generate a strong radiation field. In addition, performance assessment calculations assume instantaneous container failure and waste dissolution according to the source-term model (see Section 6.4.3.4, 6.4.3.5, and 6.4.3.6 of the CCA) (DOE 1996a). Therefore, *radiological effects on the properties of containers* have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEPs Number: W17
FEPs Title: Radiological Effects on Seals

SCR Section Number: SCR.2.2.4
Screening Decision: SO-C

Summary:

The original description and screening argument remains valid. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

Radiological effects on the properties of the waste, container, and seals, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Ionizing radiation can change the physical properties of many materials. Strong radiation fields could lead to damage of waste matrices, brittleness of the metal containers, and disruption of any crystalline structure in the seals. However, the low level of activity of the waste in the WIPP is unlikely to generate a strong radiation field. In addition, performance assessment calculations assume instantaneous container failure and waste dissolution according to the source-term model (see CCA Sections 6.4.3.4, 6.4.3.5, and 6.4.3.6). Therefore, radiological effects on the properties of the waste, containers, and seals, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number(s): W23 & W24
FEP Title(s): Subsidence (W23)
Large Scale Rock Fracturing (W24)

SCR Section Number: SCR.2.3.4
Screening Decision(s): SO-C (W23)
SO-P (W24)

Summary:

The screening arguments for W23 and W24 remain appropriate, although based on the FEP text the screening argument for W24 might be better qualified as consequence. The DOE acknowledges that proximal roof falls (see W22, CCA SCR.2.3.3) will occur and minor subsidence of stratigraphic units overlying the Salado Formation at WIPP could occur. Subsidence of geologic formations overlying the WIPP due to salt creep is shown to be only modestly perturbed and the consequence is captured by the uncertainty employed in the performance assessment. Roof falls and large-scale subsidence have therefore been screened out of the performance assessment calculations based upon low consequence. The potential effects of roof falls on flow paths are accounted for in performance assessment calculations through appropriate ranges of the parameters describing the Disturbed Rock Zone (DRZ). Continuous survey data, reported annually, reaffirm that subsidence is minimal and near the accuracy of the survey itself (COMPs, annual reports).

Italicized Text

Fracturing within units overlying the Salado and surface displacement caused by subsidence associated with repository closure have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The potential for excavation or repository-induced subsidence to create large-scale rock fracturing and fluid flow paths between the repository and units overlying the Salado has been eliminated from performance assessment calculations on the basis of the low probability of occurrence over 10,000 years.

FEP Text

Instability of the DRZ could to lead to localized roof falls in the first few hundred years. If instability of the DRZ causes roof falls, development of the DRZ may be sufficient to disrupt the anhydrite layers above the repository, which may create a zone of rock containing anhydrite extending from the interbeds toward a waste-filled room. Fracture development is most likely to be induced as the rock stress and strain distributions evolve because of creep and the local lithologies. In the long term, the effects of roof falls in the repository are likely to be minor because salt creep will reduce the void space and the potential for roof falls as well as leading to healing of any roof material that has fallen into the rooms. Because of uncertainty in the process by which the disposal room DRZ heals, the flow model used in the performance assessment assumed that a higher permeability zone remained for the long term. The PAVT modified the DRZ permeability to a sampled range. Thus, the potential effects of roof falls on flow paths are accounted for in performance assessment calculations through appropriate ranges of the parameters describing the DRZ.

The amount of *subsidence* that can occur as a result of salt creep closure or roof collapse in the WIPP excavation depends primarily on the volume of excavated rock, the initial and compressed porosities of the various emplaced materials (waste, backfill, panel and drift closures, and seals), the amount of inward creep of the repository walls, and the gas and fluid pressures within the repository. The DOE (Westinghouse 1994) has analyzed potential excavation-induced subsidence with the primary objective of determining the geomechanical advantage of backfilling the WIPP excavation. The DOE (Westinghouse 1994, pp. 3-4 to 3-23) used mass conservation calculations, the influence function method, the National Coal Board empirical method, and the two-dimensional, finite-difference code, Fast Lagrangian Analysis of Continua (FLAC) to estimate subsidence for conditions ranging from no backfill to emplacement of a highly compacted crushed salt backfill. The DOE (Westinghouse 1994, pp. 2-17 to 2-23) also investigated subsidence at potash mines located near the WIPP site to gain insight into the expected subsidence conditions at the WIPP and to calibrate the subsidence calculation methods.

Subsidence over potash mines will be much greater than subsidence over the WIPP because of the significant differences in stratigraphic position, depth, extraction ratio, and layout. The WIPP site is located stratigraphically lower than the lowest potash mine, which is near the base of the McNutt Potash Member (hereafter called the McNutt). At the WIPP site, the base of the McNutt is about 490 feet (150 meters) above the repository horizon. Also, the WIPP rock extraction ratio in the waste disposal region will be about 22 percent, as compared to 65 percent for the lowest extraction ratios within potash mines investigated by the DOE (Westinghouse 1994, p. 2-17).

The DOE (Westinghouse 1994, p. 2-22) reported the maximum total subsidence at potash mines to be about 5 feet (1.5 meters). This level of subsidence has been observed to have caused surface fractures. However, the DOE (Westinghouse 1994, p. 2-23) found no evidence that subsidence over potash mines had caused fracturing sufficient to connect the mining horizon to water-bearing units or the landsurface. The level of disturbance caused by subsidence above the WIPP repository will be less than that associated with potash mining and thus, by analogy, will not create fluid flow paths between the repository and the overlying units.

The various subsidence calculation methods used by the DOE (Westinghouse 1994, pp. 3-4 to 3-23) provided similar and consistent results, which support the premise that subsidence over the WIPP will be less than subsidence over potash mines. Estimates of maximum subsidence at the land surface for the cases of no backfill and highly compacted backfill are 2 feet (0.62 meters) and 1.7 feet (0.52 meters), respectively. The mass conservation method gave the upper bound estimate of subsidence in each case. The surface topography in the WIPP area varies by more than 10 feet (3 meters), so the expected amount of repository-induced subsidence will not create a basin, and will not affect surface hydrology significantly. The DOE (Westinghouse 1994, Table 3-13) also estimated subsidence at the depth of the Culebra using the FLAC model, for the case of an empty repository (containing no waste or backfill). The FLAC analysis assumed the Salado to be halite and the Culebra to have anhydrite material parameters.

Maximum subsidence at the Culebra was estimated to be 1.8 feet (0.56 meters). The vertical strain was concentrated in the Salado above the repository. Vertical strain was less than 0.01 percent in units overlying the Salado and was close to zero in the Culebra (Westinghouse 1994, Figure 3-40). The maximum horizontal displacement in the Culebra was estimated to be 0.08 feet (0.02 meters), with a maximum tensile horizontal strain of 0.007 percent. The DOE (Westinghouse 1994, 4-1 to 4-2) concluded that the induced strains in the Culebra will be uniformly distributed because no large-scale faults or discontinuities are present in the vicinity of the WIPP. Furthermore, strains of this magnitude would not be expected to cause extensive fracturing.

At the WIPP site, the Culebra hydraulic conductivity varies spatially over approximately four orders of magnitude, from 1×10^{-8} meters per second (0.4 meters per year) to 1×10^{-5} meters per second (400 meters per year; CCA Section 2.2.1.4.1.2). Where transmissive horizontal fractures exist, hydraulic conductivity in the Culebra is dominated by flow through the fractures. An induced tensile vertical strain may result in an increase in fracture aperture and corresponding increases in hydraulic conductivity. The magnitude of increase in hydraulic conductivity can be estimated by approximating the hydrological behavior of the Culebra with a simple conceptual model of fluid flow through a series of parallel fractures with uniform properties. A conservative estimate of the change in hydraulic conductivity can be made by assuming that all the vertical strain is translated to fracture opening (and none to rock expansion). This method for evaluating changes in hydraulic conductivity is similar to that used by the EPA in estimating the effects of subsidence caused by potash mining (Peake 1996, EPA 1996b).

The equivalent porous medium hydraulic conductivity, *K* (meters per second), of a system of parallel fractures can be calculated assuming the cubic law for fluid flow (Witherspoon et al. 1980):

$$K = \frac{w^3 \rho g N}{12 \mu D},$$

where *w* is the fracture aperture, ρ is the fluid density (taken to be 1,000 kilograms per cubic meter), *g* is the acceleration due to gravity (9.79 meters per second squared), μ is the fluid viscosity (taken as 0.001 pascal seconds), *D* is the effective Culebra thickness (7.7 meters), and *N* is the number of fractures. For 10 fractures with a fracture aperture, *w*, of 6×10^{-5} meters, the Culebra hydraulic conductivity, *K*, is approximately 7 meters per year (2×10^{-7} meters per second). The values of the parameters used in this calculation are within the range of those expected for the Culebra at the WIPP site (CCA Section 2.2.1.4.1.2).

The amount of opening of each fracture as a result of subsidence-induced tensile vertical strain, Î, (assuming rigid rock) is *DÎ/N* meters. Thus, for a vertical strain of 0.0001 meters per meter, the fracture aperture, *w*, becomes approximately 1.4×10^{-4} meters. The Culebra hydraulic conductivity, *K*, then increases to approximately 85 meters per year (2.7×10^{-6} meters per second). Thus, on the basis of a conservative estimate of vertical strain, the hydraulic conductivity of the Culebra may increase by an order of magnitude. In the performance assessment calculations, multiple realizations of the Culebra transmissivity field are generated as a means of accounting for spatial variability and uncertainty (CCA Appendix TFIELD). A change in hydraulic conductivity of one order of magnitude through vertical strain is within the range of uncertainty incorporated in the Culebra transmissivity field through these multiple realizations. Thus, changes in the horizontal component of Culebra hydraulic conductivity resulting from repository-induced subsidence have been eliminated from performance assessment calculations on the basis of low consequence.

A similar calculation can be performed to estimate the change in vertical hydraulic conductivity in the Culebra as a result of a horizontal strain of 0.00007 meters per meter (Westinghouse 1994, p. 3-20). Assuming this strain to be distributed over about 1,000 fractures (neglecting rock expansion), with zero initial aperture, in a lateral extent of the Culebra of about 800 meters (Westinghouse 1994, Figure 3-39), then the subsidence-induced fracture aperture is approximately 6×10^{-5} meters. Using the values for ρ, g, and μ, above, the vertical hydraulic conductivity of the Culebra can then be calculated, through an equation similar to above, to be 7 meters per year (2×10^{-7} meters per second). Thus, vertical hydraulic conductivity in the Culebra may be created as a result of repository-induced subsidence, although this is expected to be insignificant.

In summary, as a result of observations of subsidence associated with potash mines in the vicinity of the WIPP, the potential for subsidence to create fluid flow paths between the repository and units overlying the Salado has been eliminated from performance assessment calculations on the basis of low probability. The effects of repository-induced subsidence on hydraulic conductivity in the Culebra have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: W28
FEP Title: Nuclear Explosions

SCR Section Number SCR.2.3.6
Screening Decision: SO-P

Summary:

Editorial changes have been made for clarity as well as separating the two FEPs within the original SCR text into discrete arguments. Additional information is referenced to support the conclusions.

Italicized Text

Nuclear explosions have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text

Nuclear explosions have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years. For a *nuclear explosion* to occur, a critical mass of plutonium would have to undergo rapid compression to a high density. Even if a critical mass of plutonium could form in the system, there is no mechanism for rapid compression. Radioactivity inventories for the fissile radionuclides used in the 1996 CCA and the current CRA are presented in Table W14-B. The updated information for the WIPP disposal inventory of fissile material (Crawford 2003c and Leigh 2003a) indicates that the expected WIPP-scale quantity is 35% lower than previously estimated in TWBIR Rev3 (DOE 1996b). Thus, all CRA criticality screening arguments are conservatively bounded by the previous CCA screening arguments (Rechard et al. 1996, 2000, and 2001).

EPA FEP Number: W29, W30, W31, W72, and W73
FEP Title: Thermal Effects on Material Properties (W29)
Thermally Induced Stress Changes (W30)
Differing Thermal Expansion of Repository Components (W31)
Exothermic Reactions (W72)
Concrete Hydration (W73)

SCR Section Number: SCR.2.3.7 and 2.5.7
Screening Decision: SO-C

Summary

The thermal effects on material properties in the repository have been eliminated from performance assessment calculations on the basis of low consequence to performance of the disposal system. The screening decision remains valid. The FEP description has been updated.

