Department of Energy
Carlsbad Area Office
P. O. Box 3090
Carlsbad, New Mexico 88221

February 7, 1997

Ms. Ramona Travato, Director
US Environmental Protection Agency
Office of Radiation Programs
401 M. Street SW
Washington, DC 20460

Dear Ms. Travato:

As the Carlsbad Area Office (CAO) continues to develop responses to EPA issues provided in the December 19, 1996 letter to Al Alm, we are partially submitting them to you in order that you may begin reviewing them without awaiting completion of all items. This is the third response package. As in the earlier submittals, we have reproduced the issue verbatim from the December 19, 1996 letter and inserted the CAO response in each case. We are confident that you will find this supplemental information helpful in your review process. We will continue to provide additional packages as they are completed (about one each week).

Should you have any questions regarding this information or require anything further, please contact me at (505) 234-7300.

Sincerely,

E K Hunter for
George E. Dials
Manager

M

Enclosure

cc:
F. Marcinowski, EPA

UNIQUE NUMBER: 9700648

1200.00

UFC 1200
97-0436

EPA Comment
Enclosure 1, Page 6
194.23(a)(2)

Text of EPA comment

194.23(a)(2)
Part 194 requires a description of plausible, alternative conceptual model(s) seriously considered but not used, and an explanation of the reason(s) why such model(s) was not deemed to accurately portray performance of the disposal system.

(1) While the application describes the conceptual models used for cuttings, cavings, and spallings, there is little discussion of any alternative models that may have been evaluated.

The CCA needs to provide a more complete discussion of alternative models seriously considered. This comment also applies to all model conceptualization in the CCA PA. If there are no other plausible, alternative models, this should be stated clearly in the CCA.

(2) The Culebra is described as having heterogeneous transmissivity (CCA page 6-124, line 2-3) and uniform porosity (CCA page 6-129, line 20-26). Given the fact that flow in the Culebra is conceptualized as being predominantly in fractures, the porosity should vary with hydraulic conductivity (and transmissivity since the thickness is constant).

Future changes in the Culebra transmissivity due to dissolution need to be discussed, or reasons need to be given for discounting this alternative conceptualization of the Culebra.

DOE Response

(1) The location in the CCA of descriptions of alternative models that were seriously considered and the justification for the conceptual model selection is set out in the first of the following two tables. Only alternative models eliminated using the first or second criteria are included. As stated in Section 6.4.1 of the Compliance Certification Application (CCA), a conceptual model is a set of qualitative assumptions used to describe a system or subsystem for a given purpose. The selection of one conceptual model in preference to another can be made using one of four criteria:

1) The set of qualitative assumptions represented by the alternative models does not adequately describe the system or subsystem with regard to the given purpose.

2) Modeling using the alternative models would not yield significantly different results. The chosen model in this case would most likely be the computationally least intensive.

3) The chosen model is conservative in that it leads to overestimation of the particular performance measure (such as dose or cumulative release of radionuclides) with regard to estimates obtained using the alternative models. A conservative model may be selected if the alternatives would create overly complicated calculations, or if the alternatives are not sufficiently well characterized to be modeled.

4) The chosen model is dictated by regulatory criteria or guidance.

40 CFR Part 194.23(a)(2) requires documentation of any conceptual models that were seriously considered and eliminated because they do not accurately portray performance of the disposal system (i.e., the first criterion above).

The table distinguishes between alternatives that represent modeling simplifications and those that represent alternative approaches or alternative physics. The table is organized using the sub-headings given in Section 6.4 of the CCA, which describes the performance assessment (PA) modeling system. In some cases, however, there are no obvious alternative models to those used in the PA, and headings for these conceptual models have been omitted.

The Conceptual Model Peer Review Panel (CMPRP) considered the appropriateness of the DOE's selected conceptual models and, as part of this review, compared some of these models with alternative approaches. Relevant sections of the CMPRP report and the CMPRP Supplementary Report are indicated in the table where there is serious consideration of the alternative models.

For information, the second table lists conceptual models selected on the basis of the third and fourth criteria above. However, in these cases, the CCA generally only describes the basis for the model and does not need to consider the alternatives in detail.

Documentation of screening to decide which features, events, and processes (FEPs) should be accounted for in the conceptual models is given in Appendix SCR of the CCA. The following tables are only concerned with alternative models for those FEPs that have been accounted for in performance assessment calculations.

Table II - Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
Section 6.4.2.1 - Disposal System Geometry.			
The system is represented by a two-dimensional vertical plane for BRAGFLO modeling and by assuming that flow is both convergent on and divergent away from the repository. *This is a modeling simplification issue.*	Use of a three-dimensional model.	Appendix MASS, Attachment 4-1 explains why a three-dimensional model does not give significantly different results. Therefore, the two-dimensional model is used for computational efficiency.	3.1 3.3
The Salado is represented by impure halite with marker beds MB138 and MB139 and anhydrite layers a and b [lumped together] also modeled explicitly. *This is a modeling simplification issue.*	Use of a more detailed representation of Salado stratigraphy.	Section 6.4.5.1 refers to Christian-Frear and Webb (1996), which shows that a more detailed representation does not significantly change the PA results. Therefore, the simpler model was used for the CCA calculations.	3.1
Section 6.4.2.2 - Culebra Geometry.			
Flow in the Culebra can be represented by a numerical flow model which is supported by an extensive hydrologic data base.	Variability of Culebra hydrogeological properties is controlled by halite dissolution, topographic load, and other site characteristics.	Section 3.2 of the CMPR Report (Appendix PEER, Section 1) concludes that the selected model meets the needs of performance assessment.	3.2
The Culebra is represented by a two-dimensional horizontal geometry for SECO modeling. *This is a modeling simplification issue.*	Use of a three-dimensional model.	Appendix MASS, Attachment 15-7 describes how a three-dimensional groundwater basin model has been used to show that the two-dimensional model used in the disposal system calculations is adequate and no alternative treatment is necessary.	

Table 1 - Alternative Conceptual Models Seriously Considered in the CCA			
Model	**Alternative Model**	**Discussion in CCA**	**CMPR Section (where applicable)**
Section 6.4.3.1 - Creep Closure.			
Creep closure in the vicinity of the excavation is modeled by calculating a porosity surface based on creep closure and waste consolidation and linking it to gas generation and brine inflow. Creep is modeled using flow laws that fit available, relevant data.	An empirical reduced-modulus (RM) model was devised by Sjaardema and Krieg (1987). Several alternative flow laws exist.	Section 6.4.3.1 refers to Freeze et al. (1995), and Appendix PORSURF, Section 1 refers to Freeze (1996), which concludes that the selected model approximation is adequate. Appendix PORSURF, Attachments 1 and 7 discusses the model.	3.19
The porosity and permeability of the operational and experimental regions are fixed. *This is a modeling simplification issue.*	Use of porosities reflecting changes over time.	Appendix MASS, Section 7.1 and Appendix PORSURF, Section 4 and reference to Vaughn et al. (1995) show that the alternative treatment is does not generate significantly different results. Therefore a simplified model was opted for.	3.3 (Supplementary Report)

Table 1 - Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
Creep closure is modeled using a 2-D representation of a single room. *This is a modeling simplification issue.*	Model multiple panels and their closures.	Appendix PORSURF, Attachment 1 justifies the simplified treatment and refers to Osnes and Labreche (1995).	
Section 6.4.3.2 - Repository Flow.			
Flow into the repository from the far-field is through naturally-occurring pore spaces in response to potentiometric gradients.	Assume the interconnecting pore space is only of limited extent and is due to excavation of the repository. Assume that the most significant source of brine inflow is through the clay layers exposed during excavation, and that flow through other lithologies within the Salado is negligible by comparison.	These alternatives are described in Appendix MASS, Section 7 and references therein. The far-field flow model was selected because its results cover those of the other two, and because of uncertainty as to the most realistic model.	3.5
The Brooks-Corey equation is used to represent interaction between brine and gas.	Use the Van Genuchten/Parker equation.	Both models are included in BRAGFLO, as described in Appendix BRAGFLO, Section 4.9. Appendix PEER, Section 1, p. 3-20 (the CMPR report) refers to Christian-Frear and Webb (1996) to justify the use of the Brooks-Corey treatment.	
All liquids in the repository have the same physical properties as Salado brine.	Assume that there are several other sources of liquid in the repository such as the waste, operational activities, and Castile brine in the event of a borehole intrusion. Model the different liquids with their different flow properties. *This is a modeling simplification issue.*	The significance of these alternative fluid sources in terms of physical properties is discussed in Appendix MASS, Section 3.3, where it is shown to be of low significance. The model adopted is simpler.	

Table 1 - Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
Section 6.4.3.3 - Gas Generation.			
Gas generation was calculated using an average stoichiometry model based on metal corrosion and organic biodegradation dependent on brine availability.	Assume passivation of steel by microbially-produced gas, and reduce gas generation from corrosion processes (the reaction path model).	Appendix MASS, Sections 8 and 8.1 describe the average stoichiometry model and its historical development. An alternative mathematical representation of this model not accounting for the relationship to brine availability was considered in earlier PAs. Appendix MASS, Attachment 8-1 and Attachment 8-3 document the reaction path model and why the average stoichiometry model was selected.	3.21
Section 6.4.3.4 - Chemical Conditions in the Repository.			
Chemical conditions in the repository are constant and, with the exception of redox and gas generation reactions, at equilibrium with the backfill.	Assume that chemical equilibrium is not achieved with the backfill either immediately or over time as the backfill is consumed.	Section 9.3.1.2.10.2 and Section 9.3.2.2.2.2 discuss the likelihood of the backfill fulfilling its buffering role over a 10,000 year period.	3.22
For undisturbed performance and E2 scenarios, the brine composition in the repository is that of Salado brine. For E1 scenarios, the composition is that of Castile brine.	Assume that in E1 scenarios, the brine composition will be a mixture between Salado and Castile brine. and that the solubility is determined by the mixture proportions. *This is a modeling simplification issue.*	The alternative is discussed in Appendix SOTERM, Sections 2.2.1 and 7.2.1. The alternative would introduce further uncertainty into the modeling. The effects on solubility are encompassed by the selected model.	

Table 1 - Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
A condition of redox disequilibrium will exist between the possible oxidation states of the actinides.	Assume the actinides will be in redox equilibrium with the conditions in the repository.	Appendix SOTERM, Section 2.2.3 discusses the alternatives of oxidizing conditions in the repository and redox equilibrium. Appendix SOTERM, Section 4 discusses the likely oxidation states based on experimental observation and why the alternative states are not considered.	
Section 6.4.3.5 - Dissolved Actinide Source Term.			
The solubility of different actinides can be calculated using an equilibrium thermodynamic model employing Pitzer interaction coefficients and assuming that, for a given oxidation state, the actinides exhibit similar chemical behavior and thus have the same solubilities.	Assume that each actinide has a significantly different chemical behavior and solubility for each of its oxidation states, and solubility can only be determined using a complete thermodynamic database.	Appendix SOTERM, Section 3 dismisses the alternative of deriving a full thermodynamic database through experimental measurement as not logistically feasible. The inventory limited model is too conservative and unrealistic. The adopted model considers the best constrained parts of the system (i.e., conservatively ignores sorption, co-precipitation, etc.). The approach is justified by comparison to the available experimental data in Appendix SOTERM, Section 3.6. The Pitzer formulism is justified compared to alternatives such as SIT.	3.23
	Assume that the system is not at or cannot be properly modeled at thermodynamic equilibrium and a conservative approach is to use inventory limits with maximum concentrations.		

Table 1 - Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
Section 6.4.3.6 - Colloidal Actinide Source Term.			
Colloids present in the disposal room will be comprised of mineral fragments, intrinsic colloids, microbes and humic acids. Actinide concentrations associated with intrinsic colloids and mineral fragments can be treated as inventory-limited constants based on experimental detection limits. Humic and microbe colloid actinide concentrations can be modeled as thermodynamically-related to dissolved actinide concentrations, with a constant maximum concentration.	A full chemical equilibrium model where concentrations of actinides associated with all colloids are calculated based on equilibrium thermodynamics (and possibly accounting for sorption). An inventory-limited model with realistic maximum concentrations set by experimental observation.	The adopted conceptual model is a mixture of the two alternatives. Appendix SOTERM, Section 6 and Appendix WCA, Attachments 18-5 to 18-8 document the selection of the model and the derivation of parameter values from experimental observation. The full chemical equilibrium alternative is too complicated and too uncertain to model. The inventory-limited alternative is conservative, but less realistic.	3.24
Section 6.4.4 - The Shaft System.			
The four shafts connecting the repository to the surface are represented in BRAGFLO by a single shaft with a cross-section and volume equal to the total volume of the four real shafts and separated from the waste by the distance of the nearest real shaft.	A more realistic system with all four shafts represented individually. *This is a modeling simplification issue.*	Appendix MASS, Section 12.1 documents the development of the conceptual model. It refers to the 1992 WIPP PA, which considered alternative model representations. The CMPR Report, Section 3.1, p. 3-3 and 3-4 discusses the alternative approach given here, but accepts the conservative nature of the model used. Otherwise, the representation of the seal in the PA is based on the seal design, and there are no alternatives.	3.1

Table 1. Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
The shaft is surrounded by a DRZ which heals with time. The DRZ is represented through the permeabilities of the shaft system itself, rather than as a discrete zone. *This is a modeling simplification issue.*	Model the DRZ around the shafts as a discrete zone with permeability changing over time.	The DRZ model basis is described in Appendix SEAL, Section 7.5 and Appendix D.5. Representation of the DRZ through shaft permeabilities is justified in Appx. IRES.2 , as referenced in Section 6.4.4.	
Section 6.4.5 - The Salado.			
Interbeds have a fracture-initiation pressure above which local radial fracturing and changes in porosity and permeability occur in response to changes in pore pressure. A power function relates the permeability increase to the porosity increase. A pressure is specified above which porosity and permeability do not change.	Assume anisotropic fracturing, preferential fracture orientations determined by dip and pre-existing fractures, and different fracture propogation laws.	Appendix MASS, Attachment 13-2 dismisses the alternative as unlikely.	3.6
The permeability of the DRZ around the repository is constant and higher than intact Salado. *This is a modeling simplification issue.*	Decrease the permeability with time and salt creep to that of Salado halite.	Appendix MASS, Section 13.4 refers to Vaughn et al. (1995), who showed that the alternative did not significantly affect results.	3.7 3.3 (Supplementary Report)
Section 6.4.6 - Units above the Salado.			
Above the Salado, lateral actinide transport to the accessible environment can occur only through the Culebra. *This is a modeling simplification issue.*	Model transport through the Magenta and/or the Dewey Lake formations.	The alternatives are dismissed in Sections 6.4.6.4 and 6.4.6.6 and the argument expanded in Section 9.3.1.2.4. Appendix MASS, Section 14.1 refers to Barr et al. (1983) for modeling of the Magenta, and Beauheim (1986) for permeability measurements of the Dewey Lake. See also Wallace et al. (1995) referred to in Section 6.4.6.6.	

Table 1 - Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
Section 6.4.6.2 - The Culebra.			
For fluid flow, the Culebra is modeled as a uniform (single-porosity) porous medium with spatially variable transmissivity.	Use a dual-porosity model. Use a discrete-fracture model.	The single porosity model simplification is justified in MASS Attachment 15-7 and Section 6.4.6.2 (p. 6-129).	3.2
Recharge to the two-dimensional model of the Culebra is treated using constant head conditions on the regional grid boundaries. No vertical flow is modeled.	Include vertical recharge and leakage terms in the two-dimensional model. *This is a modeling simplification issue.*	The treatment of vertical flow is justified in Appendix MASS, Section 14.2, Appendix MASS Attachment 15-7 (p. 21), and Corbet and Knupp (1996), as referenced in Section 6.4.6.	
Section 6.4.6.2.1 - Transport of Dissolved Actinides in the Culebra.			
Radionuclide transport is modeled using a double-porosity model with the advective porosity representing fracture flow and the diffusive porosity representing matrix flow.	Use a single-porosity model. Use a discrete-fracture model.	Appendix MASS, Section 15.1 and Attachment 15-6 justifies the selection of the CCA PA model.	3.10
Sorption is modeled using a linear isotherm.	Use other models such as the Langmuir and Freundlich isotherms.	Appendix NUTS, Section 4.3.6 discusses the alternative models.	
Section 6.4.6.2.2 - Colloid Transport in the Culebra.			
Humic colloids are modeled as dissolved species. *This is a modeling simplification issue.*	Assume that humic substances influence the sorption behavior of dissolved actinides.	Appendix MASS, Section 15.3.1 describes results of experimental studies that show that the presence of humic substances in brine does not influence the sorption behavior of dissolved actinides.	

Table 1 - Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
Actinide-bearing microbial and mineral colloids in the repository are filtered out and are not transported in the Culebra. *This is a modeling simplification issue.*	Use SECOTP2D (and underlying modeling assumptions) to model the effects of colloid retardation and transport phenomena.	Appendix MASS, Sections 15.3.1 and 15.3.3 describe results of experimental studies that show that colloidal actinides are strongly attenuated or present in negligible concentrations in the Culebra.	
Section 6.4.7.1 - Releases During Drilling.			
Direct brine release through a borehole will have negligible long-term effect on repository pressure and saturation. *This is a modeling simplification issue.*	Assume that direct brine release through a borehole affects the repository pressure and saturation.	Section 6.4.7.1.1 states that the effects are transient and local and are not significant to PA results.	
Activities of each drum in a stack of three which may be intersected by a borehole are independently sampled from 569 different waste streams.	Drum activities in a 3-stack are all from the same waste stream.	Section 3.13 of the CMPRP Supplementary Report concludes that the selected model is adequate.	3.13 (Supplementary Report)
Entrainment of brine and waste from a waste panel results from single-phase gas flow (spallings) and brine flow (direct brine release).	Assume that two-phase liquid/gas releases during inadvertent intrusion will entrain brine and waste solids.	Section 3.15 of the CMPRP Supplementary Report concludes that the selected model is adequate.	3.15 (Supplementary Report)

Table 1 - Alternative Conceptual Models Seriously Considered in the CCA

Model	Alternative Model	Discussion in CCA	CMPR Section (where applicable)
Fractures in the DRZ around the walls will heal during the period of active and passive institutional controls. Drilling into this region will not lead to direct brine releases.	Open fractures within the DRZ increase local halite permeability and allow migration of brine and gas to a borehole drilled in this region.	Section 3.15 of the CMPRP Supplementary Report concludes that the selected model is adequate.	3.15 (Supplementary Report)
Section 6.4.7.2 - Long-Term Releases Following Drilling.			
The panels are not interconnected for long-term brine flow. *This is a modeling simplification issue.*	Assume that the panels are interconnected for long-term brine flow.	Section 6.4.13.6 states that this is a reasonable simplification based on detailed BRAGFLO calculations.	
Section 6.4.8 - Castile Brine Reservoirs.			
Castile brine reservoirs have limited extent and interconnectivity, with effective radii on the order of several hundred meters.	Assume that Castile brine reservoirs have effective radii much larger than the waste panel dimensions.	Section 6.4.8 describes how it is conservative to assume reservoirs are of limited extent and are thus not depleted by multiple drilling penetrations in the vicinity of the WIPP. Reservoir volumes are described in Appendix MASS, Attachments 18-3 and 18-5.	3.16

Table 2 - Significant Conceptual Models Selected on the Basis of Conservatism

Model	Alternative Model	Discussion in CCA
Section 6.4.3 - The Repository		
The repository is modeled as comprising five regions with constant dimensions.	Repository represented by a more detailed model (larger number of regions).	Section 6.4.3 and the CMPR report, p. 3-4, state that the approach is conservative, and so alternatives need only be considered on the grounds of credibility. Appendix MASS, Section 4.2 states that other geometries were considered in the 1991 and 1992 WIPP PAs.
Panel closures are modeled with the same properties as the surrounding DRZ.	Panel closures treated independently of DRZ.	Appendix MASS, Attachment 7-1 shows that the permeabilities used are sufficiently high that alternative models would be less conservative. Section 9.3.1.2.2.3 also documents why the alternative model is not necessary.
Section 6.4.3.2 - Repository Flow		
The waste disposal region is assigned a constant permeability representative of consolidated waste without backfill.	Permeability varies with degradation and creep closure.	The selected model is conservative with regard to the alternative as stated in Section 6.4.3.2, cross-referred to Vaughn et al. (1995) and Section 9.3.1.2.2.3. The alternative would be more complex to model.
Section 6.4.3.3 - Gas Generation		
Gas dissolution in brine is negligible.	Gas dissolves in and exsolves from brine causing changes in fluid flow rates and patterns.	Appendix MASS, Attachment 13-1 shows that the alternative model is less conservative, and gas dissolution is therefore not accounted for to maintain simplicity.
The gas phase is assigned the physical properties of hydrogen.	Properties of the gas phase account for the presence of carbon dioxide and methane.	Appendix MASS, Section 3.2 shows that the model selected is conservative. The alternative would increase the complexity of the modeling as proportions of the different gases would have to be tracked.

Table 2. Significant Conceptual Models Selected on the Basis of Conservatism

Model	Alternative Model	Discussion in CCA
Section 6.4.3.5 - Dissolved Actinide Source Term		
Radionuclide dissolution to solubility limits is instantaneous.	Waste and container dissolution occurs over a significant period of time.	Appendix SCR, Sections 2.3.8, 2.5.2 and 2.5.3 includes discussion which shows that this model is conservative.
Section 6.4.4 - The Shaft System		
Seal components do not retard radionuclides by sorption.	Radionuclides will be retarded by sorption to seal materials.	This is a conservative modeling selection as discussed in Appendix SCR, Section 2.5.4.
Section 6.4.5 - The Salado		
The Salado halite has a high threshold pressure that inhibits the flow of gas into it.	Gas flow into the pore spaces in the Salado halite reduces repository pressures and affects brine flow.	The selected model is justified in Appendix MASS, Section 13.1, and the alternative is dismissed as being likely to reduce releases (non-conservative).
Radionuclide retardation by sorption and dispersion is not considered for transport through the Salado.	Radionuclides will be retarded by sorption and dispersion during transport through the Salado.	This is a conservative modeling selection. The alternatives are discussed in Section 6.4.5.4 and Appendix MASS, Section 13.5.
Section 6.4.6.1 - The Tamarisk		
The unnamed lower member, Tamarisk, and Forty-niner are assumed to be impermeable.	Model these units in BRAGFLO using their true permeabilities.	The CCA PA approach is conservative in that it maximizes flow into the Culebra. This is documented in Appendix MASS, Section 14.1.
Section 6.4.6.2.1 - Transport of Dissolved Actinides in the Culebra		
Sorption of actinides in the Culebra occurs on dolomite in the matrix.	Sorption also occurs on clay minerals on fracture surfaces and on iron oxides.	Appendix MASS, Section 15.2 and Attachment 15-1 documents the CCA PA approach and its conservatism with regard to the alternatives.
Section 6.4.6.2.2 - Colloid Transport in the Culebra		

Table 2 - Significant Conceptual Models Selected on the Basis of Conservatism

Model	Alternative Model	Discussion in CCA
Newly-formed (indigenous) actinide-bearing microbial and mineral colloids and humics can be ignored.	Actinides are transported by indigenous, newly-formed colloids.	Section 6.4.6.2.1 states that the PA treatment is conservative because newly- formed colloidal actinides would be attenuated.
Section 6.4.6.2.3 - Extent of Potash Mining		
Extent of mining outside the controlled area is based on location of existing potash leases	Extent of mining outside the controlled area is based on locations of economically-viable resources.	Appendix MASS, Attachment 15-5. Regulatory-based model.
Extent of mining inside the controlled area is based on location of economically-viable resources	Extent of mining inside the controlled area is based on locations that are of lease quality or have historically been leased for potash.	Appendix MASS, Attachment 15-5. Regulatory-based model.
Section 6.4.7.1 - Releases During Drilling		
Any actinides that enter the borehole are assumed to reach the surface.	Contaminated material is lost through failed casing to thief zones during flow up the borehole.	Conservatism of CCA PA model is documented in Section 6.4.7.1.
Depletion of actinides in parts of the repository that have been penetrated by boreholes is not accounted for in calculating the releases from subsequent intrusions at such locations.	Parts of the repository that are penetrated by boreholes become depleted in actinides by any releases associated with those boreholes.	Conservatism of CCA PA model is documented in Section 6.4.13.7.

(2) This topic is addressed in the CCA in Appendix MASS, section 15.2 (pages MASS-80 and 81), and in Attachments 15-6 and 15-10 as referenced in Appendix MASS. As stated in Appendix MASS (beginning on page MASS-80, line 42):

"It is commonly assumed that there should be a relationship between the conductivity of advective porosity and its porosity and distribution, that is, that the fracture permeability, porosity, and aperture or spacing should be correlated. Data collected and analyzed at the WIPP do not support this assumption. There are no meaningful trends among these parameters for the data that have been collected. Therefore, values of these parameters are not correlated in the performance assessment."

Attachment 15-10 to Appendix MASS displays the relevant data in scatterplots that show the lack of correlation.

The possibility that Latin hypercube sampling could result in unrealistic or unreasonable combinations of parameter values was considered while developing ranges of values for parameters used in models of the Culebra for the CCA performance assessment. With this possibility in mind, parameter ranges for the Culebra (i.e., the characterization of parameter uncertainty) were set such that the DOE believes that all combinations of parameter values selected for the Culebra in the performance assessment represent potentially realistic behavior of the system. See Appendix PAR, parameter 35 (p. PAR-122 and WPO# 33055), parameter 49 (p. PAR-152, WPO# 38356), parameter 50 (p. PAR-155, WPO# 38358), and parameter 51 (p. PAR-158, WPO 38357) for additional information.

Please see the attached memorandum by Corbet et al. This memorandum was written specifically to address concerns similar to the one raised here by the EPA that have been raised by Roger Anderson. The DOE believes that the analysis presented by Corbet et al. addresses the concerns adequately and provides sound documentation of the basis for the decision not to vary the transmissivity of the Culebra in response to possible future climate changes.

M

Sandia National Laboratories

Albuquerque, New Mexico 87185-1341

date: January 16, 1997

to: Margaret Chu, MS 1335

T Corbet

Malcolm Siegel

T Corbet for J. Myers

Robert Holt

T Corbet for D. Powers

from: Tom Corbet, Malcolm Siegel, Jonathan Myers, Robert Holt, and Dennis Powers

subject: An Evaluation of a Hypothesis Proposed by Roger Anderson Regarding Climate Change and Possible Dissolution of Fracture Fillings in the Culebra

We have prepared the attached position paper addressing the hypothesis proposed by Roger Anderson regarding the potential for future climate changes to result in dissolution of fracture fillings within the Culebra and consequent changes in the permeability of the unit. We believe that this paper presents a strong argument against Anderson's assertion that performance assessment calculations should assume that the transmissivity of the Culebra will increase in the future. This work was performed under expedited CCA activity request "Future Dissolution of Culebra Fracture Fillings".

Copies with attachment

Peter Swift, MS 1341
Kurt Larson, MS 1395
Mel Marietta, MS 1395
SWCF-A:2.1.5.3.1:QA:TI:CO/CCA:climate change:Culebra transmissivity

M

Consideration of the Potential for Future Dissolution of Culebra Fracture Fillings

Abstract

Anderson (1993, 1995, 1996) advances a hypothesis that climate change has caused episodic dissolution of halite in the Rustler and Salado formations, and precipitation and dissolution of gypsum in fractures in the Culebra, and has consequently altered the permeability of the Culebra over the past 12,000 years. He proposes that performance assessment calculations should assume future increases in the transmissivity of the Culebra to account for this dissolution. We agree that dissolution of the upper Salado west of the WIPP site and dissolution of fracture fillings within the WIPP site has altered the permeability of the Culebra in the geologic past. DOE, as part of its evaluation of the possible effects of climate change, has performed simulations of regional groundwater flow which explicitly account for these processes as well as the range of climate change proposed by Anderson. However, we note that there is no basis for Anderson's claim that dissolution of gypsum from Culebra fractures has occurred over the past 12,000 years. Instead, an analysis presented in this paper that integrates flow simulations, calculations of gypsum saturation as a function of depth, and calculations of mass transfers along flow paths supports a conceptual model in which gypsum has not been dissolved from Culebra fractures over the past 600,000 years. We therefore do not agree that performance assessment calculations should assume that the transmissivity of the Culebra increases in the future.

Background

Summary of Anderson's hypothesis

Anderson (1993, 1995, 1996) advances a hypothesis that episodic dissolution of halite in the Rustler Formation and precipitation and dissolution of gypsum in fractures in the Culebra has altered the permeability of the Culebra. He proposes that these episodic periods of dissolution/precipitation are associated with climatic cycles. In particular, he proposes the following sequence of events. The strongest episode of dissolution occurred between 60,000 and 12,000 years ago. Most of the fractures in the Culebra at the WIPP site formed during this interval. Gypsum precipitated in fractures in the Culebra during a dryer climate occurring 12,000 to 4,000 years ago. From 4,000 years to present the gypsum filling in fractures has been dissolving.

Anderson's hypothesis suggests that additional dissolution will occur during the next wet climate episode. In addition, he does not agree with the assertion that a return to a wet climate, as under glacial conditions, is highly unlikely in the next 10,000 years. Consequently, Anderson (1996) concludes:

> Because one cannot realistically estimate increases in porosity due to increased wetness and flow, a safety factor which recognizes the process of dissolution of fill from fractures, and which assumes proportional increase in transmissivity, needs to be incorporated into model runs. .. model runs which incorporate increases in transmissivity of 2 orders of magnitude under conditions of wet climate during the next 10,000 years are indicated.

Anderson's hypothesis of how a future wetter climate could increase Culebra permeability includes two processes: dissolution of halite in the Rustler and dissolution of minerals that fill fractures. According to Anderson's hypothesis, the first process would increase Culebra permeability by generating new fractures. The second increases permeability by unplugging existing fractures. Anderson supports the hypothesis that the current lateral extent of halite in the Rustler near the WIPP site is due to dissolution of previously more extensive halite.