The screening arguments remain valid because all potential sources of heat and elevated temperature have been evaluated and found not to produce high enough temperature changes to affect the repository's performance. Sources of heat within the repository include radioactive decay and exothermic chemical reactions such as backfill hydration and metal corrosion. The rates of these exothermic reactions are limited by the availability of brine in the repository. Concrete hydration in the seals is a significant source of heat, but it is relatively short-lived. Energy released by the hydration of the seal concrete could raise the temperature of the concrete to approximately 53°C, and that of the surrounding salt to approximately 38°C, one week after seal emplacement. Elevated temperatures will persist for a short period of time, perhaps a few years or a few decades. The thermal stresses from these temperatures and the temperatures in the concrete itself have been calculated to be below the design compressive strength for the concrete. Thus, thermal stresses should not degrade the long-term performance of the seals. In general, the various sources of heat do not appear to be great enough to jeopardize the performance of the disposal system. The screening decisions remains valid. The original FEP descriptions have been changed slightly to include the effects of water release during carbonation of the backfill, and the effects of formation of metastable hydrated carbonate minerals.

Italicized Text

The effects of thermally induced stress, differing thermal expansion of components, and thermal effects on material properties in the repository have been eliminated from performance assessment calculations on the basis of low consequence to performance of the disposal system.

The thermal effects of exothermic reactions, including concrete hydration, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system

FEP Text

Thermally induced stress could result in pathways for groundwater flow in the DRZ, in the anhydrite layers and marker beds, and through seals, or it could enhance existing pathways. Conversely, elevated temperatures will accelerate the rate of salt creep and mitigate fracture development. Thermal expansion could also result in uplift of the rock and ground surface overlying the repository, and thermal buoyancy forces could lift the waste upward in the salt rock.

The distributions of thermal stress and strain changes depend on the induced temperature field and the *differing thermal expansion of repository components* of the repository, which depends on the components' elastic properties. Potentially, *thermal effects on material properties* (such as permeability and porosity) could affect the behavior of the repository.

Radioactive decay (W13), nuclear criticality (W14), and exothermic reactions (W72 and W73), are three possible sources of heat in the WIPP repository. According to the new BIR data, the total radionuclide inventory increases from 7.44×10^6 (DOE 1996b) to 7.84×10^6 curies (Crawford 2003b), about a 6% increase. Such a small change will not result in a significant deviation from the possible temperature rise predicted in the CCA. Exothermic reactions in the WIPP repository include MgO hydration, MgO carbonation, aluminum corrosion, cement hydration, and CaO hydration (Bennett et al. 1996). Wang (1996) has shown that the temperature rise by an individual reaction is proportional to $\sqrt{VM}$, where V is the maximum rate of brine inflow into a waste panel (or a specified reaction rate) and M is the quantity of the reactant. According to the CRA PA calculations, the average brine inflow rate upon a human intrusion is 156 m^3/year, with a maximum value of 332 m^3/year. In the CCA, the maximum brine inflow rate was assumed to be 200 m^3/year. With the new rate of 332 m^3/year, it is estimated that the temperature rise by each exothermic reaction is increased by 29%. The changes in the amounts of reactants are tabulated below in tables W29-A and B:

Table W29-A: Changes in inventory quantities from the CCA to the CRA

	CCA	CRA	Change
MgO (tons)	85,600[a]	72760 (because of the elimination of mini-sacks)[a]	-15%
Cellulosics (tons)	5,940[b]	8,250[c]	39%
Plastics (tons)	3,740[b]	6050[c]	62%
Rubber (tons)	1,100[b]	2,090[c]	90%
Aluminum alloys (tons)	1,980[b]	2,090[c]	6%
Cement (tons)	8,540[b]	9,480[d]	11%

a. U.S. DOE (2001)
b. U.S. DOE (1996b). Only CH wastes are considered. Total volume of CH wastes is assumed to be 1.1×10^5 m^3.
c. Crawford (2003a). Only CH wastes are considered.
d. Leigh (2003b). This estimate includes both reacted and unreacted cement.

Temperature rises (°C) by exothermic reactions are revised as follows:

Table W29-B: CCA and CRA Exothermic Temperature Rises

	CCA*	CRA*
MgO hydration	< 4.5	< 5.3
Backfill Carbonation	< 0.6	< 0.7
Microbial degradation	< 0.8	< 1.0
Aluminum corrosion	< 6	< 7.9
Cement hydration	< 2	< 2.7

* All values are shown in degrees Celsius

For the CCA conditions following a drilling event, aluminum corrosion could, at most, result in a short-lived (two years) temperature increase of about 6°C above ambient room temperature (about 27°C) (Bennett et al. 1996). A temperature rise of 6°C represented the maximum that could occur as a result of any combination of exothermic reactions occurring simultaneously. Revised maximum temperature rises by exothermic reactions for the CRA are still less than 10 °C (as shown in Table 2- CCA and CRA Exothermic Temperature Rises). Such small temperature changes cannot affect material properties. Thus, *thermal effects on material properties* in the repository have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: W33
FEP Title: Movement of Containers

SCR Section Number SCR.2.3.8
Screening Decision: SO-C

Summary

Movement of containers has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening decision remains valid. The FEP description has been updated.

Italicized Text

Movement of containers and the mechanical effects of backfill have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Discussion

Movement of a waste container placed in salt occurs as a result two buoyancy mechanisms (Dawson and Tillerson 1978): (1) the density contrast between the waste container and the surrounding salt and (2) the temperature contrast between a salt volume that includes a heat source and the surrounding unheated salt. When the density of the waste container is greater than the density of the surrounding salt, the container sinks relative to the salt; whereas when the salt density is greater than the container density, the container rises relative to the salt. Similarly, when a discrete volume of salt within a large salt mass is heated, the heat raises the temperature of the discrete volume above that of the surrounding salt thereby inducing density contrasts and buoyant forces that initiate upward flow of the heated salt volume. In a repository setting, the source of the heat may be radioactive decay of the waste itself or exothermic reactions of the backfill materials and waste constituents, e.g., MgO hydration, MgO carbonation, aluminum corrosion, cement hydration, and CaO hydration.

For the CCA, the density of the compacted waste and the grain density of the halite in the Salado were assumed to be 2,000 kilograms per cubic meter and 2,163 kilograms per cubic meter, respectively. Because this density contrast is small, the movement of containers relative to the salt was considered minimal, particularly when drag forces on the waste containers were also considered. In addition, vertical movement initiated in response to thermally-induced density changes for high-level waste containers of a similar density to those at the WIPP were calculated to be approximately 1 foot (0.35 meters; Dawson and Tillerson 1978, p. 22). This calculated movement was considered conservative given that containers at the WIPP will generate much less heat and will, therefore, move less. As a result, container movement was eliminated from performance assessment calculations on the basis of low consequences to the performance of the disposal system.

The calculations performed for the CCA were based on estimates of the waste inventory. However, with the initiation of waste disposal, actual waste inventory is tracked and future waste stream inventories have been refined. Based on an evaluation of these data, two factors may affect the conclusions reached in the CCA concerning container movement.

The first factor is changes in density of the waste form. For the most part, waste density will remain as assumed in the CCA. According to new BIR data (Crawford 2003a), the revised waste density has changed by only 10 percent (lower). Some future waste streams may however be more highly compacted, perhaps having a density roughly three times greater than that assumed in the CCA. In calculations of container movement, Dawson and Tillerson (1978, p. 22) varied container density by nearly a factor of three (from 2,000 kilograms per cubic meter to 5,800 kilograms per cubic meter) and found that an individual dense container could move vertically as much as about 92 feet (28 meters). Given the geologic environment of the WIPP, a container would likely encounter a dense stiff unit (such as an anhydrite stringer) that would arrest further movement far short of this upper bound; however, because of the massive thickness of the Salado salt, even a movement of 92 feet would have little impact on performance.

The second inventory factor that could affect container movement is the composition of the waste (and backfills) relative to its heat production. Radioactive decay, nuclear criticality, and exothermic reactions are three possible sources of heat in the WIPP repository. According to the new inventory data, the total radionuclide inventory increases from 7.44×10^6 (DOE 1996) to 7.84×10^6 curies (Crawford 2003b), about a 6% increase. Such a small change will not result in a significant deviation from the possible temperature rise predicted in the CCA. Exothermic reactions in the WIPP repository include MgO hydration, MgO carbonation, aluminum corrosion, cement hydration, and CaO hydration (Bennett et al. 1996). Wang (1996) has shown that the temperature rise by an individual reaction is proportional to $\sqrt{VM}$, where V is the maximum rate of brine inflow into a waste panel (or a specified reaction rate) and M is the quantity of the reactant. According to the CRA PA calculations, the average brine inflow rate upon a human intrusion is 156 m^3/year, with a maximum value of 332 m^3/year. In the CCA, the maximum brine inflow rate was assumed to be 200 m^3/year. With the new rate of 332 m^3/year, it is estimated that the temperature rise by each exothermic reaction is increased by 29%. The changes in the amounts of reactants are tabulated below:

	CCA	CRA	Change
MgO (tons)	85,600[a]	72760 (because of the elimination of mini-sacks)[a]	-15%
Cellulosics (tons)	5,940[b]	8,250[c]	39%
Plastics (tons)	3,740[b]	6050[c]	62%
Rubber (tons)	1,100[b]	2,090[c]	90%
Aluminum alloys (tons)	1,980[b]	2,090[c]	6%
Cement (tons)	8,540[b]	9,480[d]	11%

a. (DOE 2001)
b. (DOE 1996b) Only CH wastes are considered. Total volume of CH wastes is assumed to be 1.1×10^5 m^3.
c. (Crawford 2003a). Only CH wastes are considered.
d. (Leigh 2003b). This estimate includes both reacted and unreacted cement.

Temperature rises (°C) by exothermic reactions are revised as follows[2]:

	CCA*	CRA*
MgO hydration	< 4.5	< 5.3
Backfill Carbonation	< 0.6	< 0.7
Microbial degradation	< 0.8	< 1.0
Aluminum corrosion	< 6	< 7.9
Cement hydration	< 2	< 2.7

* All values are shown in degrees Celsius

Note that the revised maximum temperature rises by exothermic reactions are still less than 10 °C.

Based on the small differences between the temperature and density assumed in the CCA compared to those determined using current BIR data, the conclusion about the importance of container movement reported in the CCA will not be affected, even when more highly compacted future waste streams are considered. Also, the effects of the revised maximum temperature rise and higher density future waste streams on container movement are competing factors (high density waste will sink, whereas the higher temperature waste-salt volume will rise) that may result in even less movement. Therefore, the original FEP screening decision remains valid.

[2] Ambient room temperatures are expected to be about 27°C (Bennett et al. 1996).

EPA FEP Number: **W34**
FEP Title: **Container Integrity**

SCR Section Number **SCR.2.3.8**
Screening Decision: **SO-C Beneficial**

Summary

Container integrity has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system. The screening decision remains valid. The FEP description has been updated.

Italicized Text

Consolidation of waste is accounted for in performance assessment calculations. Container integrity has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system. Movement of containers and the mechanical effects of backfill have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Consolidation of seals and mechanical degradation of seals are accounted for in performance assessment calculations. Flow through sealed WIPP investigation boreholes drilled from the surface has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Flow through isolated, unsealed underground boreholes is accounted for in performance assessment calculations.

FEP Text

Container integrity is required only for waste transportation. As in the CCA (Helton et al. 1998), the CRA calculations show that a significant fraction of steel and other Fe-base materials will remain undegraded over 10,000 years. For all undisturbed cases, at least 30% of the steels will remain uncorroded at the end of 10,000 years. In addition, it is assumed in both CCA and CRA calculations that there is no microbial degradation of plastic container materials in 75% of PA realizations (Wang and Brush 1996). All these undegraded container materials will (1) prevent the contact between brine and radionuclides; (2) decrease the rate and extent of radionuclide transport due to high tortuosity along the flow pathways and, as a result, increase opportunities for metallic Fe and corrosion products to beneficially reduce radionuclides to lower oxidation states. Therefore, the container integrity can be eliminated on the basis of its beneficial effect on retarding radionculide transport. Both CCA and CRA assume instantaneous container failure and waste dissolution according to the source-term model.

EPA FEP Number: W35
FEP Title: Mechanical Effects of Backfill

SCR Section Number: SCR.2.3.8
Screening Decision: SO-C

Summary:

The screening argument appears valid because the backfill to waste volume ratio is relatively small. In 2001, MgO mini-sacks were eliminated from the repository, which further decreases the backfill to waste volume ratio (EPA 2001). Although the backfill will provide additional resistance to creep closure, most of the resistance will be provided by the waste. Therefore, inclusion of backfill does not significantly reduce the total subsidence in the waste rooms, and screening based on low consequence appears appropriate. No changes have been made to the FEP description, screening argument or screening decision.