Summary of relevant geologic history

The broad geologic history and features related to salt dissolution within the northern Delaware Basin have been described and summarized in several sources such as Bachman (1974, 1976, 1980, 1981), Anderson (1978, 1981, 1982), and Lambert (1983). These sources document erosion of overlying sediments and dissolution of parts of the Castile and Salado formations over large regions to the west of WIPP site. Some interpretations suggest post-depositional dissolution as early as the Permian, and major episodes occurred during Mesozoic and Cenozoic time. The eastward extent of Salado dissolution in the vicinity of the WIPP site is shown in Figure 1. A topographic depression, Nash Draw, is associated with the eastward extent of Salado dissolution in the vicinity of the WIPP site. Although dissolution of the Salado at the scale of the Delaware Basin has occurred over large areas and over a long period of geologic time, interpretations of the possible effects of halite dissolution in the vicinity of the WIPP site are based principally on geologic features at the WIPP site, in Nash Draw, and along Livingston Ridge, the eastern margin of Nash Draw.

There is evidence that Nash Draw had already started to form during the time the Gatuña Formation was being deposited. This is indicated by the fact that the Gatuña Formation is thicker in areas now occupied by Nash Draw, showing that a depression was forming during its deposition (e.g., Bachman, 1985; Powers and Holt, 1993). The Gatuña was deposited from at least 13 million years ago to about 500,000 years ago (Powers and Holt, 1993). Within Nash Draw, an analysis of upper Salado solution residue indicates that the residue formed at least 700,000 years ago (Szabo and others, 1980). Along Livingston Ridge, the surface rocks, including Mescalero caliche, show evidence of surface deformation. The upper crust of the Mescalero is interpreted to have formed about 420,000 years ago (Szabo and others, 1980). Therefore, some deformation of the eastern margin of Nash Draw has occurred since 420,000 years ago. While Gatuña deposits show Nash Draw probably formed over several million years, residues and deformed Mescalero indicate that hundreds of thousands of years were required for the margin of Nash Draw to assume its current form.

Livingston Ridge and Nash Draw developed through the combined processes of erosion and dissolution. The thickness of upper Salado units sharply decreases under Livingston Ridge and adjacent Nash Draw (Figure 1), illustrating very clearly the relationship between dissolution of the upper Salado and development of the draw and its eastern margin. There is no indication that Salado salt is thinner underneath the WIPP site due to dissolution (Powers and Holt, 1995). This observation, combined with the relatively long time period required for Nash Draw to develop, suggest that it is extremely unlikely that dissolution of halite in the Salado Formation will move eastward toward the WIPP site in the next 10,000 years.

The most prominent indicator of geologic stability at the WIPP site, proper, is the Mescalero caliche. It is a persistent unit that is considered to have developed on a surface that has been generally stable since the Mescalero began to develop about 570,000 years ago (e.g., Bachman, 1985; Szabo and others, 1980).

Summary of what is known about fracture fillings in the Culebra

We agree with Anderson that the presence or absence of mineral fillings in Culebra fractures exerts an important control on the permeability of the Culebra and that, in some regions of the WIPP site, the fracture fillings possibly have been dissolved and re-precipitated sometime in the past. Holt (in Beauheim and Holt, 1990) reports that two types of sulfate filling have been recognized in fractures in Culebra cores. The first type consists of antitaxial fibrous gypsum which formed as fractures opened incrementally. Because these fractures were filled as they open, the entire thickness of a fibrous gypsum filled fracture does not represent its maximum aperture (Durney and Ramsay, 1973). The second type of filling consists of poikilotopic gypsum cements; these cements passively filled fractures that were previously open to their full aperture. Holt (1997)

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notes that incremental fillings are most abundant to the east of the middle of the WIPP site and passive fillings are more common in the west. Holt's interpretation is that at some time in the past some of the open or passively filled fractures found in the western part of the WIPP area may have originally contained fibrous gypsum.

To our knowledge, there is no direct evidence for interpreting when Culebra fractures formed, fracture fillings were dissolved, or passive fillings precipitated.

Analysis of Anderson's hypothesis

Anderson's hypothesis has several main points:

1) Dissolution of halite in the Rustler in the vicinity of WIPP has played a role in increasing the permeability of the Culebra.

2) Dissolution/precipitation of fracture fillings has altered the permeability of the Culebra.

3) Changes in climate cause dissolution and precipitation of fracture fillings in the Culebra.

4) The timing of dissolution and precipitation of fracture fillings in the Culebra is known. In particular, fracture filling are assumed to have been precipitated and dissolved during the later portion of the last climate cycle (i.e. in the last 12,000 years).

We appreciate the long history of the hypothesis (Point 1 above) that the current lateral extent of halite in the Rustler Formation in the vicinity of WIPP represents the eastward extent of halite dissolution. Until 1984, US Geological Survey (e.g., Brokaw and others, 1972) and project (e.g., Powers and others, 1978) documents reported that eastward thinning of the Rustler across the site area was the consequence of dissolution of salt from the formation. Jones and others (1973) noted that some thickness variations were attributable to depositional processes, but details were not provided. Though some cores from the Rustler were obtained during early WIPP studies, sedimentological features were generally not described.

The enlarged waste handling shaft revealed important sedimentological and stratigraphic details that Holt and Powers (1984) found inconsistent with the hypothesis of late removal of halite from the mudstone/halite strata within the Rustler. The exhaust shaft (Holt and Powers, 1986) provided further confirmation of these features, and an extended study of Rustler facies variations was undertaken (Holt and Powers, 1988). This study is the only comprehensive study of the Rustler, including all WIPP cores, 2 shafts, outcrops, and geophysical logs. Mapping of the air intake shaft (Holt and Powers, 1990) provided additional confirmation of the comprehensive study. As a result of this comprehensive study, Holt and Powers (1988, 1993) and Powers and Holt (1990) concluded that halite was mainly distributed in the Rustler according to depositional processes, which included extensive synsedimentary removal of halite, and that little halite has been removed since that time. Beauheim and Holt (1990) showed potential areas of halite dissolution in the Rustler based on the work of Holt and Powers (1988).

Considering both the history of reports of Rustler halite dissolution and the comprehensive study for WIPP concluding that halite is distributed mainly according to depositional processes, we favor the hypothesis that little halite has been dissolved in the Rustler in the WIPP area.

We agree with the second point of Anderson's hypothesis that dissolution/precipitation of fracture fillings has altered the permeability of the Culebra. It was assumed that these processes have occurred when inferring the hydraulic properties of the Culebra for use in simulations of regional groundwater flow (see Corbet and Knupp, 1996, for a description).

The remainder of this section focuses on points 3 and 4 of Anderson's hypothesis. We note that Anderson presents the connection of climate change and dissolution/precipitation of fracture fillings as well as the timing of these as if they are observed facts. Anderson presents no basis for these aspects of his hypothesis in his papers or presentations. In addition, Anderson has not provided a conceptual model of how climate change would effect the chemistry or flow paths of groundwaters that would dissolve or precipitate the fracture fillings. In order to evaluate points 3 and 4, some understanding of how groundwater flow and groundwater chemistry in the Culebra would change under different climate scenarios is required. Pertinent information is summarized below.

Effect of climate change on groundwater flow in the Culebra

DOE has recognized the need to address how climate change effects groundwater flow in the Culebra. Given that it is not possible to observe the effects of climate change. DOE has relied on simulation as a tool to understand the possible range of the effects of climate change. The simulation results and analysis are provided by Corbet and Knupp (1996) and Corbet and Swift (1996). These simulations have explicitly included the

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range of climate scenarios suggested by Anderson as well as alteration of Culebra permeability due to past dissolution of Salado halite and gypsum in Culebra fractures.

Results from these simulations were used to develop a conceptual model of long-term groundwater flow in the Culebra. As with any effort to simulate complex natural systems, a number of simplifications and assumptions were made to perform these simulations. In addition, there is large uncertainty in model parameters. For these reasons, the simulation results are not considered to be quantitative predictions. Instead, a suite of simulations has been used to develop a qualitative description of the range of possible effects of climate change on groundwater flow at the WIPP site. Details of the conceptual model are presented by Corbet and Knupp (1996).

These simulations were designed to examine the possible effects of climate change over the period from 14,000 years in the past to 10,000 years in the future. This period includes the transition from the wet period of the last glacial maximum to the modern dryer and warmer climate. Simulation parameters were selected to assure that the full range of groundwater flow conditions that could occur over the course of a complete climate cycle are represented. It is important to note that the most extreme conditions that could occur during a wet period are bounded by the conditions that result if it is assumed that recharge to the groundwater system is sufficient to raise the water table such that it is everywhere close to the land surface. The range of recharge rates and temporal patterns used in the simulations represent both drying of the climate that occurred between 14,000 and 8,000 years ago as well as shorter wet-dry cycles that have occurred during the Holocene.

Figure 2 shows how the simulations included the effects of dissolution of Salado halite and gypsum in Culebra fractures. A description of these processes from Corbet and Knupp (1996) follows:

> *Salado Dissolution*. The top of the Salado Formation has been dissolved over large areas. This dissolution disrupts and fractures Rustler strata and consequently increases their hydraulic conductivity to varying degrees (Beauheim and Holt, 1990). In the most extreme case, the Rustler breaks into blocks which rotate and are collapsed downward. In these regions, stratigraphic continuity is disrupted and vertical hydraulic conductivity increases to the extent that the Rustler does not behave hydrologically as a layered system. In other regions in which Salado dissolution is less extensive, stratigraphic continuity is maintained but fracturing increases the hydraulic conductivity of the more brittle carbonate and anhydrite units.

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Dissolution of Pore- and Fracture-Filling Minerals. Evaporite minerals (halite, gypsum, or anhydrite) fill much of the pore space and fractures in intact Rustler units (Holt and Powers, 1988; Beauheim and Holt, 1990). Over portions of the map area, moving groundwaters have dissolved these minerals and have thereby locally increased hydraulic conductivity. For example, past dissolution of cements and fracture fillings is thought to be an important control on the pattern of hydraulic conductivity of the Culebra in the vicinity of WIPP.

Nash Draw is located in the region west of the WIPP site and west of the line marking the western limit of intact Rustler strata in Figure 2. Note that the simulations consider a region of Nash Draw-type deformation over a region that is much larger than Nash Draw itself. Note also that dissolution of fracture filling is assumed to have increased Culebra permeability over the western half of the WIPP site (i.e., to the west of the line labeled "eastern limit of dissolution of Rustler cements and pore fillings"). Figure 3 shows how these processes were represented as zones in the simulations. Upper Salado dissolution (Zone 2) was assumed to increase the permeability of the Culebra by an order of magnitude. Dissolution of fracture fillings (Zones 2 and 3) was assumed to increase the permeability of the Culebra by 1.5 orders of magnitude.

These simulations use a free-surface/seepage-face upper boundary condition that represents the important role of the topography of the land surface on regional groundwater flow. Consequently, the simulation results are thought to be representative of groundwater flow conditions that have occurred since the land surface acquired its present shape, i.e. since the Mescalero caliche began to develop 600,000 years ago. That period includes the last 5 climate cycles described by Anderson.

The conceptual model that was derived from the simulation results supports Anderson's assertion that groundwater flow in the vicinity of the WIPP responds to climate change. However, the changes in flow to the Culebra are relatively small. This conceptual model suggests the following. Groundwater, under the full range of climate conditions, enters the Culebra by slow vertical flow through the overlying rock layers. All water in the Culebra within the site boundary has passed through the Dewey Lake Formation, and the portion of the Rustler above the Culebra. A portion of Culebra groundwater within the WIPP site boundary enters the Culebra as direct vertical leakage from the overlying Tamarisk member. The rest of the water entered the Culebra by vertical downward leakage outside of the WIPP site boundary and then flowed laterally to the WIPP site. During long periods of wetter climates the water table rises, flow direction in the Culebra shifts slightly toward the west, and flow rates increase slightly (by a factor of less than 2). Although flow in the Culebra responds rapidly to changes in recharge at the water table, perhaps in hundreds of years, recharge takes tens of thousands of years to reach the

Culebra. (Flow rates would increase because near-surface changes in fluid pressures due to a higher water table would propagate through the overlying sediments to the Culebra. Propagation of pressure transients to the Culebra does not mean, however, that water recharged in the future had reached the Culebra. Future recharge would still pass slowly through the overlying strata before reaching the portion of the Culebra within the boundaries of the WIPP site.) It is unlikely that any recharge that occurs over the next 10,000 years, under any climatic scenario, will reach the Culebra over that period of time.

Geochemical environment of the Culebra

A measure of the ability of groundwater to dissolve any mineral is the saturation index calculated for that mineral. The saturation index for a given mineral is defined as:

$$SI = \log [IAP/K_{sp}]$$

where

SI = Saturation index
IAP = Ion activity product
K_{sp} = Solubility product

In the case of gypsum, the ion activity product is equal to

$$IAP_{gyp} = [Ca^{+2}] \times [SO_4^{-2}] \times [H_2O]^2$$

where the parameters in brackets are thermodynamic activities calculated from measured concentrations. The solubility product is a function of the thermodynamic properties of the mineral, solution, and solutes at the temperature and pressure of interest.

In theory, a SI less than zero for a given mineral indicates that the groundwater is undersaturated with respect to that mineral, and the potential exists for that mineral to dissolve. A SI greater than zero indicates oversaturation, and that mineral would be predicted to precipitate. A SI equal to zero indicates an equilibrium state where the rate of dissolution is balanced by an equal rate of precipitation, and no net change in the mass of solids is predicted. In practice however, SI values within the range of -0.1 to +0.1 are generally considered to be indicative of equilibrium. Values of zero are not expected because of errors in the chemical analysis of groundwater samples as well as errors in the thermodynamic data used to calculate the solubility product. Deviations between the actual versus assumed temperature, and pressure effects can also contribute to non-zero SI values under equilibrium conditions.

Several Culebra water/rock equilibria investigations have been performed and have reached differing conclusions regarding the extent of gypsum saturation. Ramey (1985) and Beauheim and Holt (1990) identified areas within the Culebra that were undersaturated with respect to gypsum. However, the models used to calculate SI values in these investigations were not valid for the high ionic strength groundwaters encountered in the vicinity of the WIPP Site. Myers and Colton (1986) and Siegel, Robinson, and Myers (1990) used two different models (EQ3NR with the Pitzer option and PHRQPITZ respectively) which both produce accurate results at high ionic strengths. These two investigations found gypsum to be saturated in every well examined, with SI_{gyp} values ranging from -0.07 to +0.09.

Anderson (1995) presents an argument that dissolution of gypsum is presently occurring in the Culebra in a region of high transmissivity in the southern portion of the WIPP site. This region of high transmissivity is important because many of the potential release paths in performance assessment flow and transport calculations pass along this region. Anderson's position is logically based on a map published by Beauheim and Holt (1990) showing Culebra waters in this region to be undersaturated with respect to gypsum. However, as noted above, the equilibrium calculations that that figure was based on are now known to be in error and have been superseded by calculations presented by Siegel, Robinson, and Myers (1990). Consequently, the most recent equilibrium calculations do not support Anderson's hypothesis that gypsum is presently being dissolved in the Culebra in the vicinity of the WIPP site.