Italicized Text

The mechanical effects of backfill have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The chemical conditioners or backfill added to the disposal room will act to resist creep closure. However, calculations have shown that because of the high porosity and low stiffness of the waste and the high waste to potential backfill volume, inclusion of backfill does not significantly decrease the total subsidence in the waste emplacement area or disposal room (Westinghouse 1994). Since 2001, DOE has eliminated MgO mini sacks from the repository reducing the total inventory from 85,600 short tons to 74,000 short tons, which further reduces the potential backfill volume (EPA 2001). Therefore, the *mechanical effects of backfill* have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: W38
FEP Title: Investigation Boreholes

SCR Section Number: SCR.2.3.8
Screening Decision: NA

Summary:

The effects of investigation boreholes (whether sealed or not) that penetrate the disposal horizon but do not intersect the waste panels are encompassed by the arguments made in FEPs H31 (Natural borehole fluid flow) and H33 (Flow through undetected boreholes). FEP W38 has been deleted from the FEPs baseline because it is redundant. The effects of drillholes drilled from the underground are accounted for in performance assessment by assumptions about the permeability of the DRZ. FEPs H31 (Natural borehole fluid flow) and H33 (Flow through undetected boreholes) encompasses the effects of W38. Therefore, W38, Investigation Boreholes, has been deleted from the FEPs Baseline.

EPA FEP Number: **W43**
FEP Title: **Convection**

SCR Section Number: **SCR.2.4.3**
Screening Decision: **SO-C**

Summary

Convection has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. This screening decision remains valid. The FEP description has been updated

Italicized text

Convection has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Temperature differentials in the repository could initiate *convection*. The resulting thermally-induced brine flow or thermally-induced two-phase flow could influence contaminant transport. Potentially, thermal gradients in the disposal rooms could drive the movement of water vapor. For example, temperature increases around waste located at the edges of the rooms could cause evaporation of water entering from the DRZ. This water vapor could condense on cooler waste containers in the rooms and could contribute to brine formation, corrosion, and gas generation.

Nuclear criticality (W13), radioactive decay (W14), and exothermic reactions (W72) are three possible sources of heat in the WIPP repository.

The characteristic velocity, Vi, for convective flow of fluid component I in an unsaturated porous medium is given by (from Hicks 1996);

$$V_i \approx -\frac{k_i}{\mu_i}\left(\alpha_i \rho_{i0} g \Delta T\right),$$

where α_i (per degree) is the coefficient of expansion of the i^{th} component, k_i is the intrinsic permeability (square meters), μ_i is the fluid viscosity (pascal second), ρ_{i0} (kilograms per cubic meter) is the fluid density at a reference point, g is the acceleration of gravity, and ΔT is the change in temperature. This velocity may be evaluated for the brine and gas phases expected in the waste disposal region.

For a temperature increase of 10°C, the characteristic velocity for convective flow of brine in the DRZ around the concrete shaft seals is approximately 7×10^{-4} meters per year (2×10^{-11} meters per second), and the characteristic velocity for convective flow of gas in the DRZ is approximately 1×10^{-3} meters per year (3×10^{-11} meters per second) (Hicks 1996). For a temperature increase of 25°C, the characteristic velocity for convective flow of brine in the concrete seals is approximately 2×10^{-7} meters per year (6×10^{-15} meters per second), and the characteristic velocity for convective flow of gas in the concrete seals is approximately 3×10^{-7} meters per year (8×10^{-15} meters per second) (Hicks 1996). These values of Darcy velocity are much smaller than the expected values associated with brine inflow to the disposal rooms of fluid flow resulting from gas generation. In addition, the buoyancy forces generated by smaller temperature contrasts in the DRZ, resulting from backfill and concrete hydration and radioactive decay, will be short-lived and insignificant compared to the other driving forces for fluid flow. The short-term concrete seals will be designed to function as barriers to fluid flow for at least 100 years after emplacement, and seal permeability will be minimized (Wakeley et al. 1995). Thus, temperature increases associated with concrete hydration will not result in significant buoyancy driven fluid flow through the concrete seal system. In summary, temperature changes in the disposal system will not cause significant thermal convection. Furthermore, the induced temperature gradients will be insufficient to generate water vapor and drive significant moisture migration.

Temperature effects on fluid viscosity would be most significant in the DRZ surrounding the hydrating concrete seals (where temperatures of approximately 38°C are expected). The viscosity of pure water decreases by about 19 percent over a temperature range of between 27°C and 38°C (Batchelor 1973, p. 596). Although at a temperature of 27°C, the viscosity of Salado brine is about twice that of pure water (Rechard et al. 1990, a-19), the magnitude of the variation in brine viscosity between 27°C and 38°C will be similar to the magnitude of the variation in viscosity of pure water. The viscosity of air over this temperature range varies by less than 7 percent (Batchelor 1973, p. 594) and the viscosity of gas in the waste disposal region over this temperature range is also likely to vary by less than 7 percent. The Darcy fluid flow velocity for a porous medium is inversely proportional to the fluid viscosity. Thus, increases in brine and gas flow rates may occur as a result of viscosity variations in the vicinity of the concrete seals. However, these viscosity variations will persist only for a short period in which temperatures are elevated, and, thus, the expected variations in brine and gas viscosity in the waste disposal region will not affect the long-term performance of the disposal system significantly.

For the CCA conditions following a drilling event, aluminum corrosion could, at most, result in a short-lived (two years) temperature increase of about 6°C. A temperature rise of 6°C represented the maximum that could occur as a result of any combination of exothermic reactions occurring simultaneously. Revised maximum temperature rises by exothermic reactions for the CRA are still less than 10 °C (as shown in Table 2- CCA and CRA Exothermic Temperature Rises). Such small temperature changes cannot affect material properties.

In summary, temperature changes in the disposal system will not cause significant thermally-induced two-phase flow. Thermal convection has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **W46**
FEP Title: **Effects of Pressure on Microbial Gas Generation**

SCR Section Number **SCR.2.5.1.1**
Screening Decision: **SO-C**

Summary

The effects of pressure on microbial gas generation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening decision remains valid. The FEP description has been updated.

Italicized Text

The effects of pressure and radiation on microbial gas generation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Directly relevant to WIPP conditions, the gas generation experiments with actual waste components at Argonne National Laboratory provide no indication of any enhancement of pressured N_2 atmosphere (2150 psia) on microbial gas generation (Felicione et al. 2001). In addition, microbial breakdown of cellulosic material, and possibly plastics and other synthetic materials in the repository, will produce mainly CO_2 and CH_4 with minor amounts of N_2O, N_2, and H_2S. The accumulation of these gaseous species will contribute the total pressure in the repository. Increases in the partial pressures of these reaction products could potentially limit gas generation reactions. However, such an effect is not taken into account in WIPP PA calculations. The rate of microbial gas production will depend upon the nature of the microbial populations established, the prevailing conditions, and the substrates present. Microbial gas generation from *degradation of organic material* is accounted for in performance assessment calculations.

Chemical reactions may occur depending on, among other things, the concentrations of available reactants, the presence of catalysts and the accumulation of reaction products, the biological activity, and the prevailing conditions (for example, temperature and pressure). Reactions that involve the production or consumption of gases are often particularly influenced by pressure because of the high molar volume of gases. The effect of high total pressures on chemical reactions is generally to reduce or limit further gas generation.

Few data exist from which the *effects of pressure on microbial gas generation* reactions that may occur in the WIPP can be assessed and quantified. Studies of microbial activity in deep-sea environments suggest (for example, Kato et al. 1994, p. 94) that microbial gas generation reactions are less likely to be limited by increasing pressures in the disposal rooms than are inorganic gas generation reactions (for example, corrosion). Consequently, the effects of pressure on microbial gas generation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **W47**
FEP Title: **Effects of Radiation on Microbial Gas Generation**

SCR Section Number **SCR.2.5.1.1**
Screening Decision: **SO-C**

Summary

The effects of radiation on microbial gas generation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening decision remains valid. The FEP description has been updated. The FEP description has been updated.

Italicized Text

The effects of pressure and radiation on microbial gas generation have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Radiation may slow down microbial gas generation rates, but such an effect is not taken into account in WIPP PA calculations. According to the new BIR data, the total radionuclide inventory increases from 7.44 x 10^6 (DOE 1996b) to 7.84 x 10^6 (Crawford 2003c) curies, about a 6% increase. As a matter of fact, the radionuclide inventory in the contact handle waste, which accounts for the most volume of WIPP wastes, even decreases from 6.42 x 10^6 (DOE 1996b) to 5.89 x 10^6 curies (Crawford 2003c). Such a small increase will not change the original screening argument.

Experiments investigating microbial gas generation rates suggest that the effects of alpha radiation from TRU waste is not likely to have significant effects on microbial activity (Barnhart et al. 1980; Francis 1985). Consequently, the *effects of radiation on microbial gas generation* have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: W50
FEP Title: Galvanic Coupling

SCR Section Number SCR.2.5.1.2 Corrosion
Screening Decision: SO-C

Summary:

The original screening argument confused galvanic coupling internal and external to the repository (see W95). As such, the original screening decision for galvanic coupling was screened out on probability however, it is more appropriate to screen this FEP on consequence. The screening decision has therefore been changes to SO-C and a clear distinction between which FEP considers internal and external coupling was included in the FEP discussions.

Consideration of the present FEP, Galvanic Coupling, is restricted to consideration of effects between or among materials within the repository. Galvanic coupling with materials outside the repository is considered in FEP W95, Galvanic Coupling.

Galvanic coupling (within the repository) is unlikely to occur on a large scale. On a very small scale, galvanic coupling could occur whenever two dissimilar metals are in contact and a conducting medium is present. However, the resulting corrosion would cause the same effects as the other corrosion processes already included in the assessments. Thus, galvanic coupling, as a distinct corrosion mechanism, would have negligible effects on repository performance.

Galvanic coupling has been screened out on the basis of low consequence. No new information has become available that affects the screening argument; the FEP screening argument and screening decision remain unchanged.

Italicized Text

The effects of Galvanic Coupling have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Galvanic coupling (i.e. establishing an electrical current through chemical processes) could lead to the propagation of electric potential gradients between metals in the waste form, canisters, and other metals external to the waste form, potentially influencing corrosion processes, gas generation rates and chemical migration.

Metallic ore bodies external to the repository are non-existent (Appendix GCR) and therefore galvanic coupling between the waste and metals external to the repository would not occur. However, a variety of metals will be present within the repository as waste metals and containers, creating a potential for formation of galvanic cells over short distances. As an example, the presence of copper could influence rates of hydrogen gas production resulting from the corrosion of iron. The interactions between metals depend upon their physical disposition and the prevailing solution conditions, including pH and salinity. Good physical and electrical contact between the metals is critical to the establishment of galvanic cells.

Consequently, given the preponderance of iron over other metals within the repository and the likely passivation of many nonferrous materials, the influence of these electrochemical interactions on corrosion, and therefore gas generation, is expected to be minimal. Therefore, the effects of galvanic coupling have been eliminated from performance assessment calculations on the basis of low consequence.

EPA FEP Number: W52
FEP Title: **Radiolysis of Brine**

SCR Section Number: SCR.2.5.1.3
Screening Decision: SO-C

Summary:

Gas generation from radiolysis of brine has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. There is no new information available that affects the screening decision; the FEP screening argument and screening decision remain unchanged. Additional information has been added to the screening discussions.

Italicized Text

Gas generation from radiolysis of brine has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Radiolysis of brine in the WIPP disposal rooms, and of water in the waste, will lead to the production of gases and may significantly affect the oxygen content of the rooms. This in turn will affect the prevailing chemical conditions and potentially the concentrations of radionuclides that may be mobilized in the brines.

The overall reaction for the radiolysis of water in the waste and brine is

$$H_2O \rightleftharpoons H_2 + 1/2O_2$$

However, the production of intermediate oxygen-bearing species that may subsequently undergo reduction, will lead to reduced oxygen gas yields. The remainder of this section is concerned with the physical effects of gas generation by radiolysis of brine.

Reed et al. (1993) studied radiolytic gas generation during experiments lasting between 155 and 182 days. These experiments involved both synthetic brines similar to those sampled from the Salado at the WIPP repository horizon, and brines occurring in reservoirs in the Castile, as well as real brines sampled from the Salado in the repository workings. The brines were spiked with $^{239}Pu(VI)$ at concentrations between 6.9×10^{-9} and 3.4×10^{-4} molal. During these relatively short-term experiments, hydrogen gas was observed as the product of radiolysis. Oxygen gas was not observed; this was attributed to the formation of intermediate oxygen-bearing species. However, given sufficient exposure to alpha-emission, oxygen production may reach 50 percent that of hydrogen.