The fact, however, that water within the Culebra is in equilibrium with gypsum does not necessarily prove that gypsum dissolution will not occur for two reasons: 1) the water may have achieved equilibrium by dissolving gypsum in the Culebra, and 2) water in the Culebra may be a partial equilibrium system in which changes in ionic strength along flow paths in the Rustler may alter the solubility of gypsum (Siegel and Anderholm, 1994). The current understanding of Culebra hydrogeology and hydrochemistry, however, suggests that gypsum dissolution due to either of these processes is not occurring. The first process, that equilibrium may have been obtained by dissolving gypsum in the Culebra, is not thought to be occurring because the available data indicate that groundwater that is presently entering the Culebra is already saturated with respect to gypsum. The second process, that water in the Culebra may be a partial equilibrium system, has been evaluated by Siegel and Anderholm (1994). Their analysis shows that, if water in the Culebra is a partial equilibrium system, gypsum is presently precipitating along flow paths that follow the high transmissivity region. Details of these arguments against present-day dissolution are provided in the following paragraphs and in Siegel and Anderholm (1994).

The current dominant flow path of groundwater entering the Culebra is vertical leakage from overlying units. Chemical analyses of groundwater samples obtained from these overlying units were used to determine SI_{gyp} with the EQ3NR solubility/speciation code (Wolery, 1992). Results are shown in Table 1 and are plotted as a function of depth in Figure 4. The uppermost five samples were obtained in the vicinity of the Exhaust Shaft from the upper Dewey Lake near the contact with the overlying Triassic units at depths between 43 to 65 feet. These samples were undersaturated with respect to gypsum (SI_{gyp} = -0.54 to -0.61). The Dewey Lake contains extensive gypsum cement, but this cementation only occurs at depths below ~100 feet. This is evidenced by the fact the next two samples from the Dewey Lake at depths of 148 and 225 feet are in equilibrium with gypsum (SI_{gyp} = -0.08 and -0.06). The two lowest samples are from the Magenta at depths of 384 and 504 feet, and are also in equilibrium with gypsum. (SI_{gyp} = 0.01 and -0.04).

Table 1. Gypsum Saturation Indices

Well	Unit	Depth (ft)	Gypsum S.I.
ESB-C2507	Upper Dewey Lake	43	-0.54
ESB-ES001	Upper Dewey Lake	43	-0.55
ESB-C2506	Upper Dewey Lake	44	-0.53
ESB-C25C5	Upper Dewey Lake	51	-0.61
ESB-C2505	Upper Dewey Lake	65	-0.60
RANCH	Dewey Lake	148	-0.08
WQSP6A	Dewey Lake	225	-0.06
H4C	Magenta	384	0.01
H6C	Magenta	504	-0.04

These results suggest that groundwater entering the Culebra during present times equilibrates with gypsum well before entering the Culebra, probably by dissolution of gypsum cement within the Dewey Lake or Magenta or dissolution of anhydrite in the Tamarisk or Forty-niner members of the Rustler Formation.

Once equilibrated with gypsum, in an equilibrium system, groundwater will no longer be capable of dissolving additional gypsum along the flow path. However, as mentioned above, water in the Culebra dolomite may be a partial equilibrium system. As discussed by Siegel and Anderholm (1994), in such a system, saturation with respect to gypsum does not preclude either dissolution or precipitation of this mineral. Increases of ionic strength along current postulated flow paths are consistent with an influx of solutes from dissolution of evaporite salts in the Rustler formation. The changes in ionic strength and changes in the proportions of solutes suggest that gypsum continues to precipitate along the flow path while equilibrium is maintained.

Combining flow and geochemical information to address points 3 and 4 of Anderson's hypothesis

The conceptual model of regional groundwater flow suggests that all of the Culebra groundwater within the WIPP site boundary has passed through the overlying units. A portion of Culebra groundwater within the WIPP site boundary enters the Culebra as direct vertical leakage from the overlying Tamarisk member. The rest of the water enters the Culebra by vertical downward leakage outside of the WIPP site boundary and then flows laterally to the WIPP site. Vertical leakage through the anhydrite units above the Culebra, however, is very slow. Travel times from the water table to the Culebra within the WIPP site are probably tens of thousands of years. The Rustler units overlying the Culebra consist mainly of anhydrite and dolomite. The lower part of the Dewey Lake contains gypsum filling in fractures. Therefore groundwater has been in contact with sulfate minerals for long periods of time before reaching the Culebra.

The gypsum saturation calculations suggest that groundwater in the units above the Culebra, and within the Culebra itself is saturated with respect to gypsum. It is likely that groundwater is saturated with respect to gypsum by the time it reaches the base of the Dewey Lake and that it will not dissolve gypsum in the Rustler Formation. In addition, calculations by Siegel and Anderholm (1994) suggest that additional gypsum will likely precipitate in the Culebra fractures due to changes in ionic strength along the flow path.

The results of flow simulation indicate that for the most extreme climate scenario (future recharge rates that are fast enough to raise the water table to near the land surface in several thousand years) that the amount of flow through the Culebra would not increase by more than a factor of 2. Future recharge would still pass slowly through, and react with, the overlying strata before reaching the Culebra. It would take tens of thousands of years for future recharge to reach the portion of the Culebra within the boundaries of the WIPP site. Consequently, there is no reason to believe that water chemistry in the Culebra at the WIPP site is sensitive to climate change on a scale of tens of thousands of years.

This conceptualization, therefore, does not support the third and fourth points of Anderson's hypothesis. There is no indication that a change to a wetter climate would result in water that is undersaturated with respect to gypsum to be introduced to the Culebra. Instead, flow simulations, calculations of gypsum saturation as a function of depth, and calculations of mass transfers along flow paths support a conceptual model in which gypsum has not been dissolved from Culebra fractures over the past 600,000 years.

Summary and Conclusions

We have evaluated Anderson's suggestion that calculations of future flow in the Culebra over the next 10,000 years should assume a 100-fold increase in the transmissivity of the Culebra to represent to possible impact of dissolution of fillings in fractures in the Culebra. We agree that it is likely that gypsum has been dissolved from Culebra fractures in the geologic past, but are not aware of any information to suggest that dissolution has occurred over the last climate cycle, as Anderson has stated. We used a conceptual model of groundwater flow based on three-dimensional simulations, calculations of gypsum saturation as a function of depth, and calculations of mass transfers along flow paths to examine the possibility that chemistry conditions in the Culebra are sensitive to changes in climate. This analysis suggests that groundwater flow rates in the Culebra could fluctuate in response to climate change, but that flow rates during wet periods would not be more than twice what they are today. In addition, recharge to the groundwater system flows slowly through, and reacts with, overlying units that either contain gypsum in fractures and pores or consist mainly of anhydrite. Travel time for future recharge to the Culebra is tens of thousands of years. For any climate scenario, it is likely that groundwater is saturated with respect to gypsum before it reaches the Culebra and will not dissolve additional gypsum from the Culebra.

Although it is not possible, at this time, to absolutely rule out some change to the hydraulic properties of the Culebra over the next 10,000 years, such a change is not consistent with our current understanding of the geologic history and hydrogeology of this region and, in particular, our conceptual understanding of how groundwater flow and chemistry in the Culebra respond to changes in climate. We therefore do not agree that performance assessment calculations should assume that the transmissivity of the Culebra increases in the future.

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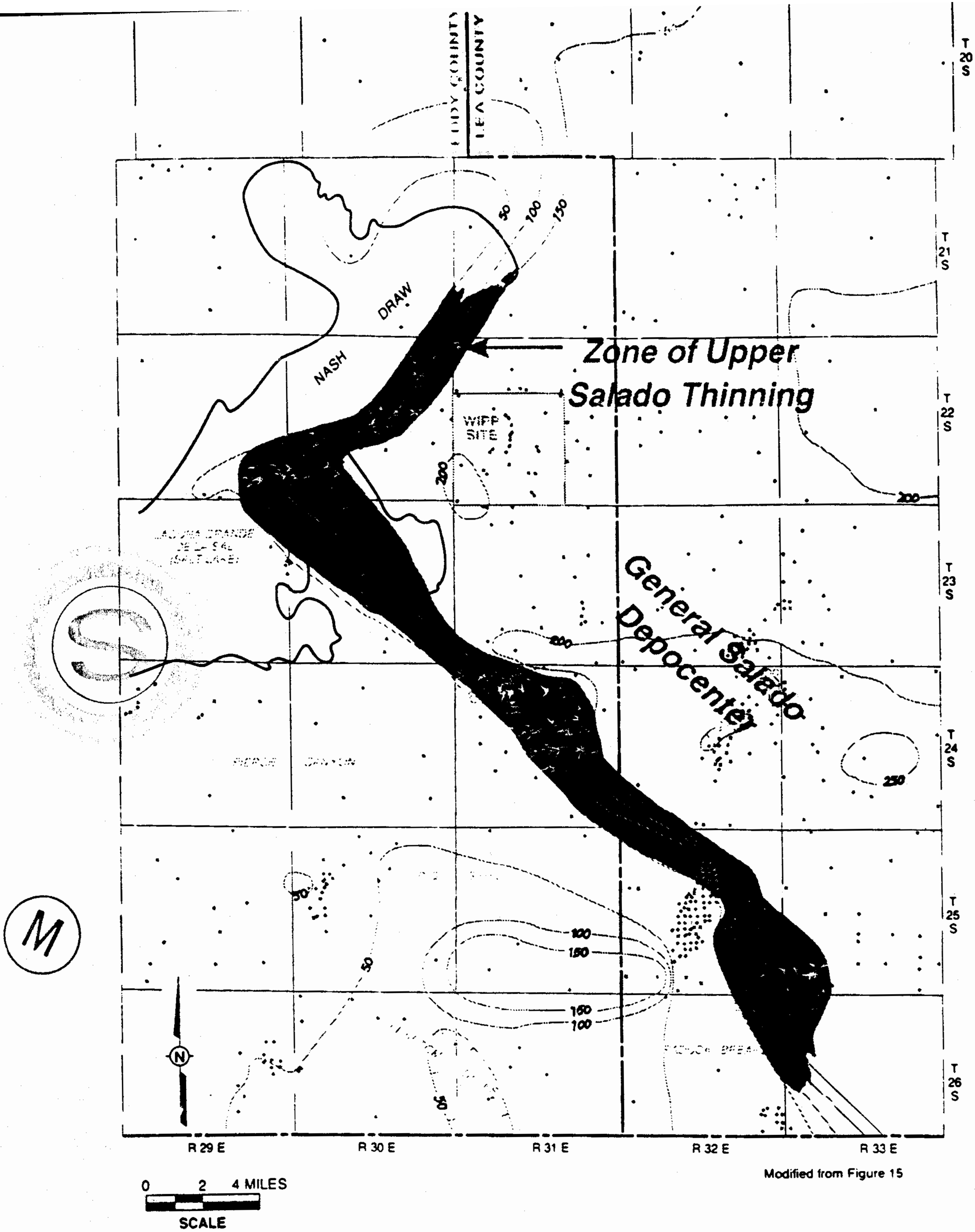

Figure 1. Extent of upper Salado Dissolution. Contour lines show thickness (in feet) from the base of Marker Bed 103 to the top of the Salado Formation. The steep change in upper Salado thickness (shaded region) indicates the eastward extent of dissolution of

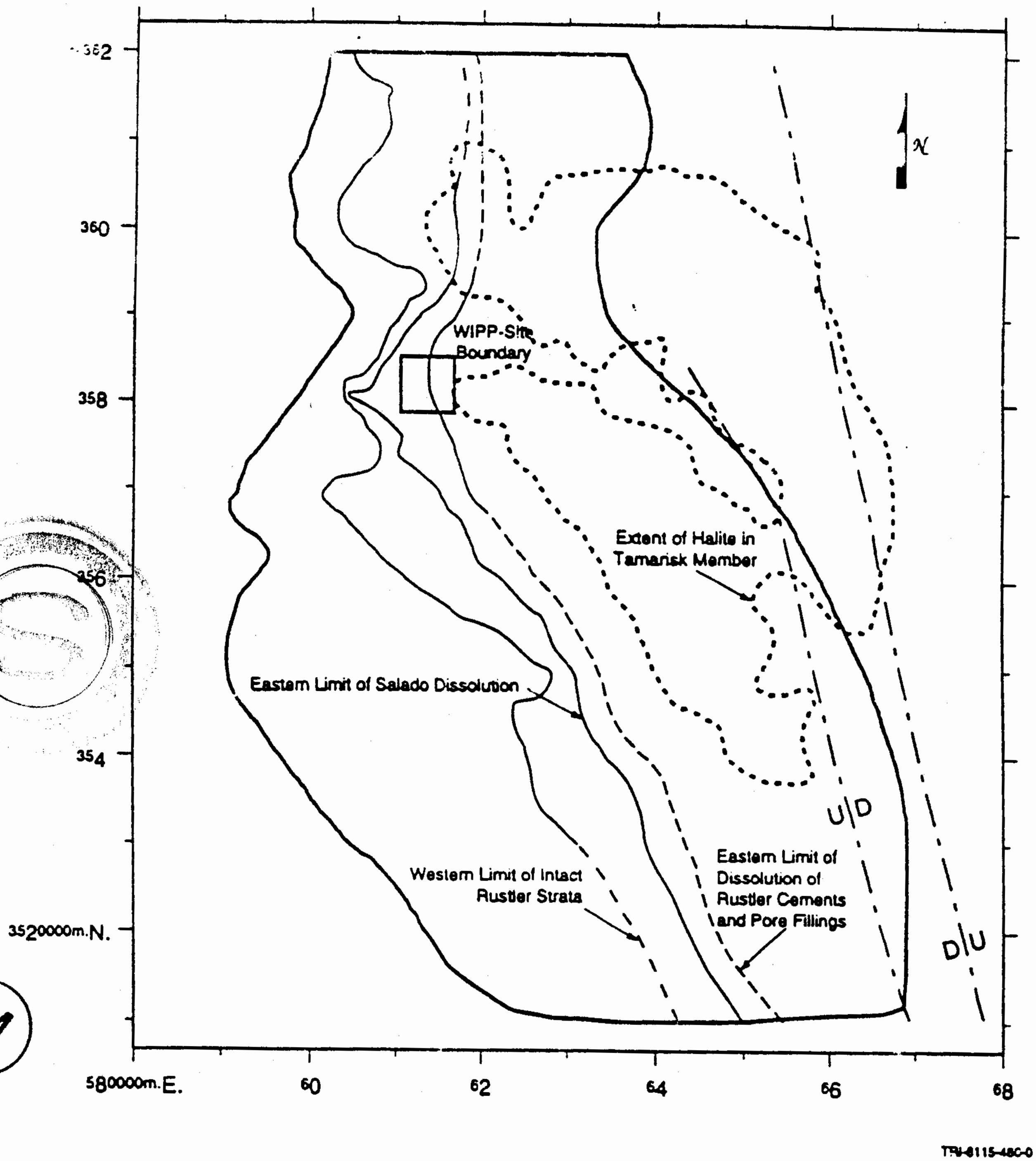

Figure 2. Regions in which hydraulic conductivity of Rustler units has been affected by post-depositional geologic processes. (Corbet and Knupp, 1996)