An estimate of the potential rate of gas generation due to the radiolysis of brine, R_{RAD}, can be made by making the following assumptions:

- Gas production occurs following the reaction above, so that 1.5 moles of gas are generated for each mole of water consumed.
- Gas production occurs as a result of the alpha decay of ^{239}Pu.
- ^{239}Pu concentrations in the disposal room brines are controlled by solubility equilibria.
- All of the dissolved plutonium is ^{239}Pu.

R_{RAD} is then given by

$$R_{RAD} = \frac{Y_g C_{Pu} SA_{Pu} \bar{E}\alpha V_B}{N_D N_A}$$

$$R_{RAD} = \frac{\left(\frac{1.5 \text{ molecule gas}}{\text{molecule } H_2O}\right)\left(3.15\times10^{7}\ \frac{\text{sec}}{\text{yr}}\right)\left(3\times10^{-4}\ \frac{\text{mol}}{\text{L}}\right)\left(5.42\times10^{11}\ \frac{\text{Bq}}{\text{mol}}\right)\left(5.15\times10^{6}\ \frac{\text{eV}}{\text{dis}}\right)\left(\frac{0.015\, H_2O}{100\text{eV}}\right)\left(4.36\times10^{8}\,\text{L}\right)}{\left(8\times10^{5}\ \text{drums}\right)\left(6.022\times10^{23}\ \frac{\text{molecules}}{\text{mole}}\right)}$$

R	=	rate of gas production (moles per drum per year)
Y_g	=	radiolytic gas yield, in number of moles of gas produced per number of water molecules consumed
C_{Pu}	=	maximum dissolved concentration of plutonium (molar)
SA_{Pu}	=	specific activity of ^{239}Pu (5.42×10^{11} becquerels per mole)
$\bar{E}\alpha$	=	average energy of α-particles emitted during ^{239}Pu decay (5.15×10^{6} eV)
G	=	number of water molecules split per 100 eV of energy transferred from alpha-particles
V_B	=	volume of brine in the repository (liters)
N_D	=	number of CH drums in the repository ($\sim 8 \times 10^{5}$)
N_A	=	Avogadro constant (6.022×10^{23} molecules per mole)

The value of G used in this calculation has been set at 0.015, the upper limit of the range of values observed (0.011 to 0.015) during experimental studies of the effects of radiation on WIPP brines (Reed et al. 1993). A maximum estimate of the volume of brine that could potentially be present in the disposal region has been made from its excavated volume of 436,000 cubic meters. This estimate, in particular, is considered to be highly conservative because it makes no allowance for creep closure of the excavation, or for the volume of waste and backfill that will be emplaced, and takes no account of factors that may limit brine inflow. These parameter values lead to an estimate of the potential rate of gas production due to the radiolysis of brine of 0.6 moles per drum per year.

Assuming ideal gas behavior and repository conditions of 30 °C and 14.8 MPa (lithostatic pressure), this is equivalent to approximately 6.8×10^{4} liters per year.

Potential gas production rates from other processes that will occur in the repository are significantly greater than this. For example, under water-saturated conditions, microbial degradation of cellulosic waste has the potential to yield between 1.3×10^6 and 3.8×10^7 liters per year; anoxic corrosion of steels has the potential to yield up to 6.3×10^5 liters per year.

In addition to the assessment of the potential rate of gas generation by radiolysis of brine given above, a study of the likely consequences on disposal system performance has been undertaken by Vaughn et al. (1995). A model was implemented in BRAGFLO to estimate radiolytic gas generation in the disposal region according to the equation above. A set of BRAGFLO simulations was performed to assess the magnitude of the influence of the radiolysis of brine on contaminant migration to the accessible environment. The calculations considered radiolysis of H_2O by 15 isotopes of thorium, plutonium, uranium, and americium. Conditional complementary cumulative distribution functions (CCDFs) of normalized contaminated brine releases to the Culebra via a human intrusion borehole and the shaft system, as well as releases to the subsurface boundary of the accessible environment via the Salado interbeds, were constructed and compared to the corresponding baseline CCDFs calculated excluding radiolysis. The comparisons indicated that radiolysis of brine does not significantly affect releases to the Culebra or the subsurface boundary of the accessible environment under disturbed or undisturbed conditions (Vaughn et al. 1995). Although the analysis of Vaughn et al. (1995) used data that are different than those used in the performance assessment calculations, estimates of total gas volumes in the repository are similar to those considered in the analysis performed by Vaughn et al. (1995).

Therefore, gas generation by radiolysis of brine has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **W53**
FEP Title: **Radiolysis of Cellulose**

SCR Section Number: **SCR.2.5.1.3**
Screening Decision: **SO-C**

Summary

Gas generation from radiolysis of cellulosics has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening decision remains valid.

Italicized Text

Gas generation from radiolysis of brine and cellulosics, and helium production, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The formation and transport of radioactive gases has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Molecke (1979) compared experimental data on gas production rates caused by *radiolysis of cellulose* and other waste materials with gas generation rates by other processes including bacterial (microbial) waste degradation. The comparative gas generation rates reported by Molecke (1979, p. 4) are given in terms of most probable ranges, using units of moles per year per drum, for drums of 0.21 cubic meters in volume. A most probable range of 0.005 to 0.011 moles per year per drum is reported for gas generation due to radiolysis of cellulosic material (Molecke 1979, p. 4). As a comparison, a most probable range of 0.0 to 5.5 moles per year per drum is reported for gas generation by bacterial degradation of waste.

The data reported by Molecke (1979) are consistent with more recent gas generation investigations made under the WIPP program, and indicate that radiolysis of cellulosic materials will generate significantly less gas than other gas generation processes. Gas generation from radiolysis of cellulosics therefore can be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Radiolytic gas generation is controlled by the radioactivity of wastes and the waste properties. According to the new BIR data, the total radionuclide inventory increases from 7.44×10^6 (DOE 1996b) to 7.84×10^6 (Crawford 2003c) curies, about a 6% increase. Interestingly, the radionuclide inventory in the contact handled waste, which accounts for the most volume of WIPP wastes, decreases from 6.42×10^6 (DOE 1996b) to 5.89×10^6 curies (Crawford 2003c). Such a small increase will not affect radiolytic gas generation. However, the new inventory data indicates a 39% increase in cellulose (Crawford 2003a). Because the additional cellulose component is mainly derived from the Advanced Mixed Waste Treatment Plant (AMWTP) wastes, which have relatively low radioactivity, the increase in total cellulose quantity will not significantly affect the prediction of total radiolytic gas generation. Therefore, the original screening argument remains valid.

Radiolytic gas generation is also limited by transportation requirements, which state that the hydrogen generated in the innermost layer of confinement must be no more than 5% over 60 days (DOE 2000). Thus, the maximum rate allowed for transportation is 0.201 m^3/drum x 5% x 1000 L/m^3/60 days x 365 days/year = 61 L/drum/year, smaller than the maximum microbial gas generation rate. Note that this estimate is very conservative and the actual rates are even smaller. It is a general consensus within the international research community that the effect of radiolytic gas generation on the long-term performance of a low/intermediate level waste repository is negligible (Rodwell et al. 1999).

EPA FEP Number: W54
FEP Title: Helium Gas Production

SCR Section Number: SCR.2.5.1.3
Screening Decision: SO-C

Summary:

The maximum possible generation rate of helium will be insignificant compared to other possible sources of gas generation within the repository. Consequently, the effects of helium production have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. No new information has become available that affects the screening argument; the FEP screening argument and screening decision remain unchanged. Additional information has been added to the screening discussions.

Italicized Text

Gas generation from helium production has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Helium gas production will occur by the reduction of α-particles (helium nuclei) emitted from the waste. The maximum amount of helium that could be produced can be calculated from the number α-particles generated during radioactive decay. The α-particles are converted to helium gas by the following reaction:

$$^{4}He^{2+} + 2e^{-} \rightarrow He(g)$$

The inventory (I) that may be emplaced in the repository is approximately 4.07 million curies or 1.5×10^{17} becquerels (see Appendix BIR). Assuming that the inventory continues to yield α-particles at this rate throughout the 10,000-year regulatory period the maximum rate of helium gas produced (R_{He}) may be calculated from

$$R_{He} = \frac{I\left(\frac{1\ \text{He atom}}{\alpha\text{ - decay}}\right)}{N_A}$$

R_{He} is the rate of helium gas production in the repository (mole per second)
I is the waste inventory, 1.5×10^{17} becquerels, assuming that 1 becquerel is equal to 1 α-decay per second, and N_A is Avogadro constant (6.022×10^{23} atoms per mole). These assumptions regarding the inventory lead to maximum estimates for helium production because some of the radionuclides will decay by beta and gamma emission.

R_{He} is approximately 5.5×10^{-7} moles per second based on an alpha emitting inventory of 4.07 million curies. Assuming ideal gas behavior and repository conditions of 30 °C and 14.8 MPa or 146 atm (lithostatic pressure), yields approximately 1.3 liters per year.

Gas production rates by microbial degradation of organic materials and anoxic corrosion of steel are likely to be significantly greater than 1.3 liters per year. For example, anoxic corrosion of steels is estimated to yield 0 to 6.3×10^5 liters of H_2 per year (CCA Chapter 6.0, Section 6.4, and Appendix MASS). Even if gas production by microbes and corrosion was minimal and helium production dominated gas generation, the effects would be of low consequence because of the low total volume.

The effects of helium production have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: W55
FEP Title: Radioactive Gases

SCR Section Number: SCR.2.5.1.3
Screening Decision: SO-C

Summary:

The formation and transport of radioactive gases has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. No new information has become available that affects the screening argument; the FEP screening argument and screening decision remain unchanged. Additional information has been added to the screening discussions.

Italicized Text

The formation and transport of radioactive gases has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Based on the composition of the anticipated waste inventory as described in Appendix BIR (DOE 1996b), the radioactive gases that will be generated in the repository are radon and ^{14}C labeled carbon dioxide (CO_2) and methane (CH_4).

Appendix BIR indicates that a small amount of ^{14}C, 2.88 grams, or 12.85 curies, will be disposed in the WIPP. This amount is insignificant in comparison with the 40 CFR § 191.13 cumulative release limit for ^{14}C.

Notwithstanding this comparison, consideration of transport of radioactive gases could potentially be necessary in respect of the 40 CFR § 191.15 individual protection requirements. ^{14}C may partition into carbon dioxide and methane formed during microbial degradation of cellulosic and other organic wastes (for example, rubbers and plastics). However, total fugacities of CO_2 in the repository are expected to be very low because of the action of the MgO backfill which will lead to incorporation of CO_2 in solid $MgCO_3$. Similarly, interaction of CO_2 with cementitious wastes will limit CO_2 fugacities by the formation of solid $CaCO_3$. Thus, because of the formation of solid carbonate phases in the repository, significant transport of ^{14}C as $^{14}CO_2$ has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Potentially significant volumes of CH_4 may be produced during the microbial degradation of cellulosic waste. However, volumes of $^{14}CH_4$ will be small given the low total inventory of ^{14}C, and the tendency of ^{14}C to be incorporated into solid carbonate phases in the repository. Therefore, although transport of ^{14}C could occur as $^{14}CH_4$, this effect has been eliminated from the current performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Radon gas will contain proportions of the alpha emitters ^{219}Rn, ^{220}Rn, and ^{222}Rn. All of these have short half-lives, but ^{222}Rn is potentially the most important because it is produced from the abundant waste isotope, ^{238}Pu, and because it has the longest half-life of the radon isotopes (≈ 4 days). ^{222}Rn will exhibit secular equilibrium with its parent ^{226}Ra, which has a half-life of 1600 years. Consequently, ^{222}Rn will be produced throughout the 10,000-year regulatory time period. Conservative analysis of the potential ^{222}Rn inventory suggests activities of less than 716 curies at 10,000 years (Bennett 1996).

Direct comparison of the estimated level of ^{222}Rn activity with the release limits specified in 40 CFR § 191.13 cannot be made because the release limits do not cover radionuclides with half-lives less than 20 years. For this reason, production of radon gas can be eliminated from the performance assessment calculations on regulatory grounds. Notwithstanding this regulatory argument, the small potential radon inventory means that the formation and transport of radon gas can also be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: W57
FEP Title: **Kinetics of Speciation**

SCR Section Number: SCR.2.5.2
Screening Decision: SO-C

Summary:

The EPA has agreed that the kinetics of speciation is appropriately screened out on the basis of the absence of consequence to the disposal system. No new information that would change the screening argument has arisen since the submission of the CCA. The original screening discussions have been edited for clarity of expression.