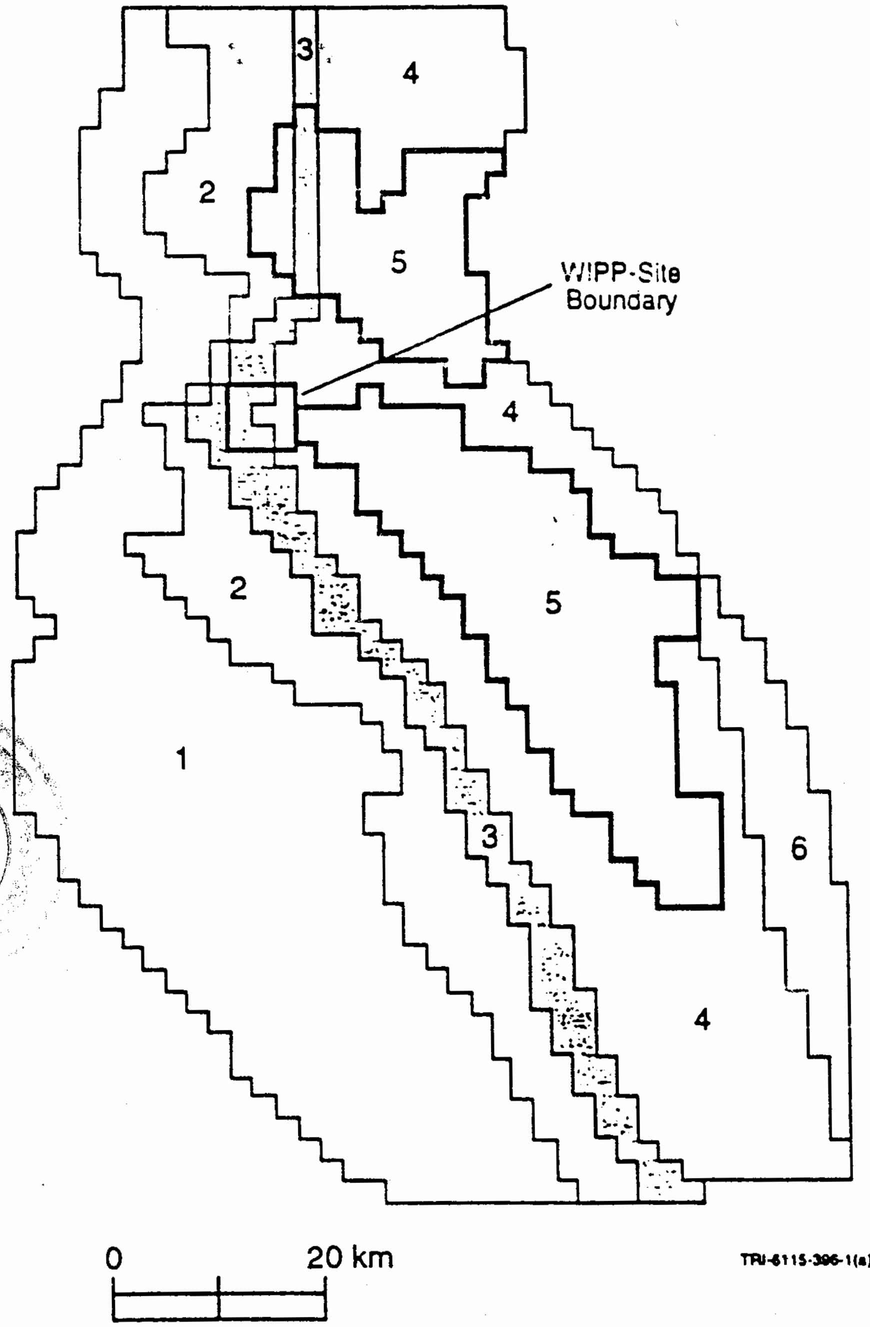

Figure 3. Zonation approach used to represent the effects of depositional setting and post-depositional processes. Zone 1 is a region in which dissolution of the upper Salado has fractured and disrupted overlying strata to the extent that stratigraphic layering is not preserved over long distances. In Zone 2, dissolution of the upper Salado is thought to have fractured the Rustler, but did not disrupt layering. Fractures that predate dissolution of the upper Salado are mostly filled with gypsum. These fracture fillings have been removed in Zones 2 and 3. Zone 4 represents intact strata. The region occupied by the halite facies of the mudstone/halite layers is indicated by Zone 5. A graben structure is shown as Zone 6.

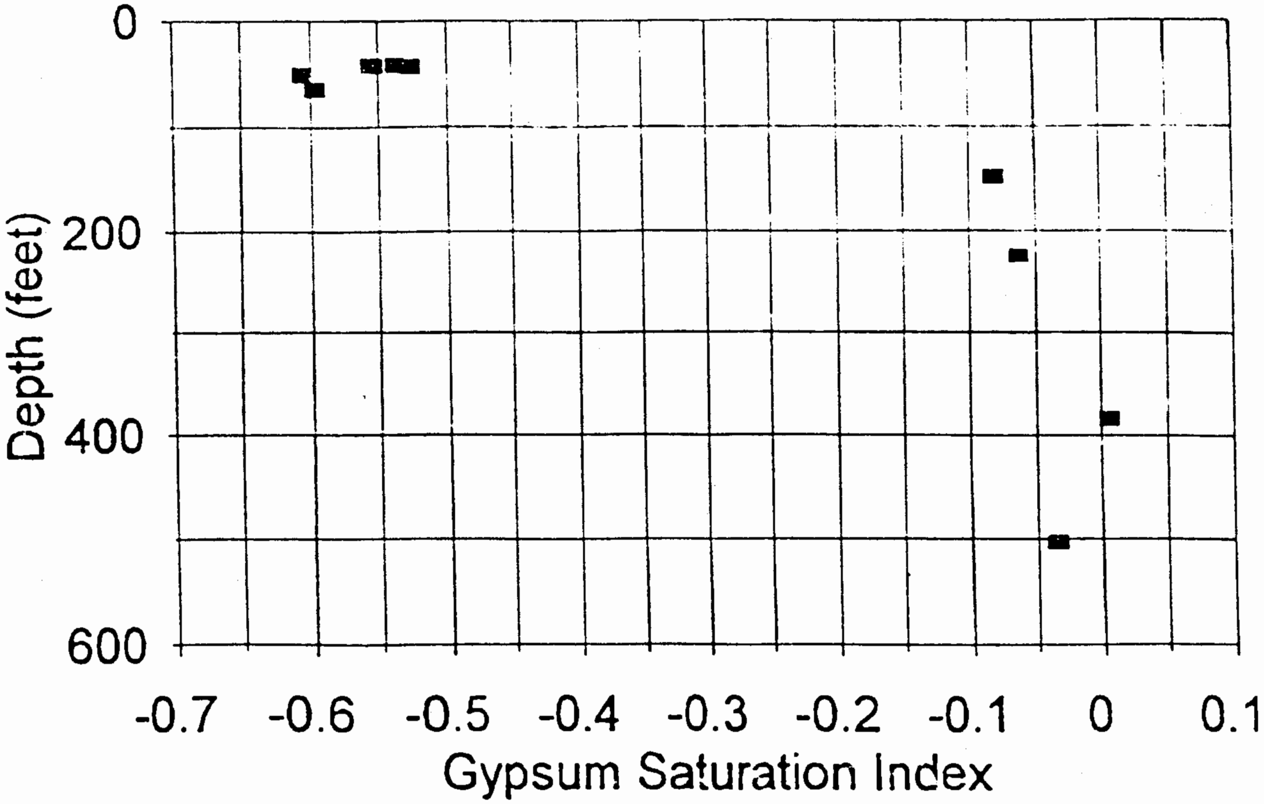

Figure 4. Gypsum saturation versus depth.. Data points with values less than -0.5 are from the upper portion of the Dewey Lake.

EPA Comment
Enclosure 1, Page 11
194.24(a)

Comment Text

194.24(a)
Part 194 requires DOE to provide information on the chemical, radiological and physical composition of waste proposed disposed at WIPP. The information must include waste component and their approximate quantities in the waste.

(1) The CCA does not provide data on the inventory of the organic compounds, phosphate, acetate, critrate, oxalate, or EDTA. DOE has indicated that these components are "negligible" or "not used" in performance assessment (Tables WCA-3 and WCA-4), implying that identification of these materials is not necessary. Nevertheless, this determination was made based upon assumed quantities and reactions, which would appear to necessitate an understanding of the quantities of these waste components present in the waste inventory.

The CCA needs to provide information pertaining to the estimated inventory of organic compounds, phosphate, and potential organic ligand.

(2) The CCA omits data concerning radionuclides Iodine 129, Technetium 99 and Tin 126, as well as data on total alpha activity.

These radionuclides were identified as important in 40 CFR 191 Appendix A: therefore, the inventory should be addressed in the CCA.

(3) TWBIR states that stored radionuclide inventories for Argonne National Laboratory-East, Argonne National Laboratory-West, and Teledyne-Brown Engineering were not reported.

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Provide the inventory data for Argonne National Laboratory-East and West, and Teledyne-Brown Engineering.

DOE Response

(1) The estimated organic or cellulosic content is described in section 2.3, *Roll-up of WIPP Waste Material Parameters by Final Waste Form*. In this section the cellulosic Waste Material Parameter Disposal Inventory content for final waste forms is estimated to range up to 960 kilograms per cubic meter with an estimated average value of 54 kilograms per cubic meter. Table 2-2 of the TWBIR, Rev. 3 provides these values. Table 2-2 also provides estimated Waste Material Parameter Disposal Inventory values

for other organic-containing materials such as Rubber, Plastics, Solidified Organic Material, and Soils. Greater detail (e.g., physical description and source) of these Waste Material Parameters may be found in the waste stream profiles in TWBIR, Rev. 2.

The quantity of phosphates in the BIR inventory is not necessary for the estimation of repository performance. Actinide phosphates are very insoluble and their presence at any significant level would thus lead to lower predicted actinide solubilities. Additionally, no beneficial effect of phosphates was included in the estimation of solubilities used to evaluate the repository performance in the CCA.

The BIR estimated the quantity of organic ligands based on a specific data call to the generator sites. The results of this data call are documented in the TWBIR rev. 3, Appendices B-3, B-4, and B-5. However, there is no quantity of organic ligands which can be added to the repository which will be detrimental to repository compliance. The negligible impact of organic ligands on repository actinide chemistry was confirmed by the Waste Characterization Analysis Peer Review Panel which stated in their Supplementary Report "The Panel agrees that under the conditions of MgO backfill, chelating agents will have a negligible effect on repository performance", WCL-1. The conservatism of this assumption is further enhanced in that no benefit was assumed from the biodegradation of the organic ligands or from the fact that much of the organic ligands in the waste will already be complexed with metals in the waste before emplacement. Additionally, an interpretation of the CCDF calculations in the absence of the MgO backfill has shown that for a significant number of the realizations, both of the most significant elements with respect to compliance (i.e. Am and Pu) are inventory limited. Therefore, for those realizations there is nothing, including organic ligands, that can be added to the repository which can increase the Americium and Plutonium concentrations since there is no more solid material available to dissolve. This interpretation supports the assertion that the quantity of organic ligands placed in the repository is inconsequential to demonstrating that the disposal system is compliant with the 191 standard. The quantity of organic ligands specified in the TWBIR is thus irrelevant.

(M)

(2) Attachment WCA.8.1 contains information for the isotopes in question. See Tables 1 through 5 and footnotes "e" and "m" to Table 3 (which also state that 5 radionuclides. Am 241, Pu 238, Pu 239, Pu 240, and Pu 242 make 99.9936% of the Unit of Waste value).

(3) The inventory data for Argonne National Laboratory-East [AE], Argonne National Laboratory-West [AW] and Teledyne Brown Engineering [TB] is presented in the following table. In relation to the total amount of waste currently reported in the DOE complex, these three sites, AE, AW, and TB, represent about 0.03% of stored CH TRU waste. Since both the volumes and radioactivity of waste stored at these three

sites is a very small percentage of the total (e.g., in the case of TB this represents only 1 drum out of an approximately 850,000 drum inventory) resources were concentrated on the major sites to refine their reported volumes and radioactivity values.

Estimated Stored Volumes and Activities at AE, AW, and TB

Site	Stored Final Form Volumes CH (cubic meters)[1]	Stored CH Radioactivity (curies)[2]	Stored Final Form Volumes RH (cubic meters)[1]	Stored RH Radioactivity (curies)[2]
AE	11	130	1.7[2]	10
AW	6.5	N/A	19	N/A
TB	0.21[3]	0.1[4]	None	None
Total	17.71	130	20.8	10
Total Inventory	58,000	1,916,140	3,600	685,920
Percentage	0.03%	0.007%	0.6%	0.001%

Footnotes:
1. From TWBIR, Rev. 3 (except as noted)
2. From Integrated Data Base, DOE/RW-0006, Rev. 12, December 1994 (except as noted)
3. Represents one stored drum
4. Derived from TWBIR, Rev. 2 Waste Stream Profile Forms

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EPA Comment
Enclosure 1, Page 18
194.41(a)

Comment Text

Active Institutional Controls

194.41(a)
Part 194 states that the CCA should include detailed descriptions of proposed active institutional controls, the controls' location, and the period of time the controls are proposed to remain active. Assumptions pertaining to active institutional controls and their effectiveness in terms of preventing or reducing radionuclide releases should be supported by such descriptions.

The implementation time line and the description of active institutional controls do not outline the process for implementing and maintaining AICs.

The CCA should include a list or time line that outlines the major AIC milestones and actions that will [be] taken to protect the repository in the pre- and post-closure phases. The CCA should describe how long each individual measure will continue to be effective, how it will be actively maintained, and cite empirical evidence which supports the periods of times asserted for effectiveness. For instance, when the Department asserts that a perimeter fence will be maintained for a minimum of 100 years, the Department should also identify minimum requirements for fence performance, how this will be inspected/determined, and how often and by what mechanism maintenance or replacement will be performed.

DOE Response

Appendix AIC, Figure 1 (attached), illustrates the planned schedule for implementation of the active institutional controls for access control to the site. The schedule is based upon closure of WIPP's Salt Handling Shaft in the first or second quarter of 2029 as indicated in the Decontamination & Decommissioning schedule published in Appendix D&D of the CCA. The following is an expanded discussion of the schedule.

January 2024 - Based upon historical experience, it is anticipated that archeological artifacts will be found during an archeological survey of the area including the fence and roadway. Upon artifact discovery, a Council of Native American Indians will need to be convened to determine whether or not any of the artifacts constitute a religious site.

January 2026 - Assuming that one or more religious sites are found, a two year period has been allowed for settling any issues arising from the planned construction's disruption of a religious site(s). Upon completion of the archeological survey and closure of any issues derived therefrom, demographic studies will be undertaken for the purpose of determining appropriate signage to be posted around the site perimeter. These studies will include consultation with the state of New Mexico and local Indian Tribes to ensure that appropriate written and graphic warning messages are provided. The objective of these studies and consulting efforts is to determine not only appropriate warning context, but also appropriate languages to be included in the signage.

December 2027 - Finalize signage configuration

June 2027 - Planned award for construction of the fence protecting the repository footprint and the roadway used for surveillance patrolling of the fence. This sequence of construction award provides an additional 18 months of time in the event either the closure of archeological issues or development of appropriate signage results in more complex and time consuming activities than are currently anticipated.

January 2028 - Initiation of contractual agreements to provide security surveillance patrols will include contacts with security service organizations and the Eddy County Sheriff's Department. Survey of security services companies (Survey form attached) confirm that the capability exists to provide a surveillance patrol at the WIPP site after closure. A discussion with the current Eddy County Sheriff's Department administration confirms that WIPP is in the Sheriff's region of responsibility. Calls for assistance in mitigating the consequences of unlawful acts of trespassing, vandalism, or destruction will be responded to by a Sheriff's representative.

(M)

June 2028 - One year is allowed for fence and road construction under the assumption that during the course of the archeological survey and closure of archeological issues all applicable permitting requirements with respect to the fence and access road will be completed. Recent experience in constructing approximately 7 miles of fencing in accordance with Bureau of Land Management fence standards supports that one year is a reasonable time frame. Discussions with a construction organization experienced with WIPP topography supports that construction of an unpaved roadway can easily be accomplished within one year.

September 2028 - Upon completion of fence and road construction, negotiations will be undertaken to conclude maintenance contracts for each feature. Included within the contracts terms will be requirements for detailed annual inspections and corrective actions to restore identified deviations to within normal limits of the initial material conditions of the fence and roadway. The contract terms will also include a requirement for the contractor to respond in a timely fashion for implementation of corrective action of any deviations which develop in the intervening intervals between scheduled annual inspections. Initiation of contract negotiations after completion of the fence and roadway permits potential contractors to inspect the physical conditions which will prevail during the contract period.

January 2029 - One year is a reasonable time to solicit and negotiate the surveillance patrol contract. This allows time for potential contractors to inspect the site and for the successful contractor to make any additional personnel, hardware, or transportation additions which may be needed.

March 2029 - Complete training of surveillance patrol personnel and initiate routine patrols. A two month period is provided for training patrol personnel. Patrols are planned for 2-3 times per week. This minimizes the number of personnel required to be trained to ensure depth in the organization for illness, untimely departure from the organization's employ, and vacation.

March 2029 - Appendix D&D schedules closure of the final shaft (Salt Handling Shaft)for March 2029. Final shaft closure is the event which marks the committed initiation of Active Institutional Controls. Although additional site presence will be required for some time after final shaft closure for completion of the removal of surface structures and land restoration, surveillance patrols will commence upon completion of this final closure event.

Vigilance of site integrity will also be provided by activities supporting the monitoring programs described in Appendix MON and decommissioning activities subsequent to final closure of the repository. The monitoring activities will include groundwater surveillance for 30 years after closure, observation of drilling activities for at least 100 years after closure, and subsidence monitoring for at least 100 years after closure. The decommissioning of all structural facilities related to WIPP operational activities will require an additional 2 years (schedule in Appendix D&D) after closure. These post closure activities will provide for random site occupancy for many years adding a level of protection against unlawful entrance within the fenced repository footprint at the surface.

During the development of the specification for fencing procurement and installation, the DOE will conduct a survey of best available materials to include within the fence material specification. In addition a survey of the type of fencing used for similar applications at other TRU waste sites will be conducted to determined the range of configurations and materials used. At a minimum, the fencing will comply with the Bureau of Land Management's standard wire spacing for fencing used for the combination of cattle (requiring greater restriction of livestock movements) with deer, elk, moose, or antelope. National standards applicable to wire fencing at the time will be consulted and used as minimum requirements with respect to material and configuration. Wire will be no less than class 3 (galvanized high tensile). Stress panels embedded in concrete will be placed every 80 rods (1320 feet-the length of barb wire on a standard reel). Galvanized pipe posts will be placed at a minimum 100 feet intervals with at least 4 to 5 steel T-posts in between galvanized pipe posts and 2 stays between T-posts.

Discussions with local fencing contractors support that properly maintained barb wire fencing can be expected to last over fifty years in the WIPP area when effectively maintained. From these same discussions, it has also been learned that the most detrimental environmental condition to wire fencing longevity is from wind blown sand. The alkalinity in sand can reduce the protective aspects of the galvanizing which leads to corrosion and failure. Within the surveillance patrol check list and the annual fence inspection checklist are specific items relating to the reporting of sand build up. Such conditions, if and when they develop, will be corrected within the conditions established for the fence and road maintenance contract.

The roadway will be constructed by grading and compacting the surface sediments. Caliche will then be emplaced over the compacted surface sediments, watered, and compacted to form the roadway. Similarly constructed areas have been built throughout the WIPP site and have performed well with significantly more traffic than is expected for the access control roadway. With annual inspections of the roadway and timely corrective action for any identified deviations detrimental to the performance of the roadway, the road will last as long as necessary to provide surveillance access. Some additional roadwork will be required prior to construction of the Permanent Marker System for those portions of the roadway which will be subject to use by heavy construction equipment. However, during the construction period the daily occupancy of the repository footprint area will provide for effective access control and elimination of activities which might result in an intrusion of the repository itself. Upon completion of the Permanent Marker System, a re-evaluation of the access control and surveillance road will be made and appropriate configuration changes implemented to provide for continued surveillance during the entire active institutional controls period.

The DOE recognizes that the commitment to provide a fencing arrangement for a period of at least 100 years will probably require one or more instances of extensive fence re-building. However, the planned surveillance supplemented by a detailed annual inspection program will ensure that the day-to-day condition of the fence and the access to inspect and maintain the fence as required will be achieved and sustained over the long-term.

Table 1, **PATROL INSPECTION CHECKLIST,** represents the level of information that the DOE will expect surveillance patrols to determine in the course of routinely surveying the fenced area several times per week. These patrols will be documented and any required corrective actions will be accomplished by either the security force or the maintenance contractor. In developing the contractual conditions, corrective action responsibility and interfacing protocols between contractors will be included as part of the contract(s) to ensure that timely and effective repairs are made. In the event circumstances require that the prime patrol be assigned to a commercial security organization, the Eddy County Sheriff's Department will provide support in the event the contractor requires such support. The Eddy County Sheriff's Department has acknowledged that the WIPP site is within it's jurisdiction and that support will be provided in the event unlawful acts are identified. The Eddy County Sheriff's Department also has mutual assistance pacts with adjacent counties and the state police for additional law enforcement resources in as emergency or due to immediate availability of Eddy County personnel.

To provide information regarding the capability of commercial security firms, a survey of potential security service providers was conducted. Table 2, **WIPP SECURITY PATROL CAPABILITIES SURVEY,** was responded to by several firms. In every case the reply to the described capability was positive. Based upon this information, DOE has every reason to believe that an effective security patrol arrangement can be developed which will ensure that the integrity of the repository is not compromised during the active controls period.

Table 3, **ANNUAL INSPECTION CHECKLIST,** represents the level of detail expected to be implemented by the maintenance contractor during the annual inspections of the fence and roadway. Conducting annual inspections and providing maintenance to maintain the fence and roadway within design requirements will add longevity to the structures and reduce the need for frequent extensive fence replacement as the fence material ages.

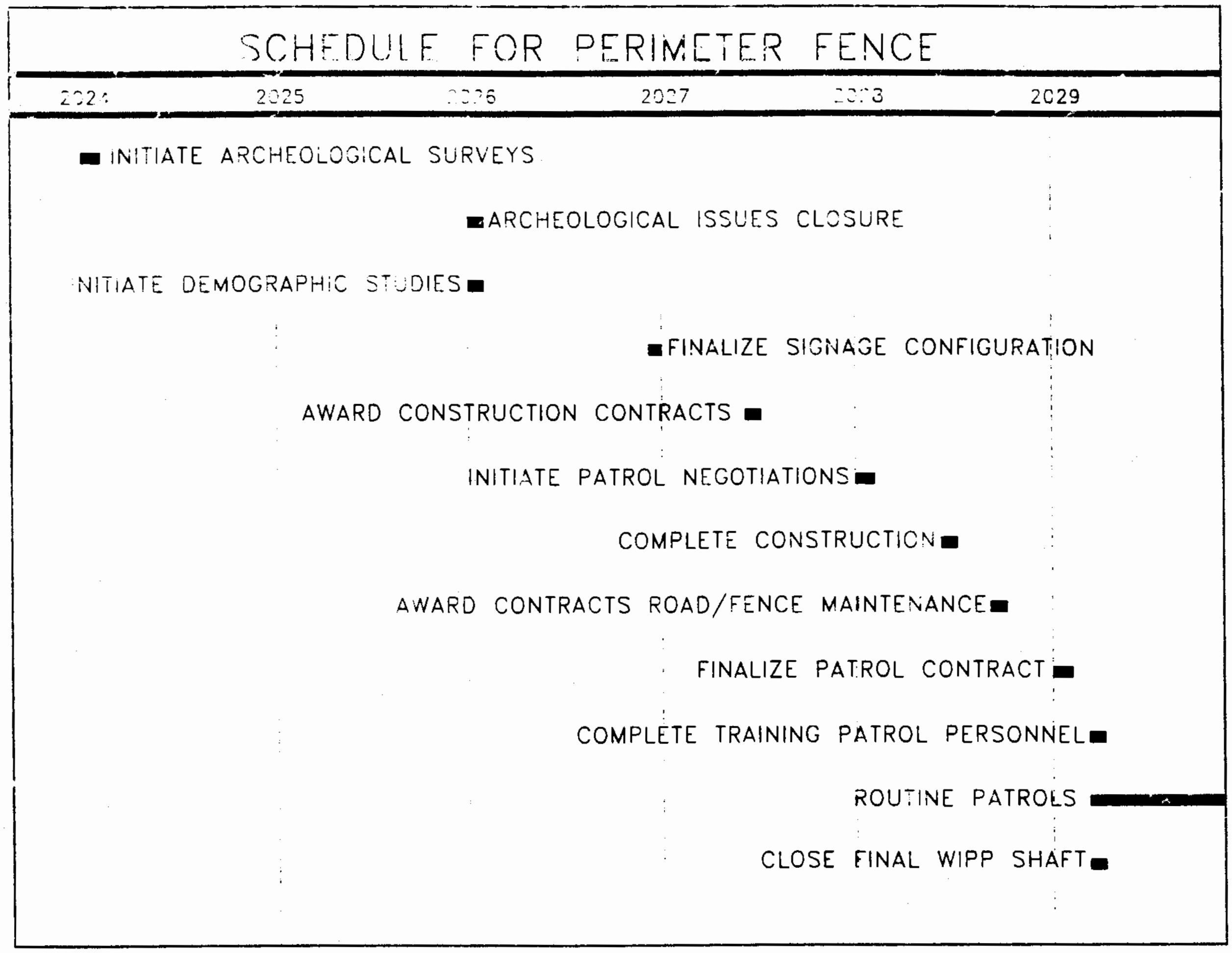
SCHEDULE FOR PERIMETER FENCE
2025
2027
2029
INITIATE ARCHEOLOGICAL SURVEYS
ARCHEOLOGICAL ISSUES CLOSURE
NITIATE DEMOGRAPHIC STUDIES
FINALIZE SIGNAGE CONFIGURATION
AWARD CONSTRUCTION CONTRACTS
INITIATE PATROL NEGOTIATIONS
COMPLETE CONSTRUCTION
AWARD CONTRACTS ROAD/FENCE MAINTENANCE
FINALIZE PATROL CONTRACT
COMPLETE TRAINING PATROL PERSONNEL
ROUTINE PATROLS
CLOSE FINAL WIPP SHAFT

Figure 1

PATROL INSPECTION CHECKLIST

1. Integrity of gates' structural condition:
   - No corrosion
   - No visible signs of damage
   - No evidence of intrusion
   - No evidence of dismantling
   - No buildup of wind driven sand covering gate structure
   - No other visible signs of damage to the structure.

2. Integrity of gates' locking devices
   - Locking devices in place
   - No evidence of tampering

3. Integrity of barb wire
   - No visible signs of corrosion
   - No loose/removed wire stays
   - No sagging wire
   - No broken/cut wire
   - No evidence of intrusion
   - No buildup of wind driven sand covering wire

4. Integrity of fence posts
   - No corrosion
   - No broken, bent, or removed fence posts
   - No buildup of wind blown sand around fence posts
   - No loose or removed wire-to-post connections
   - No loose, destroyed, or missing warning signs

5. Integrity of roadway
   - No evidence of heavy equipment traffic on roadway
   - No evidence of recreational use of roadway (motorcycles, dune buggies, etc.)
   - No potholes, road cuts, or weather damage which could render the roadway impassible

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Table 1 (continued)

6. Integrity of protected area
   - No visible evidence of resource investigation
   - No presence of man-made equipment within the protected area
   - No evidence of livestock within the protected area
   - No evidence of removal, destruction, or vandalism against Permanent Marker test structures (berm section and monuments)
   - No evidence of recreational use within the protected area (motorcycles, dune buggies, camping, etc.)

7. Integrity of the withdrawal area
   - No evidence of resource investigation
   - No presence of man-made heavy equipment

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Table 2

WIPP SECURITY PATROL CAPABILITIES SURVEY

ORGANIZATION ____________________

1. Can your organization provide experienced security personnel?
   Yes ___
   No ___

2. Can your organization provide reliable transportation to conduct staggered patrols of the WIPP area at least 3 times per week?
   Yes ___
   No ___

3. Can your organization provide mobile communications capability which would allow security personnel to contact the Eddy County Sheriff's Department in the event assistance is required to mitigate the consequence's of an emergency situation or an unlawful act?
   Yes ___
   No ___

4. Can your personnel be trained to observe and report on the status of conditions identified in the attached PATROL INSPECTION CHECKLIST for a fenced security area (approximately 0.25 square miles), and the WIPP withdrawal area (16 square miles) ?
   Yes __
   No __

5. Can your personnel be trained to understand governmental regulations restricting access and public use of a fenced security area and limited access to and public use of the WIPP withdrawal area ?
   Yes __
   No __

(M)

Table 2 (continued)

6. **Can your personnel be trained to complete written reports and inspection check lists?**
   Yes __
   No __

7. **Can your personnel be trained to understand the limits of their ability to apprehend personnel involved in unlawful acts of trespassing, vandalism, or destruction of government property?**
   Yes __
   No __

8. **Can your personnel be qualified and permitted to carry firearms in the course of providing security services?**
   Yes __
   No __

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Table 3

ANNUAL INSPECTION CHECKLIST

1. Detailed inspection of gate structural condition
   - No visible signs of corrosion
   - No cracked welds
   - No loose fasteners
   - Removal of any sand buildup impinging on gate structure
   - Structural integrity of gate hinges not impaired
   - Gate supports structurally sound
   - Gate closure and locking mechanism functional

2. Detailed inspection of fence wire
   - No visible signs of corrosion
   - No cut or broken wire
   - Wire tension within specification
   - No missing of broken wire stays
   - Removal of any wind blown sand impinging on wire

3. Detailed inspection fence posts
   - No visible signs of corrosion
   - No broken, bent, or removed fence posts
   - No loose fence posts (structurally sound emplacement into the ground)
   - No loose, broken, or removed wire to post connectors
   - No evidence of erosion leading to loose fence post or fence post failure
   - No loose, destroyed, or missing warning signs

4. Detailed inspection of roadway
   - No potholes, road cuts, or weather damage which could render the roadway impassible
   - No evidence of insufficient drainage resulting in actual or potential damage to roadway
   - No evidence of loss of roadway surface integrity
   - No evidence of excessive intrusion of wind blown sand over the roadway

Note: Inspection deviations will be corrected as a part of the inspection program.