Italicized Text

The effects of reaction kinetics in chemical speciation reactions have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Chemical speciation of actinides describes the composition and relative distribution of dissolved species, such as the hydrated metal ion, or complexes, whether with organic or inorganic ligands. Conditions affecting chemical speciation include temperature, ionic strength, ligand concentration and pH of the solution. Some ligands, such as hydroxide, may act to decrease actinide solubility, while others, such as citrate, frequently have the opposite influence, often increasing actinide solubility.

Disposal Room Equilibrium Conditions

The concentrations of radionuclides that can be dissolved in brines within the disposal rooms will depend on the thermodynamic stabilities and solubilities of the respective metal complexes. The FMT calculations and database input used to determine the brine solubilities of radionuclides takes into account the expected conditions, including temperature, ionic strength, pH, and ligand concentration. The chemical speciation at equilibrium is accounted for in performance assessment calculations in the estimates of radionuclide solubility in the disposal rooms.

Kinetics of Complex Formation

The waste that is emplaced within the WIPP contains radionuclides, including actinides or actinide bearing materials in solid phases, e.g. metal oxides, salts, coprecipitated solids, and contaminated objects. In the event of contact with brine, the solution phase concentration of dissolved radionuclides is controlled both by the solution composition, and by the kinetics of dissolution of the solid phases, effectively approaching equilibrium from undersaturation. Solution complexation reactions of most metal ions with common inorganic ligands, such as carbonate and hydroxide, and with organic ligands such as acetate, citrate, oxalate, and EDTA are kinetically very fast, reaching equilibrium in fractions of a second, an inconsequentially short time increment on the scale of the 10,000 year regulatory period. Reactions of these types are generally so fast that special techniques must be adopted to measure the reaction rates; as a practical matter, the reaction rate is limited by the mixing rate when metal solutions are combined with ligand solutions. As a result, the rate of approach to an equilibrium distribution of solution species takes place much more rapidly than dissolution, making the dissolution reaction the rate limiting step. The effects of reaction kinetics in aqueous systems are discussed by Lasaga et al. (1994) who suggest that in contrast to many heterogeneous reactions, homogeneous aqueous geochemical speciation reactions involving relatively small inorganic species occur rapidly and are accurately described by thermodynamic equilibrium models that neglect explicit consideration of reaction kinetics.

For that reason, the rate at which solution species approach equilibrium distribution is of no consequence to repository performance. Kinetics of chemical speciation may be eliminated from performance assessment calculations on the basis of no consequence.

EPA FEP Number: **W59**
FEP Title: **Precipitation of Secondary Minerals**

SCR Section Number: **SCR.2.5.3**
Screening Decision: **SO-C Beneficial**

Summary:

Precipitation of secondary minerals in the disposal room and in geologic units will lead to reductions in nuclide concentrations via the sequestration of radionuclides by coprecipitation and by encapsulation of radionuclide precipitates, and will retard radionuclide transport through sorption. Within the disposal room, metal oxides/oxy-hydroxides will form by corrosion of waste packages and waste components; brucite will form by hydration of MgO backfill; carbonate minerals will form by carbonation of MgO backfill and cement phases; secondary cement alteration phases will form through brine-cement waste form interactions; and chloride and sulfate minerals will be precipitated due to water uptake during hydration and corrosion reactions. In geologic units above the repository, iron oxides/oxy-hydroxides, carbonates, sulfates may form as groundwaters mix. Mineral precipitation in geologic units above the repository is assumed to be uniform, and in addition to sorbing or sequestering radionuclides, will be beneficial by reducing permeability and slowing the groundwater flow. The screening decision remains valid. The original FEP description has not been changed. Additional information has been added to the screening discussions.

Italicized Text

The formation of radionuclide bearing precipitates from groundwaters and brines and the associated retardation of contaminants have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

FEP Text

Dissolution of waste and *precipitation of secondary minerals* are relevant because of their control of the concentrations of radionuclides in any brines and groundwaters and the rates of contaminant transport. Waste dissolution is accounted for in performance assessment calculations. Mineral dissolution and precipitation processes also have the potential to alter rock permeabilities and, hence, groundwater flow. Mineral precipitation, for example, may block pores or fill fractures, resulting in modification of the groundwater flow field.

At low temperatures, precipitation and dissolution reactions are caused by changes in fluid chemistry that result in chemical undersaturation or oversaturation (Bruno and Sandino 1987, p. 12). Precipitation can be divided into two stages: nucleation and crystal growth. Following nucleation, growth rates depend on the rates of surface processes and the transport of materials to the site of growth. The style of mineral dissolution often depends on whether the rate-controlling process is a surface reaction or is related to the transport of material away from the site of dissolution. The former case may result in selective dissolution along crystallographically controlled features, whereas the latter may lead to rapid bulk dissolution (Berner 1981, p. 117). Thus, it is expected that a range of kinetic behavior will be exhibited by different mineral precipitation and dissolution reactions in different geochemical systems.

Geological Units

During groundwater flow, any radionuclide precipitation processes that occur will lead to reduced contaminant transport. No credit is given to the potentially beneficial occurrence of such reactions in performance assessment calculations. The formation of radionuclide-bearing precipitates from groundwaters and brines and the associated retardation of contaminants has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system

EPA FEP Number: **W60**
FEP Title: **Kinetics of Precipitation and Dissolution**

SCR Section Number: **SCR.2.5.3**
Screening Decision: **SO-C Beneficial**

Summary:

During the original WIPP Certification, the EPA questioned the screening argument for this FEP. The EPA stated in EPA TSD Scope of Performance Assessment, W60 Kinetics of Precipitation and Dissolution,

> The screening argument in SCR.2.5.3 appears reasonable to EPA. Initially, EPA thought the argument appeared questionable because the CCA assumed that precipitation reactions are always rapid and complete. As a result, the EPA questioned the gas pressures in the repository, the chemical conditions, and the actinide solubilities. The DOE has since submitted experimental results indicating that the predicted reactions occur and time frames are somewhat rapid. The EPA reconsidered this assessment and concluded that the precipitation assumptions are necessary (and conservative), and are supported by experimental data.

Other than that stated above, no new information that would change the screening argument has arisen since the submission of the CCA. The original text has been edited for clarity of expression.

Italicized Text

The effect of reaction kinetics in controlling the rate of waste dissolution within the disposal rooms has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

FEP Text

Precipitation and Dissolution

Dissolution of waste and *precipitation of secondary minerals* control the concentrations of radionuclides in brines and can influence rates of contaminant transport. Waste dissolution is accounted for in performance assessment calculations. The formation of radionuclide-bearing precipitates from groundwaters and brines and the associated retardation of contaminants have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

At low temperatures, precipitation and dissolution reactions are caused by changes in fluid chemistry that result in chemical undersaturation or oversaturation (Bruno and Sandino 1987). Precipitation can be divided into two stages: nucleation and crystal growth. Following nucleation, growth rates depend on the rates of surface processes and the transport of materials to the growth site. Mineral dissolution often depends on whether a surface reaction or transport of material away from the reaction site act as the rate controlling process. The former case may cause selective dissolution along crystallographically controlled features, whereas the latter may induce rapid bulk dissolution (Berner 1981). Thus, a range of kinetic behaviors will be exhibited by different mineral precipitation and dissolution reactions in geochemical systems.

The following subsections discuss dissolution of waste in the disposal rooms and precipitation in geological units of the WIPP disposal system.

Disposal Room

The waste that is emplaced within the WIPP contains radionuclides, including actinides or actinide bearing materials in solid phases, e.g. metal oxides, salts, coprecipitated solids, and contaminated objects. In the event of contact with brine, the solution phase concentration of dissolved radionuclides is controlled both by the solution composition, and by the kinetics of dissolution of the solid phases, effectively approaching equilibrium from undersaturation. Solution complexation reactions of most metal ions with common inorganic ligands, such as carbonated and hydroxide, and with organic ligands such as acetate, citrate, oxalate, and EDTA are kinetically very fast, reaching equilibrium in less than one second, which is infinitesimally small on the time scale of the 10,000 year regulatory period. The rate at which thermodynamic equilibrium is approached between solution composition and the solubility controlling solid phases will be limited by rate of dissolution of the solid materials in the waste. As a result, until equilibrium is reached, the solution concentration of the actinides will be lower than the concentration that is predicted based upon equilibrium of the solution phase components with the solubility limiting solid phases. The WIPP actinide source term model, which describes interactions of the waste and brine, is described in detail in CCA Section 6.4.3.5. The assumption of instantaneous equilibrium in waste dissolution reactions is a conservative approach, yielding maximum concentration estimates for radionuclides in the disposal rooms because a time weighted average resulting from a kinetically accurate estimate of solution compositions would have lower concentrations at early times. Waste dissolution at the thermodynamic equilibrium solubility limit is accounted for in performance assessment calculations. However, the *kinetics of dissolution* within the disposal rooms has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

Geological Units

During groundwater flow, radionuclide precipitation processes that occur will lead to reduced contaminant transport. No credit is given in performance assessment calculations to the potentially beneficial occurrence of precipitation reactions. The formation of radionuclide-bearing precipitates from groundwaters and brines and the associated retardation of contaminants have been eliminated from performance assessment calculations on the basis of beneficial consequence to disposal system performance. As a result *kinetics of precipitation* also has been eliminated from performance assessment calculations because no credit is taken for precipitation reactions.

EPA FEP Number: **W65**
FEP Title: **Reduction-Oxidation Fronts**
SCR Section Number: **SCR.2.5.5**
Screening Decision: **SO-P**

Summary:

Large-scale reduction-oxidation fronts have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years. There is no new information that would change the screening decision. Changes have been made to the FEP text to remove reference to other FEP descriptions, screening arguments and screening decisions.

Italicized Text

The migration of reduction-oxidation fronts through the repository has been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text

The development of *reduction-oxidation fronts* in the disposal system may affect the chemistry and migration of radionuclides. Reduction-oxidation fronts separate regions that may be characterized, in broad terms, as having different oxidation potentials. On either side of a reduction-oxidation front, the behavior of reduction-oxidation-sensitive elements may be controlled by different geochemical reactions. Elements that exhibit the greatest range of oxidation states (for example, U, Np, Pu) will be the most affected by reduction-oxidation front development and migration. The migration of reduction-oxidation fronts may occur as a result of diffusion processes, or in response to groundwater flow, but will be restricted by the occurrence of heterogeneous buffering reactions (for example, mineral dissolution and precipitation reactions). Indeed, these buffering reactions cause the typically sharp, distinct nature of reduction-oxidation fronts.

Of greater significance is the possibility that the flow of fluids having different oxidation potentials from those established within the repository might lead to the development and migration of a large-scale reduction-oxidation front. Reduction-oxidation fronts have been observed in natural systems to be the loci for both the mobilization and concentration of radionuclides, such as uranium. For example, during investigations at two uranium deposits at Poços de Caldas, Brazil, uranium was observed by Waber (1991) to be concentrated along reduction-oxidation fronts at the onset of reducing conditions by its precipitation as UO_2. In contrast, studies of the Alligator Rivers uranium deposit in Australia by Snelling (1992) indicated that the movement of the relatively oxidized weathered zone downwards through the primary ore body as the deposit was eroded and gradually exhumed led to the formation of secondary uranyl-silicate minerals and the mobilization of uranium in its more soluble U(VI) form in near-surface waters. The geochemical evidence from these sites suggests that the reduction-oxidation fronts had migrated only slowly, at most on the order of a few tens of meters per million years. These rates of migration were controlled by a range of factors, including the rates of erosion, infiltration of oxidizing waters, geochemical reactions, and diffusion processes.

The migration of large-scale reduction-oxidation fronts through the repository as a result of regional fluid flow is considered unlikely over the regulatory period on the basis of comparison with the slow rates of reduction-oxidation front migration suggested by natural system studies. This comparison is considered conservative because the relatively impermeable nature of the Salado suggests that reduction-oxidation front migration rates at the WIPP are likely to be slower than those observed in the more permeable lithologies of the natural systems studied. Large-scale reduction-oxidation fronts have therefore been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years

EPA FEP Number: **W67**
FEP Title: **Localized Reducing Zones**

SCR Section Number: **SCR.2.5.5**
Screening Decision: **SO-C**

Summary

The formation of localized reducing zones has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. The screening argument remains valid. The FEP description has been updated.

Italicized Text

The effects of reduction-oxidation reactions related to metal corrosion on reduction-oxidation conditions are accounted for in performance assessment calculations. Reduction-oxidation reaction kinetics are accounted for in performance assessment calculations. The migration of reduction-oxidation fronts through the repository has been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years. The formation of localized reducing zones has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The dominant reduction reactions in the repository include steel corrosion and microbial degradation. The following bounding calculation shows that molecular diffusion alone will be sufficient to mix brine chemistry over a distance of meters and therefore the formation of localized reducing zones in the repository is unlikely.

The diffusion of a chemical species in a porous medium can be described by Fick's equation (e.g., Richardson and McSween 1989, p.132):

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial X}\left(D_{eff}\frac{\partial C}{\partial X}\right) \qquad (1)$$

where C is the concentration of the diffusing chemical species; t is the time; X is the distance; and D_{eff} is the effective diffusivity of the chemical species in a given porous medium. D_{eff} is related to the porosity (ϕ) of the medium by (e.g., Oelkers, 1996):

$$D_{eff} = \phi^2 D \qquad (2)$$

where D is the diffusivity of the species in pure solution. The D values for most aqueous species at room temperatures fall into a narrow range, and 10^{-5} cm^2/sec is a good approximation (e.g., Richardson and McSween 1989, p.138). From the WIPP PA calculations (Bean et al. 1996, p.7-29; WIPP PA Department, 1993, equation B-8), the porosity in the WIPP waste panels after room closure is calculated to be 0.4 to 0.7. From Equation (2), the effective diffusivity D_{eff} in the waste is estimated to be 2 ~ $5x10^{-6}$ cm^2/sec (= 6 ~ $16x10^{-3}$ m^2/year).

Given a time scale of T, the typical diffusion penetration distance (L) can be determined by scaling Equation (1):

$$L = \sqrt{D_{eff} T} \ . \qquad (3)$$

Using Equation (3), the diffusion penetration distance in the WIPP can be calculated as a function of diffusion time, as shown in Figure 1.

Direct brine release requires the repository gas pressure to be at least 8 MPA (Stoelzel et al. 1996). The CRA calculations show that it will take at least 100 years for the repository pressure to reach this critical value by gas generation processes. Over this time scale, according to Equation (3) and Figure 1, molecular diffusion alone can mix brine composition effectively at least over a distance of ~ 1 meter.

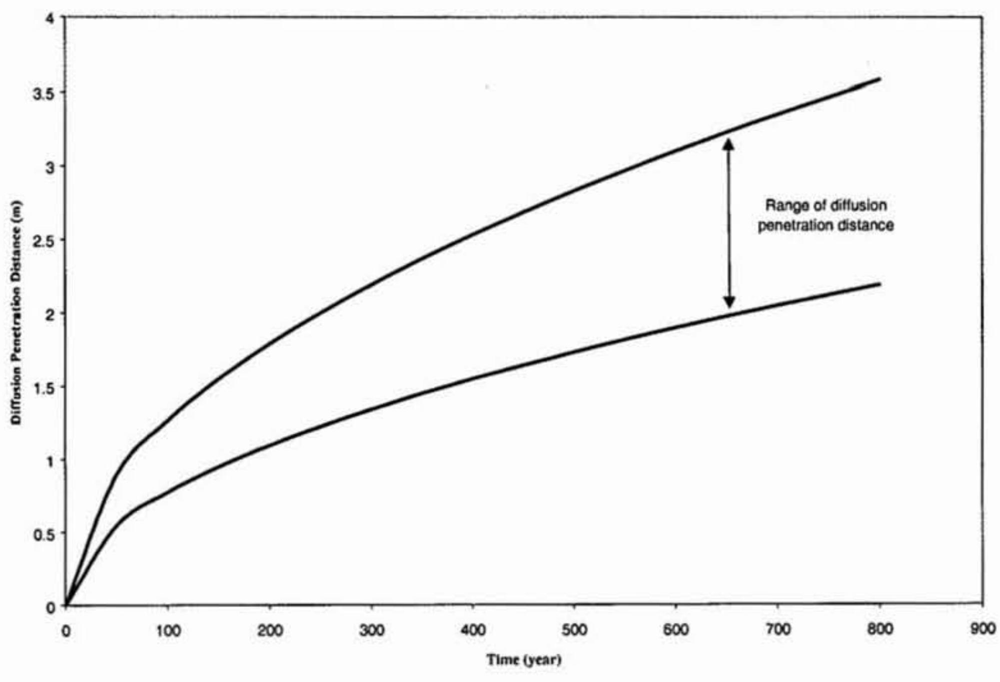

Figure 1. Diffusion penetration distance in the WIPP as a function of diffusion time

The above calculation assumes diffusion only through liquid water. This assumption is applicable to steel corrosion, the humid rate of which is zero. Note that microbial reactions can also consume or release gaseous species. The diffusion of a gaseous species is much faster than an aqueous one. Thus, molecular diffusion can homogenize microbial reactions even at a much large scale.

The height of waste stacks in the repository after room closure (h) can be calculated by:

$$h = \frac{h_0(1-\phi_0)}{1-\phi} \tag{5}$$

where h_0 and ϕ_0 are the initial height of waste stacks and the initial porosity of wastes, which are assumed to be 4 m and 0.88, respectively, in the WIPP PA. For $\phi = 0.4 - 0.7$, h is estimated to be 0.8 to 1.4 m. This means that molecular diffusion alone can homogenize redox reaction in the vertical dimension of the repository. Therefore, the formation of localized reducing zone is unlikely. The general repository environment will become reducing shortly after room closure, due to metal corrosion and microbial reactions.

EPA FEP Number:	**W68, W69 & W71**
FEP Title:	**Organic Complexation (W68)** **Organic Ligands (W69)** **Kinetics of Organic Complexation (W71)**
SCR Section Number:	**SCR.2.5.6**
Screening Decision:	**UP W68 & W69** **SO-C W71**

Summary:

The organic complexation was screened out for the CCA PA, on the basis that transition metals (in particular Fe, Ni, Cr, V, and Mn, present in waste drum steel) would compete effectively with the actinides for the binding sites on the organic ligands, thus preventing significant complexation of actinides organics. Although the CRA calculations include the effects of organic ligands (acetate, citrate, EDTA, and oxalate) on actinide solubility calculations, based on a revised thermodynamic database, the rate at which organic ligands are complexed to actinides is of no consequence to repository performance. Kinetics of organic ligands complexation may be eliminated from performance assessment calculations on the basis of no consequence.

Italicized Text

The effects of anthropogenic organic complexation reactions, including the effects of organic ligands, humic and fulvic acids, have been incorporated in the performance assessment calculations. The kinetics of organic ligand complexation is screened out because the rate at which organic ligands are complexed to actinide is so fast that it has no consequence to repository performance

FEP Text

From a PA standpoint, the most important actinides are Th, U, Np, Pu, and Am. Dissolved Th, U, Np, Pu, and Am will speciate essentially entirely as Th(IV), U(IV) or U(VI), Np(IV) or Np(V), Pu(III) or Pu(IV), and Am(III) under the strongly reducing conditions expected due to the presence of Fe(II) and microbes. (DOE 1996a, Appendix SOTERM, SOTERM-33 – SOTERM-36).

Some *organic ligands* can increase the actinide solubilities. An estimate of the complexing agents in the transuranic solidified waste forms schedules for disposal in WIPP is presented in the April 8, 2003 memo from Crawford to Leigh (Crawford 2003b). Acetate, citrate, oxalate, and EDTA were determined to be the only water-soluble and actinide complexing organic ligands present in significant quantities in the TWBIR. These ligands and their complexation with actinides (Th(IV), U(VI), Np(V), and Am(III)) in a variety of ionic strength media were studied at Florida State University (FSU)

(Choppin et al. 2001). The FSU studies showed that acetate, citrate, oxalate, and EDTA are capable of significantly enhancing dissolved actinide concentrations. Lactate behavior was also studied at FSU because it appeared in the preliminary inventory of nonradiactive constituents of the TRU waste to be emplaced in the WIPP (Brush 1990); lactate did not appear in the TWBIR.

The solubility of the actinides is calculated using FMT (Fracture-Matrix Transport), a computer code for calculating actinide concentration limits based on thermodynamic parameters. The parameters for FMT are derived both from experimental investigations specifically designed to provide parameter values for this model and from the published literature.

Although the FSU experimental work on organic ligands complexation showed that acetate, citrate, oxalate, and EDTA are capable of significantly enhancing dissolved actinide concentrations, SNL did not include the results in the FMT calculations for the CCA PA because 1. the thermodynamic database for *organic complexation* of actinides was not considered adequate at the time, and 2. side-calculations using thermodynamic data for low-ionic-strength NaCl solutions showed that transition metals (in particular Fe, Ni, Cr, V, and Mn, present in waste drum steel) would compete effectively with the actinides for the binding sites on the organic ligands, thus preventing significant complexation of actinides organics (DOE 1996a, Appendix SOTERM, SOTERM-36 - SOTERM-41).

The CRA calculations include the effects of organic ligands (acetate, citrate, EDTA, and oxalate) on actinide solubilities in the FMT calculations (Brush and Xiong 2003). The FMT database includes all of the results of experimental studies (Choppin et al. 2001) required to predict the complexation of dissolved An(III), An(IV), and An(V) species by acetate, citrate, EDTA, and oxalate (Giambalvo 2002a and 2002b).

Solution complexation reactions of most metal ions with common inorganic ligands, such as carbonate and hydroxide, and with organic ligands such as acetate, citrate, oxalate, and EDTA are kinetically very fast, reaching equilibrium in fractions of a second, an inconsequentially short time increment on the scale of the 10,000 year regulatory period. Reactions of these types are generally so fast that special techniques must be adopted to measure the reaction rates; as a practical matter, the reaction rate is limited by the mixing rate when metal solutions are combined with ligand solutions.

For that reason, the rate at which organic ligands are complexed to actinide is of no consequence to repository performance. *Kinetics of organic complexation* may be eliminated from performance assessment calculations on the basis of no consequence.

EPA FEP Number: **W75**
FEP Title: **Chemical Degradation of Backfill**

SCR Section Number: **SCR.2.5.8**
Screening Decision: **SO-C**

Summary:

The screening argument remains valid. As MgO degrades chemically, its physical properties change. Previously the DOE provided a paper by Bynum et. al., (1997) which summarizes the experimental results pertaining to chemical degradation of backfill acquired by 1997. The most current MgO data, obtained after the CCA, are summarized in the 2001 MRS Proceedings paper by A.C. Snider. The current data show that new MgO will essentially behave as it was designed. Changes have been made to the FEP text to reference new experimental results and to remove reference to other FEP descriptions, screening arguments and screening decisions.

Italicized Text

The effects on material properties of the chemical degradation of backfill have been eliminated from performance assessment calculations on the basis of low consequence.

FEP Text

Degradation of the chemical conditioners or backfill added to the disposal room is a prerequisite of their function in buffering the chemical environment of the disposal room (Section SCR.2.5.2). However, the chemical reactions (Snider 2001) and dissolution involved will change the physical properties of the material. Because the mechanical and hydraulic characteristics of the backfill have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system, the effects of the *chemical degradation of backfill* on material properties have been eliminated from performance assessment calculations on the same basis.

EPA FEP Number: **W83**
FEP Title: **Rinse**

SCR Section Number: **SCR.2.6.3**
Screening Decision: **SO-C**

Summary:

Suspensions of particles larger than colloids are generally unstable and do not persist for very long. The rinse process likely cannot occur under undisturbed conditions because brine flow would not be rapid enough to create a suspension of particles and transport them to the accessible environment. The only reasonable conditions under which suspensions could be formed would be during a drilling event with particles of waste suspended in the drilling fluid are carried to the surface. This effect is covered in performance assessment.

FEP Number W83, Rinse, is screened out on the basis of consequence. No new information has become available that affects the screening argument; the FEP screening argument and screening decision remain unchanged.

Italicized Text

The formation of particulates through rinse and subsequent transport of radionuclides in groundwater and brine has been eliminated from performance assessment calculations for undisturbed conditions on the basis of low consequence to the performance of the disposal system.

FEP Text

Suspensions with particles that have sizes larger than colloids are unstable because the particles undergo gravitational settling. It is unlikely that brine flow will be rapid enough within the WIPP disposal rooms to generate particulate suspensions through *rinse* and transport under undisturbed conditions. Mobilization of suspensions would effect a local and minor redistribution of radionuclides within the room and would not result in increased radionuclide transport from the repository. The formation of particulates through rinse and transport of radionuclides in groundwater and brine has been eliminated from performance assessment calculations for undisturbed conditions on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **W88**
FEP Title: **Biofilms**

SCR Section Number: **SCR.2.6.4**
Screening Decision: **SO-C Beneficial**

Summary

The effects of biofilms on microbial transport have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system. The screening decision remains valid.

Italicized Text

The effects of biofilms on microbial transport have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

FEP Text

Microbes will be introduced into the disposal rooms during the operational phase of the repository and will also occur naturally in geological units throughout the disposal system.