EPA Comment
Enclosure 2, page 2
194.23(a)(1) & 194.23(a)(2)

Comment Text

194.23(a)(1) & 194.23(a)(2)
Sections 194.23(a)(1) and 194.23(a)(2) require a description of the conceptual models and alternative plausible conceptual models and an explanation of the reason why such alternative models were not deemed accurate.

Appendix MASS states "The conceptual model used in performance assessment for groundwater flow in the Culebra treats the Culebra as a confined two-dimensional aquifer with constant thickness and spatially varying transmissivity." The treatment of the Culebra as a fully confined system is contradictory to the modeling results presented by Corbett and Knupp (CCA Reference No. 147) which indicate on Page 5 that "Vertical leakage may contribute as little as 5% or more than 50% of the total inflow to the portion of the Culebra that lies within the WIPP-site boundary."

The Department needs to provide additional support for the use of a fully confined system for the conceptual model, including information on why the Culebra should not be treated as unconfined (an alternative conceptualization) in certain areas.

DOE Response

(M)

As is noted in Section 6.4.6 of the CCA, the model of Culebra groundwater flow used for performance assessment calculations is a simplified implementation of the groundwater-basin conceptual model described in Sections 2.2.1.1, 2.2.1.4, Appendix MASS Section 14.2, and in Corbet and Knupp (1996). The groundwater-basin conceptual model suggests that the contribution of vertical leakage to the Culebra is uncertain (as little as 5% or more than 50% of the total inflow to the portion of the Culebra that lies within the WIPP-site boundary). The flow model used for performance assessment calculations simplifies the implementation by making the assumption that the vertical leakage can be neglected. The justification for making this assumption is documented in Appendix MASS, Attachment 15-7. The justification is based on several points. First, three-dimensional simulations show that all of the outflow from the portion of the Culebra that lies within the WIPP-site boundary is by lateral flow along the Culebra. This means that a two-dimensional model can represent all reasonably expected release paths from the Culebra. Second, the two-dimensional model provides a good approximation of the actual Culebra flow field. The approximation is good because the simulated flow fields are well constrained by transmissivity and hydraulic head measurements. The impact of neglecting vertical leakage when calculating realizations of the transmissivity distribution is small because these distributions are partially calibrated using transient data from pumping tests. The length of time of the pumping tests is too short for these tests to be affected by vertical leakage.

Reference

Corbet, T. F., and P. M. Knupp, 1996. *The Role of Regional Groundwater Flow in the Hydrogeology of the Culebra Member of the Rustler Formation at the Waste Isolation Pilot Plant (WIPP), Southeastern New Mexico.* SAND96-2133. Sandia National Laboratories, Albuquerque, NM. CCA Reference Number 147.

EPA Comment
Enclosure 2, page 3
194.23(a)(ii)

Comment Text:

194.23(a)(3)(ii)
Section 194.23(a)(3)(ii) requires documentation that the "mathematical models incorporate equations and boundary conditions which represent that mathematical formulations of the conceptual models."

The BRAGFLO User's Manual is unclear on how the effects of wicking are integrated into the mathematical model.

The Department needs to clarify the incorporation of wicking into the mathematical model.

DOE Response:

The treatment of wicking in the BRAGFLO mathematical model is completely described on pages 125 and 126 of the BRAGFLO User's Manual (Appendix BRAGFLO).

In summary, the wicking model is incorporated to describe the effects a capillary fringe might have on gas generation rates. Because there is a significant difference in gas generation rates between humid conditions (low or zero) and brine-wetted conditions, and because there is considerable uncertainty in the two-phase characteristics of future, degraded waste, the wicking model was incorporated to provide for uncertainty in the quantity of waste experiencing wetted conditions. The logical minimum quantity of waste under wet conditions is equal to the actual brine saturation in a model cell as calculated by BRAGFLO. The maximum quantity of waste in a model cell under wet conditions occurs when a capillary fringe is well developed and fully covers waste surfaces. The wicking model covers the range of uncertainty in the process through sampling of the parameter SATWICK. The wicking equation is applied to each model cell containing waste in the BRAGFLO domain. Other parameters in the model (LARXN, ALPHARXN) are selected to provide improved numerical convergence at low true brine saturations, but to not change the overall behavior of the model.

It is important to realize the wicking model affects only parameters provided as inputs to the gas generation equations in BRAGFLO. Brine saturations in the BRAGFLO model elements, a primary variable of BRAGFLO, are not affected by the wicking model.

EPA Comment
Enclosure 2, Pages 3-4
194.23(a)(3)(iv)

Comment Text

Section 194.23(a)(3)(iv) requires "computer models accurately implement the numerical models" and are free of coding errors and produce stable results.

Appendix PAR identifies the assigned values for both longitudinal and transverse dispersivity in the Culebra as 0.0. Although this value would appear to lead to conservative results by reducing the amount of surface area available for matrix diffusion, there is insufficient evidence presented in the CCA that the SECOTP code will provide stable solutions at such low dispersivities. In fact, in a letter from James McCord to James Ramsey (Sandia National Lab), provided as an attachment to the Parameter Record Package for non-Salado longitudinal dispersivity, Dr. McCord states "Assuming that the numerical codes used correctly solve the governing partial differential equations, simulations using local dispersivities less than or equal to 2 m will yield results consistent with field scale dispersive spreading observations as reported by Gelhar et al. (1992)."

The Department needs to provide evidence that the numerical solver method implemented in the SECOTP code correctly solves the partial differential equations at the dispersivities of 0.0 over the range of Courant numbers used in the CCA.

DOE Response

Numerical approximations of advection-dominate transport problems may result in spatial oscillations near regions where the concentration gradients are steep. These oscillations (commonly referred to as undershoot and overshoot) are caused by the inability of second order numerical approximations to accurately propagate short wavelength harmonics. The problem tends to become severe when the local Peclet number exceeds a value of 10 because the short wavelength harmonics become increasingly important (Huyakorn and Pinder, 1983, p. 206). The Peclet number, which is inversely proportional to the dispersion coefficient, is quite large when the dispersivities are set equal to zero.

In most transport simulators this problem is addressed by enhancing spatial discretization and/or introducing numerical dispersion by reducing the order of the numerical approximation (upwind or upstream weighting discretization schemes). Fully-weighted upwind schemes do not have undershoot and overshoot problems, but numerical dispersion is often quite large and the resulting solution may not be accurate.

To avoid oscillatory behavior limit numerical dispersion, a total variation diminishing (TVD) flux limiter scheme is invoked in SECOTP2D. The underlying concept is the application of upwinding techniques where needed to the degree necessary to prevent non-physical oscillations. A discussion of TVD including references is found on page 7 of the *WIPP PA User's Manual for SECOTP2D, Version 1.30* (Appendix SECOTP2D of the CCA).

In the CCA, zero dispersivity coefficients were used in both the longitudinal and transverse directions. The dispersion coefficients are extremely small, but non-zero, due to contributions from the molecular diffusion component. Because the SECOTP2D results did not exhibit oscillatory behavior, the CCA runs are in and of themselves a test of the stability of SECOTP2D and demonstrate that zero dispersivities are not a problem for SECOTP2D.

Reference:

Huyakorn, P.S., and G.F. Pinder, 1983. *Computation Methods in Subsurface Flow*, Academic Press, Inc., New York, NY. (Textbook)

EPA Comment
Enclosure 2, Page 6
194.23(c)(4)

Comment Text

194.23(c)(4)
Section 194.23(c)(4) requires "detailed descriptions of data collection procedures, sources of data, data reduction and analysis, and code input parameter development."

A low transmissivity region appears consistently in the calibrated transmissivity fields in the eastern portion of the site where there are limited data (Appendix TFIELD). From the histogram of Culebra transmissivity data, the P-18 data point could be argued to be a statistical outlier. Given the large variation of transmissivity data over the wider region, the P-18 data point could also be valid. If the low transmissivity region is an artifact, then it will bias some travel times high.

The Department needs to determine whether there are any physical explanations for an artificially low transmissivity data point at P-18, and provide evidence to explain how one data point can produce low transmissivity in a region far separated from that data point. The transmissivity fields need to be calibrated with the P-18 data point removed to verify that the low transmissivity region is due to the single data point at P-18.

DOE Response

Regarding the physical explanation for the low transmissivity observed at P-18, the DOE recognizes that there is not independent test data from other, nearby, boreholes that confirm this value. However, the low value observed at P-18 is consistent with the conceptual model of regional hydraulic conductivity adopted by Corbet and Knupp (1996). P-18 is the only borehole of those used for calibrating the transmissivity distribution that is located in a region in which the Culebra was assigned a very small hydraulic conductivity for the purpose of simulating regional groundwater flow. The low conductivity for this region was based on a conceptual model of how geologic processes have modified the hydraulic conductivity of rocks above the Salado Formation. Specifically, P-18 is in a region of the Culebra that underlies halite deposits in the Tamarisk member. The following description of this region is from Corbet and Knupp (1996).

Proximity to Halite Deposits. In regions where halite deposits are present in the Rustler, halite replaces gypsum in the rock matrix and fills fractures in units that underlie or overlie the halite deposits (e.g., Holt and Powers, 1988). The hydraulic conductivity in units affected by gypsum replacement and fracture filling is possibly as low as that of the halite deposits.

The presence of halite in the pores and fractures in the Culebra is based on a conceptual model of geologic processes. However, samples of the Culebra are not available from this region to confirm the conceptual model.

The extent of this region of low hydraulic conductivity is indicated by the dashed line labeled "Extent of Halite in Tamarisk Member" in the attached figure (Figure 2-6 of Corbet and Knupp). Within this region, the hydraulic conductivity was assumed to be two orders of magnitude less than that of intact Culebra that does not underlie halite deposits.

With respect to the calibration of the transmissivity fields, the DOE concludes that the transmissivity value assigned to the P-18 borehole has had a minor effect upon the groundwater travel times within the Culebra. This is due to the multi-categorical approach used in GRASP-INV during the CCA PA calculations. An explanation supporting this follows.

Figure 3-10 in the GRASP-INV Analysis Package provided to the EPA illustrates the histogram of the Culebra transmissivities. The transmissivity at P-18 (-10 $\log_{10}$ m^2/s) is represented by the outlier on the left side of the histogram. As described in the CCA Appendix TFIELD, the indicator categorical approach was used to segment this histogram into two separate categories. The first category ranged from -2 to -6 $\log_{10}$ (m^2/s) while the second category ranged from -6 to -10 $\log_{10}$ (m^2/s). The value of -6 was chosen because it seems to split the histograms properly and coincidently, it corresponds to the median of the transmissivity distribution.

Splitting the histogram into two categories allowed for the optimization of the low T and high T parts of the model domain to be conducted somewhat independently. In obtaining the transmissivity assigned to a grid block, a 'local' CDF of this type is built by GRASP-INV for each grid block by calculating a mean and variance of the nearest 10 neighbors. A 'local' CDF is then determined by using this mean and variance and assuming a Gaussian distribution. This local CDF is then sampled to obtain the transmissivity assigned to the grid block.

P-18's transmissivity value had a minimal impact upon the groundwater travel times because it had a minimal impact upon the mean value of the local CDF's. The mean value was generally much higher than P-18's value since nine other values with transmissivities several orders of magnitude higher than P-18's transmissivity value were included in the mean estimate (used for the local CDF's).

References

Corbet, T. F., and P. M. Knupp, 1996. The Role of Regional Groundwater Flow in the Hydrogeology of the Culebra Member of the Rustler Formation at the Waste Isolation

Pilot Plant (WIPP), Southeastern New Mexico. SAND96-2133. Sandia National Laboratories, Albuquerque, NM. CCA Reference Number 147.

Holt, R.M., and D.W. Powers, 1988. Facies Variability and Post-Depositional Alteration within the Rustler Formation in the Vicinity of the Waste Isolation Pilot Plant, Southeastern New Mexico, DOE/WIPP 88-004. US Department of Energy, Carlsbad, NM. Included in the CCA as Appendix FAC.

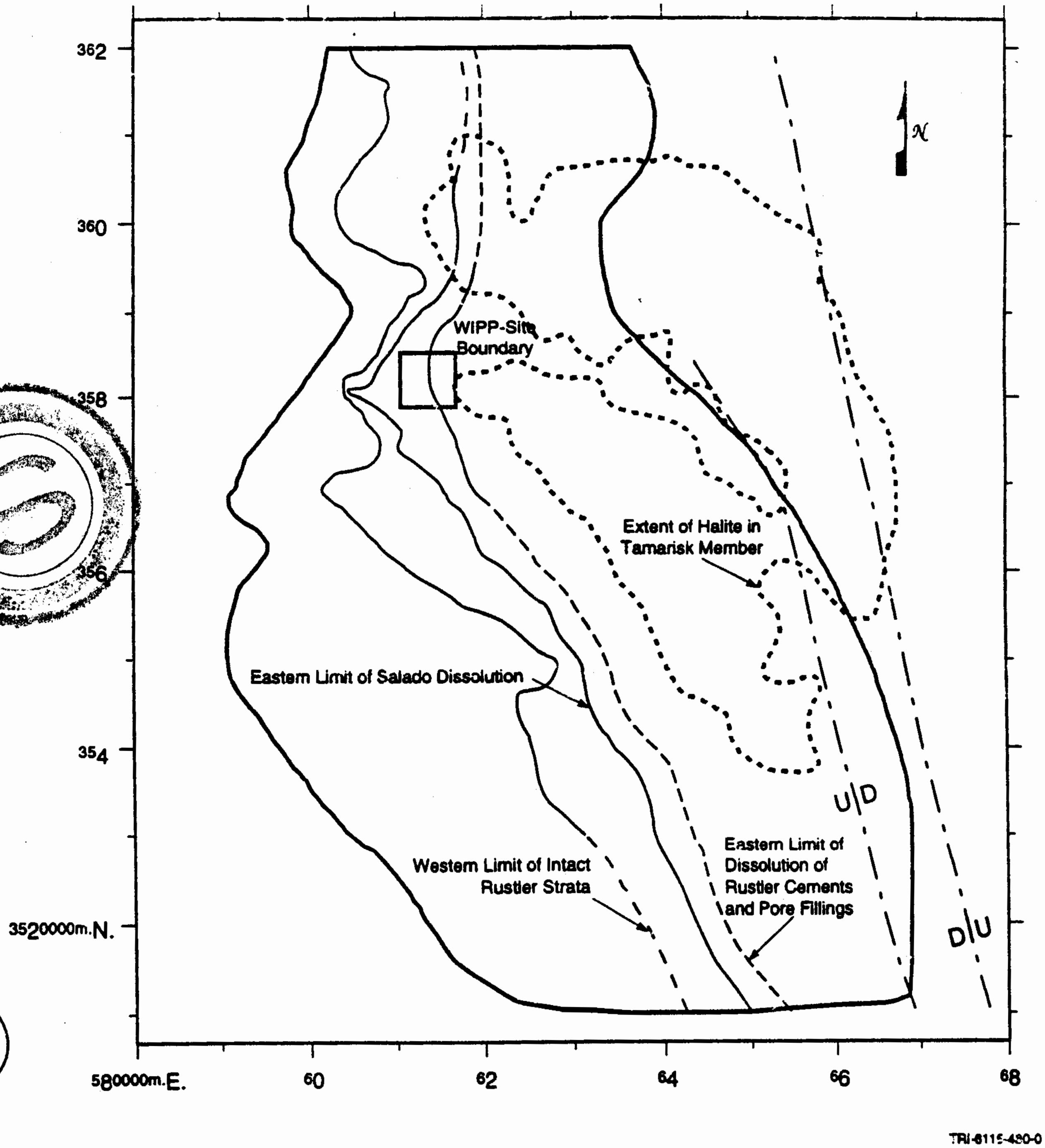

Figure 2-6. Regions in which hydraulic conductivity has been affected by post-depositional geological processes.