Biofilms (W88) may influence microbial and radionuclide transport rates through their capacity to retain, and therefore retard, both the microbes themselves and radionuclides. The formation of biofilms in deep subsurface environments such as in the WIPP is controversial. Since the microbial degradation experiments at Brookhaven National Laboratory (BNL) bracket expected repository conditions, the potential effect of biofilm formation on microbial degradation and transport, if any, has been captured in the PA parameters derived from those experiments. As a matter of fact, no apparent formation of stable biofilms was observed in the BNL experiments. The formation of biofilm tends to reduce cell suspension and mobility. This effect has been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

EPA FEP Number: **W89**
FEP Title: **Transport of Radioactive Gases**

SCR Section Number: **SCR.2.6.5**
Screening Decision: **SO-C**

Summary:

The production and potential transport of radioactive gases are eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

Italicized Text

The transport of radioactive gases has been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

SCR Text

The production and potential transport of radioactive gases are eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system. Transportable radioactive gases are comprised mainly of isotopes of radon and carbon-14. Radon gases are eliminated from performance assessment because their inventory is small (<20 Ci, Ref. Crawford 2003c) and their half-lives are short (<4 days), resulting in insignificant potential for release from the repository. The updated information for the WIPP disposal inventory of C-14 (Crawford 2003c, Leigh 2003a) indicates that the expected WIPP-scale quantity (3.6 Ci) is 70% lower than previously estimated (~13 Ci) in the TWBIR Rev 3 (DOE 1996b). Thus, all CRA screening arguments for C-14 are conservatively bounded by the previous CCA screening arguments.

EPA FEP Number: **W93**
FEP Title: **Soret Effect**

SCR Section Number: **SCR.2.7.3**
Screening Decision: **SO-C**

Summary:

The Soret Effect (temperature-driven diffusion) is generally an insignificant contributor to radionuclide transport. Soret diffusion is negligible compared to the other radionuclide transport processes. The maximum temperature gradient at the WIPP occurs near the shaft seals shortly after placement of the concrete. No enhanced radionuclide transport is anticipated from the heat of hydration because the concrete has its lowest (intact) permeability at this time.

The Soret Effect is screened out on the basis of lack of consequence to the performance of the disposal system. There is no new information available that affects the screening decision; the FEP screening argument and screening decision remain unchanged

Italicized Text

The effects of thermochemical transport phenomena (the Soret Effect) have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

According to Fick's law, the diffusion flux of a solute is proportional to the solute concentration gradient. In the presence of a temperature gradient there will also be a solute flux proportional to the temperature gradient (the ***Soret Effect***). Thus, the total solute flux, J, in a liquid phase may be expressed as

$$J = - D\nabla C - ND\nabla T ,$$

where C is the solute concentration, T is the temperature of the liquid, D is the solute diffusion coefficient, and

$$N = S_T C(1-C) ,$$

in which S_T is the Soret coefficient. The mass conservation equation for solute diffusion in a liquid is then

$$\frac{\partial C}{\partial t} = \nabla \bullet (D\nabla C + ND\nabla T) .$$

When temperature gradients exist in solutions with both light and heavy solute molecules, the heavier molecules tend to concentrate in the colder regions of the solution. Typically, large temperature gradients are required for Soret diffusion to be significant compared to Fickian diffusion.

Radioactive decay, nuclear criticality, and exothermic reactions are three possible sources of heat in the WIPP repository. The DOE (1980) estimated that radioactive decay of CH-TRU waste will result in a maximum temperature rise at the center of the repository of 1.6 °C at 80 years after waste emplacement. Sanchez and Trellue (1996) have shown that the total thermal load of RH-TRU waste will not significantly affect the average temperature increase in the repository. Temperature increases of about 3 °C may occur at the locations of RH-TRU containers with maximum thermal power (60 watts). Such temperature increases are likely to be short-lived on the time scale of the 10,000 year regulatory period because of the rapid decay of heat-producing nuclides in RH-TRU waste, such as ^{137}Cs, ^{90}Sr, ^{241}Pu, and ^{147}Pm, whose half-lives are approximately 30, 29, 14, and 3 years, respectively. Soret diffusion generated by such temperature gradients will be negligible compared to other radionuclide transport mechanisms.

Temperature increases resulting from exothermic reactions are discussed in W72. Potentially the most significant exothermic reactions are concrete hydration, backfill hydration, and aluminum corrosion. Hydration of the seal concrete could raise the temperature of the concrete to approximately 50 °C and that of the surrounding salt to approximately 38 °C one week after seal emplacement.

However, the concrete seals will act as barriers to fluid flow for at least 100 years after emplacement, and seal permeability will be minimized (Wakeley et al. 1995). As a result, short-term temperature increases associated with concrete hydration will not result in significant Soret diffusion through the seal system.

The maximum temperature rise in the disposal panels will be less than 5 °C as a consequence of backfill hydration. Note that active institutional controls will prevent drilling within the controlled area for 100 years after disposal. Heat generation by radioactive decay and concrete seal hydration will have decreased substantially after 100 years, and the temperatures in the disposal panels will have decreased nearly to the temperature of the undisturbed host rock.

If the repository were to be inundated following a drilling intrusion, aluminum corrosion could, at most, result in a short-lived (two years) temperature increase of about 6 °C. These calculated maximum heat generation rates resulting from aluminum corrosion and backfill hydration could not occur simultaneously because they are limited by brine availability; each calculation assumes that all available brine is consumed by the reaction of concern. Thus, the temperature rise of 6 °C represents the maximum that could occur as a result of a combination of exothermic reactions occurring simultaneously. Temperature increases of this magnitude will not result in significant Soret diffusion within the disposal system.

The limited magnitude and spatial scale of temperature gradients in the disposal system indicate that Soret diffusion will be insignificant, allowing the effects of thermochemical transport to be eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **W94**
FEP Title: **Electrochemical Effects**

SCR Section Number: **SCR.2.7.4**
Screening Decision: **SO-C**

Summary:

Transport phenomena arising from electric field gradients developed by electrochemical processes may operate over very limited ranges and that any radionuclide transport associated with them is similarly limited to very short distances.

Electrochemical effects have been screened out on the basis of low consequence to the disposal system. There is no new information available that affects the screening decision; the FEP screening argument and screening decision remain unchanged.

Italicized Text

The effects of electrochemical transport phenomena caused by electrochemical reactions have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

The variety of waste metals and metal packaging in the repository may allow galvanic cells spanning short distances to be established. The interactions among the metals depend upon their physical characteristics and the chemical conditions in the repository. For example, good physical and electrical contact, which is critical to the establishment of galvanic cells, may be impeded by electrically non-conductive waste materials. Additionally, in order to establish a galvanic cell, it is necessary that the metals have different values for standard reduction potentials. For example, a galvanic cell is not expected to be formed by contact of two segments of metals with identical compositions. As a result, galvanic cells can only be established by contact of dissimilar metals, as might happen due to contact between a waste drum and the contents, or between contents within a waste package. The localized nature of electrochemical transport is restricted to the size scale over which galvanic cells can develop, i.e. on the order of size of waste packages. Since the possible range of transport is restricted by the physical extent of galvanic activity *electrochemical effect* cannot act as long-range transport mechanisms for radionuclides and therefore are of no consequence to the performance of the repository.

EPA FEP Number: **W95**
FEP Title: **Galvanic Coupling**

SCR Section Number: **SCR.2.7.4**
Screening Decision: **SO-P**

Summary:

Electrochemical potentials in the repository are generally small and galvanic coupling can occur only over very short ranges (possibly the size of a waste drum). Thus, since electrochemical and galvanic effects can occur only over a very limited range, any radionuclide transport associated with them is similarly limited to very short distances.

The effects on transport of galvanic coupling between the waste and metals external to the repository have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years. There is no new information available that affects the screening decision; the FEP screening argument and screening decision remain unchanged

Italicized Text

The effects of galvanic coupling between the waste and metals external to the repository on transport have been eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

FEP Text

With regard to the WIPP, *galvanic coupling* refers to the establishment of galvanic cells between metals in the waste form, canisters, and other metals external to the waste form. Long range electric potential gradients may exist in the subsurface as a result of groundwater flow and electrochemical reactions. The development of electric potential gradients may be associated with the weathering of sulfide ore bodies, variations in rock properties at geological contacts, bioelectric activity associated with organic matter, natural corrosion reactions, and temperature gradients in groundwater. With the exception of mineralization potentials associated with metal sulfide ores, the magnitude of electric potentials is usually less than about 100 millivolts and the potentials tend to average to zero over distances of several thousand feet (Telford et al. 1976). Metals external to the waste form can include natural metallic ore bodies in the host rock. However, metallic ore bodies and metallic sulfide ores do not exist in the region of the repository (CCA Appendix GCR). As a result, galvanic coupling between the waste and metallic materials outside the repository can not occur. Therefore, galvanic coupling is eliminated from performance assessment calculations on the basis of low probability of occurrence over 10,000 years.

EPA FEP Number: **W96**
FEP Title: **Electrophoresis**

SCR Section Number: **SCR.2.7.4**
Screening Decision: **SO-C**

Summary:

Transport phenomena arising from electric field gradients developed by electrochemical processes may operate over very limited ranges and that any radionuclide transport associated with them is similarly limited to very short distances. No new information that would change the screening argument has arisen since the submission of the Compliance Certification Application.

Italicized Text

The effects of electrochemical transport phenomena, caused by electrophoresis, have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

FEP Text

Long range (in terms of distance) electric potential gradients may exist in the subsurface as a result of groundwater flow and electrochemical reactions. The development of potentials may be associated with the weathering of sulfide ore bodies, variations in rock properties at geological contacts, bioelectric activity associated with organic matter, natural corrosion reactions, and temperature gradients in groundwater. With the exception of mineralization potentials associated with metal sulfide ores, the magnitude of such potentials is usually less than about 100 millivolts and the potentials tend to average to zero over distances of several thousand feet (Telford et al. 1976, p. 458). Short range potential gradients due to corrosion of metals within the waste may be set up over distances that are restricted to the size scale of the waste packages.

A variety of metals will be present within the repository as waste metals and metal packaging, which may allow electrochemical cells to be established over short distances. The types of interactions that will occur depend on the metals involved, their physical characteristics, and the prevailing solution conditions. Electrochemical cells that may be established will be small relative to the size of the repository, limiting the extent to which migration of contaminants by electrophoresis can occur. The electric field gradients will be of small magnitude and confined to regions of electrochemical activity in the area immediately surrounding the waste material. As a result, electrophoretic effects on migration behavior due to both long and short range potential gradients have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **W97**
FEP Title: **Chemical Gradients**

SCR Section Number: **SCR.2.5.7**
Screening Decision: **SO-C**

Summary:

Although chemical gradients will exist in the repository, the Salado, and the Culebra, their effects should be over only a short range. Any chemical fronts or gradients are likely to be confined to small regions around or within waste packages or at boundaries between different geologic media. Due to the limited spatial extent of chemical gradients, their effect on radionuclide transport should be small.

FEP Number W97, Chemical Gradients, is screened out on the basis of low consequence to the performance of the disposal system. There is no new information available that affects the screening decision; the FEP screening argument and screening decision remain unchanged.

Existing Italicized Text from SCR

The effects of enhanced diffusion across chemical gradients have been eliminated from performance assessments on the basis of low consequence to the performance of the disposal system.

FEP Text

Chemical gradients within the disposal system, whether induced naturally or resulting from repository material and waste emplacement, may influence the transport of contaminants. Gradients will exist at interfaces between different repository materials and between repository and geological materials. Distinct chemical regimes will be established within concrete seals and adjoining host rocks. Similarly, chemical gradients will exist between the waste and the surrounding rocks of the Salado. Other chemical gradients may exist due to the juxtaposition of relatively dilute groundwaters and brines or between groundwaters with different compositions. Natural gradients currently exist between different groundwaters in the Culebra.

Enhanced diffusion is a possible consequence of chemical gradients that occur at material boundaries. However, the distances over which enhanced diffusion could occur will be small in comparison to the size of the disposal system. Processes that may be induced by chemical gradients at material boundaries include the formation or destabilization of colloids. For example, cementitious materials that will be emplaced in the WIPP as part of the waste and the seals contain colloidal-sized materials, such as calcium-silicate-hydrate gels, and alkaline pore fluids. Chemical gradients will exist between the pore fluids in the cementitious materials and the less alkaline surroundings. Chemical interactions at these interfaces may lead to the generation of colloids of the inorganic, mineral fragment type. Colloidal compositions may include calcium and magnesium oxides, calcium hydroxide, calcium-aluminum silicates, calcium-silicate-hydrate gels, and silica. Experimental investigations of the stability of inorganic, mineral fragment colloidal dispersions have been carried out as part of the WIPP colloid-facilitated actinide transport program (Papenguth and Behl 1996). Results of the investigations indicate that the salinities of the WIPP brines are sufficient to cause destabilization of mineral fragment colloidal dispersions. Therefore, concentrations of colloidal suspensions originating from concrete within the repository are expected to be extremely low, and are considered in performance assessment calculations.

EPA FEP Number: **W98**
FEP Title: **Osmotic Processes**

SCR Section Number: **SCR.2.5.7**
Screening Decision: **SO-C**

Summary:

Osmotic processes should only occur at interfaces between waters of different salinities. Osmotic processes may tend to concentrate radionuclides along these interfaces. The net effect of osmotic processes would be to further retard the migration of radionuclides. It is not included in the modeling because waters are of comparable salinities and osmotic effects are considered beneficial in limiting radionuclide migration.

FEP Number W98, Osmotic Processes, is screened out on the basis of beneficial consequence to the performance of the disposal system. There is no new information available that affects the screening decision; the FEP screening argument and screening decision remain unchanged.

Italicized Text

The effects of osmotic processes have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

FEP Text

Osmotic processes, i.e. diffusion of water through a semi permeable or differentially permeable membrane in response to a concentration gradient, may occur at interfaces between waters of different salinities. Osmotic processes can occur if waters of different salinities and/or compositions exist on either side of a particular lithology such as clay, or a lithological boundary that behaves as a semi permeable membrane. At the WIPP, clay layers within the Salado may act as semi permeable membranes across which osmotic processes may occur.

In the absence of a semi permeable membrane, water will move from the more dilute water into the more saline water. However, the migration of dissolved contaminants across an interface may be restricted depending upon the nature of the membrane. A hydrological gradient across a semi permeable membrane may either enhance or oppose water movement by osmosis depending on the direction and magnitude of the gradient. Dissolved contaminants that cannot pass through a semi permeable membrane may be moved towards the membrane and concentrated along the interface when advection dominates over osmosis and reverse osmosis occurs. Thus, both osmosis and reverse osmosis can restrict the migration of dissolved contaminants and possibly lead to concentration along interfaces between different water bodies. The effects of osmotic processes have been eliminated from performance assessment calculations on the basis of beneficial consequence to the performance of the disposal system.

EPA FEP Number: W99
FEP Title: Alpha Recoil

SCR Section Number SCR.2.5.7
Screening Decision: SO-C

Summary:

Alpha recoil will probably have only a minor effect in preferentially leaching ^{234}U. The effect of alpha recoil in natural uranium-bearing groundwater systems is often not measurable due to the heterogeneous distribution of radioactivity. Thus, its effect is not likely to be significant at the WIPP.

FEP Number W99, Alpha Recoil, is screened out on the basis of low consequence to the performance of the disposal system. There is no new information available that affects the screening decision; the FEP screening argument and screening decision remain unchanged. Changes have been made to the FEP text for clarity and to remove reference to other FEP descriptions, screening arguments and screening decisions.

Italicized Text

The effects of alpha-recoil processes on radionuclide transport have been eliminated from performance assessment calculations on the basis of low consequence to performance of the disposal system.

FEP Text

Alpha particles are emitted with sufficiently high energies that daughter nuclides recoil appreciably to conserve system momentum. For example, ^{238}U decays to ^{234}Th with emission of a 4.1 MeV alpha particle. The law of conservation of momentum requires that the daughter nuclide, ^{234}Th, recoils in the opposite direction with an energy of approximately 0.07 MeV. The energy is great enough to break chemical bonds or cause ^{234}Th to move a short distance through a crystal lattice. If the ^{234}Th is close enough to the surface of the crystal, it will be ejected into the surroundings. ^{234}Th decays to ^{234}Pa which decays to ^{234}U with respective half-lives of 24.1 days and 1.17 minutes. The recoil and decay processes can lead to the apparent preferential dissolution or leaching of ^{234}U relative to ^{238}U from crystal structures and amorphous or adsorbed phases. Preferential leaching may be enhanced due to radiation damage to the host phase resulting from earlier radioactive decay events. Consequently, ^{234}U sometimes exhibits enhanced transport behavior relative to ^{238}U. The influence of *alpha-recoil* processes on radionuclide transport through natural geologic media is dependent on many site-specific factors, such as mineralogy, geometry, and microstructure of the rocks, as well as geometrical constraints on the type of groundwater flow, e.g. porous or fracture flow. Studies of natural radionuclide-bearing groundwater systems often fail to discern a measurable effect of alpha-recoil processes on radionuclide transport above the background uncertainty introduced by the spatial heterogeneity of the geological system.

Consequently, the effects of the alpha-recoil processes that occur on radionuclide transport are thought to be minor. These effects have therefore been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number: **W100**
FEP Title: **Enhanced Diffusion**

SCR Section Number: **SCR.2.5.7**
Screening Decision: **SO-C**

Summary:

Enhanced diffusion only occurs where there are higher than average chemical gradients. The spatial extent of chemical gradients should be quite limited and as enhanced diffusion occurs, it will tend to reduce the chemical gradient. Thus, the driving force for the enhanced diffusion will be reduced and eventually eliminated as the system approaches steady state or equilibrium conditions. Due to the limited spatial extent of enhanced diffusion, its effect on radionuclide transport should be small.

The effects of enhanced diffusion across chemical gradients at material boundaries have been eliminated from performance assessments on the basis of low consequence to the performance of the disposal system. The FEP screening argument and screening decision remain unchanged. Changes have been made to the FEP text for clarity and to remove reference to other FEP descriptions, screening arguments and screening decisions.

Italicized Text

Enhanced diffusion is a possible consequence of chemical gradients that occur at material boundaries. However, the distances over which enhanced diffusion could occur will be small in comparison to the size of the disposal system. Therefore, the effects of enhanced diffusion across chemical gradients at material boundaries have been eliminated from performance assessments on the basis of low consequence to the performance of the disposal system.

FEP Text

Processes that may be induced by chemical gradients at material boundaries include the formation or destabilization of colloids. For example, cementitious materials, emplaced in the WIPP as part of the waste and the seals, contain colloidal-sized phases such as calcium-silicate-hydrate gels, and alkaline pore fluids. Chemical gradients will exist between the pore fluids in the cementitious materials and the less alkaline surroundings. Chemical interactions at these interfaces may lead to the generation of colloids of the inorganic, mineral fragment type. Colloidal compositions may include calcium and magnesium oxides, calcium hydroxide, calcium-aluminum silicates, calcium-silicate-hydrate gels, and silica. Concentrations of colloidal suspensions originating from concrete within the repository are considered in performance assessment calculations even though expected to be extremely low.

Distinct interfaces between waters of different salinities and different densities may limit mixing of the water bodies and affect flow and contaminant transport. Such effects have been eliminated from performance assessment calculations on the basis of low consequence to the performance of the disposal system.

EPA FEP Number:	**W101, W102 & W103**
FEP Title:	**Plant Uptake (W101)** **Animal Uptake (W102)** **Accumulation in Soils (W103)**
SCR Section Number:	**SCR.2.8.1**
Screening Decision:	**SO-R** **SO-C for 40 CFR 191.15**

Summary:

DOE has stated that FEPs related to plant uptake, animal uptake and accumulation in soils have been eliminated from the compliance assessment calculations on the basis of low consequence. DOE indicated that the screening of these FEPs is justified based upon the results of performance assessment calculations, which show that releases to the accessible environment under undisturbed conditions are restricted to lateral migration through anhydrite beds within the Salado Formation. Performance assessments for evaluating compliance with the EPA's cumulative release requirements in 40 CFR § 191.13 need not consider radionuclide migration in the accessible environment. Therefore, FEPs that relate to plant uptake and animal uptake in the accessible environment have been eliminated from performance assessment calculations on regulatory grounds. No changes have been made to the screening argument, description or screening decision.

Italicized Text

Plant uptake, animal uptake, and accumulation in soils have been eliminated from compliance assessment calculations for 40 CFR § 191.15 on the basis of low consequence. Plant uptake and animal uptake in the accessible environment have been eliminated from performance assessment calculations for 40 CFR § 191.13 on regulatory grounds. Accumulation in soils within the controlled area has been eliminated from performance assessment calculations for 40 CFR § 191.13 on the basis of beneficial consequences.

FEP Text

The results of the calculations presented in CRA Section 6.5 show that releases to the accessible environment under undisturbed conditions are restricted to lateral releases through the DRZ at repository depth. Thus, for evaluating compliance with the EPA's individual protection requirements in 40 CFR § 191.15, FEPs that relate to plant uptake, animal uptake, and accumulation in soils have been eliminated from compliance assessment calculations on the basis of low consequence.

Performance assessments for evaluating compliance with the EPA's cumulative release requirements in 40 CFR § 191.13 need not consider radionuclide migration in the accessible environment. Therefore, FEPs that relate to plant uptake and animal uptake in the accessible environment have been eliminated from performance assessment calculations on regulatory grounds. Accumulation in soils that may occur within the controlled area would reduce releases to the accessible environment and can, therefore, be eliminated from performance assessment calculations on the basis of beneficial consequence.

EPA FEP Number(s): W104, W105, W106, W107 & W108
FEP Title(s): Ingestion (W104)
Inhalation (W105)
Irradiation (W106)
Dermal Sorption (W107)
Injection (W108)

SCR Section Number: SCR.2.8.2
Screening Decision: SO-R
SO-C for 40 CFR §191.15

Summary:

The screening arguments remain valid. The DOE stated in CCA that the results of the performance assessment calculations indicate that releases to the accessible environment under undisturbed conditions are restricted to lateral migration through anhydrite beds within the Salado Formation. The DOE further stated that based upon the bounding approach taken for evaluating compliance with EPA's individual protection requirements in 40 CFR §191.15 and the groundwater protection requirements in Subpart C of 40 CFR §191, these above mentioned exposure pathways were found to be of low consequence. However, the analysis did not include analysis of doses from other potential exposure pathways such as stock consumption or irrigation. These weaknesses were remedied by DOE's submittal of a more detailed dose analysis, which included all of the appropriate additional pathways (DOE 1997c).

In both the PAVT and CCA calculations (DOE 1997 a, b & c) a very conservative bounding-analysis approach was used to estimate potential doses. Using this approach, the calculated maximum potential dose (millirems) to any internal organ due to beta particle and photon radioactivity from man-made radionuclides in drinking water was 2.9×10^{-4} in the PAVT and 4.2×10^{-3} for the CCA. Further, the annual effective dose equivalent to the total body due to beta particle and photon radioactivity is 1.5×10^{-5} in the CCA and 2.3×10^{-4} for the CCA. All of these values are well below the acceptable standard of 4 millirems per year as specified in 40 CFR § 141.16(a). Finally, the calculated maximum potential doses (millirems) to an individual due to meat consumption, vegetable consumption, and inhalation of re-suspended irrigated soil are 2.7×10^{-7}, 0.031, and 2.1×10^{-5}, respectively, in the PAVT and 3.3×10^{-8}, 0.46, 3.1×10^{-4}, respectively, in the CCA. All of these values are well below the individual protection standard, an annual committed effective dose of 15 millirems as specified in 40 CFR § 191.15(a). Therefore, the original text remains valid; no changes have been made to the FEP screening arguments or decisions.

Italicized Text

Ingestion, inhalation, irradiation, dermal sorption, and injection have been eliminated from compliance assessment calculations for 40 CFR § 191.15 and Subpart C of 40 CFR Part 191 on the basis of low consequence. FEPs that relate to human uptake in the *accessible environment have been eliminated from performance assessment calculations for 40 CFR § 191.13 on regulatory grounds.*

FEP Text

As described in CCA Section 8.1.1, releases to the accessible environment under undisturbed conditions are restricted to lateral migration through anhydrite interbeds within the Salado. Because of the bounding approach taken for evaluating compliance with the EPA's individual protection requirements in 40 CFR § 191.15 and the groundwater protection requirements in Subpart C of 40 CFR Part 191 (see CCA Sections 8.1.2.2 and 8.2.3), FEPs that relate to human uptake by *ingestion, inhalation, irradiation, dermal sorption,* and *injection* have been eliminated from compliance assessment calculations on the basis of low consequence.

Performance assessments for evaluating compliance with the EPA's cumulative release requirements in 40 CFR § 191.13 need not consider radionuclide migration in the accessible environment. Therefore, FEPs that relate to human uptake in the accessible environment have been eliminated from performance assessment calculations on regulatory grounds.

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