EPA Comment
Enclosure 2, Page 10
194.43(a)

COMMENT
Passive Institutional Controls

194.43(a)
Section 194.43(a) requires "Any compliance shall include detailed descriptions of the measures that will be employed to preserve knowledge about the location design, and contents of the disposal system."

DOE may assume only that the passive institutional control (PIC) design as proposed will satisfy the compliance criteria, not the design as it is constructed 100 years in the future will do so. Chapter 7 of the CCA and related appendices leave open the possibility that the conceptual design that is finally implemented could be radically different from anything that might be approved by EPA during the period of its regulatory authority. For instance, Appendix PIC states, "It should be noted that the illustrations used to support this conceptual design report are not intended to represent the final configurations, rather they are for the purpose of representing the type of configurations which are intended to be used in the final design." [Page 4] The explanation of DOE's schedule for implementation does not allow EPA to evaluate the proposed design as a final design. As a result, DOE's commitment to a specific design and the Department's ability to implement the design as proposed are rendered ambiguous.

EPA acknowledges that, if the WIPP is certified, the conceptual design as proposed in the initial application is likely to undergo substantial modification over the course of several decades as our knowledge and technical capabilities expand. Nevertheless, EPA cannot certify an undefined "final design" as it may exist 100 years in the future. EPA considers it more appropriate to assume for the purpose of certification that the conceptual design that is proposed is the same one that will be implemented.

The Department must provide more explicit information in support of its proposed design and schedule for implementation of PICs. At a minimum, this information should include:

- *which steps DOE can and cannot accomplish during the operational period and the reasons why;*
- *the rationale behind the timing of the various stages of implementation;*
- *specific actions that DOE will take to test PICs, when those actions will occur, and what DOE expects to learn by testing--especially in terms of how testing could lead to substantial modifications to the conceptual design; and*

- *evidence that DOE, in proposing the design as practicable, gave serious consideration to the amount of time, human effort, and money likely to be required to implement the major aspects of the design.*

For example, the statement that "this design concept will be revisited over the operational lifetime of the WIPP" lacks explication (Section 7.3, Par 2). The process of re-certification offers an obvious opportunity for DOE to notify EPA of improvements to the conceptual design throughout the 35-year period of disposal and decommissioning. Yet "revisitation" during the operational period is not accounted for in the chapter. In fact, it appears from the time line represented in Figure 7-16 (Page 7-83) that most of the work that will inform any revisions to the design will be conducted after the operation period. The areas in which DOE anticipates modifying the conceptual design during the operational period are not clearly identified.

DOE Response

The design described in Appendix PIC for the Permanent Marker System is the final design which the EPA should evaluate. This design meets the regulatory requirements. Its construction and implementation processes are practicable with today's technology. The DOE acknowledges the appropriateness of EPA's assuming that the conceptual design that is proposed is the same one that will be implemented. If circumstances where such that the DOE had to initiate construction of the permanent marker system today, the system described in Appendix PIC would be the configuration installed. Under these considerations it is appropriate to recognize the described system as the final design representing the system which will be installed on the order of 100 years in the future. However, the reality is that in acting responsibly with respect to its public obligation, the DOE should take advantage of technological improvements and information gained during the operational period that may refine some aspects of the design. For example, if in the future, materials are developed which duplicate the environmentally stable characteristics of granite and the fabrication and installation of the permanent marker components can be accomplished with this new material at a lower cost, then the DOE will have to give serious consideration to its use. Similarly if during the planned decades of testing the granite monuments, data is obtained suggesting modifications to the planned configurations that would have significant effects on the monuments durability without the expenditure of a disproportionate amount of funds, then it would only be responsible for the DOE to evaluate appropriate changes to the design and make those changes which are prudent and cost effective.

With the exception of final construction of the Permanent Marker System, all aspects of preparing for and implementing the Passive Institutional Controls will be performed during the operational period of WIPP with the following exceptions. Information about the long term degradation of granite, the durability of the berm configuration, the degradation of buried markers material, and the long term degradation of the magnetic material used in the WIPP environment may result in some refinements to the design following completion of the operational period. In addition, advancement in materials over the decades between decommissioning and construction of the permanent marker systems could lead to reconsideration of the use of granite. This information and knowledge can be significantly enhanced by accumulating the data over a period of several decades after site restoration. To fully construct the Permanent Marker System immediately after site restoration would deprive the final configuration of what could be significant advancements in materials and/or design refinements which mitigate the long term effects of environmental aggression.

STAGING RATIONALE

The following is the rationale for the time line in Figure 7-16 (Page 7-83).

1998-2005 Construct Test Berm. Provide as long a term for determining material and configuration performance as possible but don't expend the effort prior to obtaining a permit.

2003 Establish Filing System. Determine the system early in the operational phase to permit the back fitting of already developed documents to the filing system and ensure that future documents are accommodated within the system.

2018-2023 Test Message Comprehension. Allow operational experience to develop to the point near facility closure to ensure that the messages relating to WIPP content and WIPP history are accurate.

2023-2033 Establish Agreements and Submit Information to Publishers. This is the period of planned decontamination and decommissioning which will end with the termination of on-site permanency. Most of the pertinent information related to WIPP will be available. Information to prevent inadvertent intrusion into the repository should be widespread upon returning the site configuration to its natural environment.

2023-2034 Establish Agreement With Archival Record Center Recipients. This is post operational when the majority of documents are by now developed and therefore a more accurate assessment can be made of what documents are available and what documents are acceptable to the recipient. In addition, waiting this length of time takes advantage of world events and changes that may influence distribution and archival technology.

2033-2034 Develop Summary Document. The summary document should be developed at the end of the decommissioning phase so that it may accurately reflect WIPP history and status.

2035 Promulgate Information Accumulated Through WIPP Closure and Decommissioning. At this point the documents are all available that deal with the WIPP up through decommissioning and therefore this is the logical time to make the distribution. All on-site activity should be terminated and only Active Institutional Controls are in effect.

2083-2090 Final Design. Nearly a century of weathering will have been experienced by the test berm and monuments. Evaluation of that information and technological advancements in construction materials or processes should then be reflected in a final design.

2083-2093 Finalize Archival Information. This is coincident with construction of the permanent marker system and should end the need to accumulate information for widespread archival distribution.

2090-2093 Construct Permanent Marker System. All on-site work completed prior to the end of the 100 years credit permitted for active institutional controls.

2093 Promulgate Archival & Records Center Information. This is the final formal information dissemination effort regarding the WIPP's historical development and planned 10,000 year configuration.

OPERATIONAL PERIOD ACTIVITIES

The DOE expects to pursue various aspects of the Passive Institutional Controls program refining the description presented in Appendix PIC throughout the operational period of the WIPP. EPA will be provided status reports and plans regarding the progress towards final implementation of the passive controls as a part of the re-certification update every five years. The more salient features of this effort are:

- **First Five Year Period**- The following activities described in Appendix PIC will be addressed in the first five years of WIPP operation:
  - Survey stone monuments within a 150 mile radius of WIPP to evaluate the environmental affects on various types of granite (blue, gray, black etc.)
  - Identify suitable sources of caliche and riprap and contract for delivery during construction of the berm test section

- **Berm Testing**- Detailed plans for the construction of a test section of the berm to be included in the Permanent Marker System will be submitted to the EPA in the recertification application for the second five year period of operation (2002). This test section will provide a means of testing various configurations and material distributions, the construction and installation of test monuments, the fabrication and installation of samples of buried markers for testing long performance, the performance testing of radar reflectors buried within the berm, and the performance testing of magnets buried within the berm Actual construction of the test section of the berm and the installation of test monuments and buried markers will be concluded during the second recertification period to permit time for consolidation of the base of the berm. The base structure will use salt excavated from the WIPP.

- **Establish Archival Filing System**- The filing system under which WIPP documentation will be gathered for archival storage will be established in 2003 and implementation will be initiated by 2004. The EPA will be provided a status report on the specifics of the system and the progress in bringing all WIPP documents under that system in the recertification application for the third five year period of WIPP operation (2007).

- **Test Message Comprehension**- Detailed plans for conducting message comprehension will be included in the recertification submittal for the fifth five year period of operation (2017). Actual testing will occur during the fifth five year period and any resulting refinements to the messages which result from the testing will be provided to EPA at the end of the five year period. The diagrams accompanying the level IV message on pages 115-122 of Appendix PIC are not anticipated to change except to reflect actual conditions as they exist at the time of engraving the diagrams in stone. The focus of the message comprehensiveness will be on the text material itself.

- **Submit Information to Publishers**- During the sixth and seventh five year periods of operation (2023-2033), and after closure of the salt shaft, the DOE will contact major publishers, professional organizations, and map makers to conclude arrangements for their acceptance of WIPP information and its publishing. The organizations with which satisfactory arrangements are made will be identified to EPA along with a summary of what each organization has agreed to publish and the status of the publishing commitment in the DOE update following conclusion of site restoration.

- **Establish Agreement With Archival Recipients and Record Centers**- The DOE will submit to the EPA a plan for soliciting the participation of specific archives and record centers in the recertification application for the sixth five year period (2022). The solicitation and agreements effort will be completed by the conclusion of site restoration. This list will include any changes from the current plans resulting from events occurring during the period from 1997-2022.

- **WIPP Summary Document**- The summary document described in Appendix PIC, page 92 will be completed at the conclusion of site restoration and provided to EPA. The document will summarize the history of WIPP up to site restoration.

- **Promulgate Information Accumulated Through WIPP Closure and Decommissioning**- The DOE will distribute archival documents in 2035. The DOE will provide a status report on the distribution at the end of 2035 and annually thereafter until the initial distribution is completed.

- **Archival Auditing**- Within two years following the distribution of material to archives, the DOE will conduct an audit of selected archives to verify retention and retrievability of the material. Follow-up auditing will be conducted every 15 years thereafter until conclusion of the Active Institutional Controls. The EPA will be provided the results of these audits and any actions which result from audit findings at the conclusion of each audit.

The dimensional characteristics of the Permanent Marker System are not expected to change as a result of the testing program for the berm, monuments, and buried markers. What may change are materials used and/or configuration as a result of data obtained over the decades testing is planned to be in effect. The advantage of long term testing can only be obtained by permitting the test structures to experience the vagaries of the environment for decades. If at anytime during the operational period, observational data and evaluation support that refinements to the design should be implemented, DOE will make the necessary design refinements and describe them to the EPA in the recertification application following the identification of the changes. However, for subtle environmental effects which come about slowly the full realization and design refinements necessary to mitigate the effects may not be recognized during the operational period. As a result there may be refinements which are not identified until after the operational period expires. In addition, for obvious reasons, the final development of WIPP related descriptive material and its distribution to archives and record centers will not be concluded until the Permanent Marker System is fully constructed.

The berm test section will be constructed to the overall dimensions described in Appendix PIC. However, the thickness of individual layers of caliche, riprap, and soil/riprap and well as the ratio of soil to riprap in the top layer will be varied. Monitoring the performance of the variations should provide information relative to the following:

- Does the variation in thickness of riprap significantly affect water penetration of or erosion of the underlying caliche layer beyond some particular thickness of the riprap?
- Similarly does the variation in thickness of the caliche layer significantly affect water penetration of or erosion of the salt base beyond some particular thickness

of the caliche?

- Can a correlation be determined between the amount of annual rainfall and water penetration of the berm overburden?
- What ratio of soil to riprap provides an effective combination of wind/water erosion resistance and effectively promotes the growth of indigenous plant life?
- Will the environment support foreign vegetation on the berm surface which serves more effectively to stabilize the soil against wind and water erosion?
- How long does it take for the salt used in the base construction of the berm to consolidate under natural environmental conditions to the point of providing a stable berm foundation?

The surveying for data on the durability of various types of granite in the WIPP environment will provide insight into the types of material which should be specified in the procurement of test monuments. The condition of engraving found in this survey will also provide information that may affect the design specified for the test components. Once erected, these test monuments will be monitored over a period of nearly nine decades. Data regarding the durability of the granite material and the effects of weathering on the engraved lettering and diagrams will be used to refine the final design. The data could lead to substantial changes in the configuration of the monuments and the information center. It is not anticipated that there will be substantial changes to the design of the buried rooms.

The data obtained by monitoring the interface of granite and caliche could give rise to modifying the use of caliche as a fill material. If data obtained during the operational phase indicates that there is aggressive deterioration of the granite at the interface, the DOE will change fill composition during the operational period to permit the gathering of additional test information.

Considering the designed configuration of the Permanent Marker System and its major components, it is not anticipated that wind blown sand will present a substantial issue. The large expanse of the system and the fact that sand moves from one locale to another reduces the risk of the entire system being masked from future generations. However, during the decades of testing some data will be developed relative to the affects of wind blown sand. Should the current assumptions prove to be wrong, significant changes to the configuration would be included in refining the design and those changes will be described in the recertification application following the identification of the refinement.

From the information obtained by the testing experience gained during the operational period, the DOE will refine the design of the Permanent Marker System and then make the appropriate changes to the test structures where such changes are deemed significant with respect to longevity of the marker system. In each instance of refinement to the design, the DOE will describe the refinement in the following recertification application. Making these changes prior to completion of site restoration will then provide an additional 50-60 years of weathering to determine the effectiveness of the changes. Any changes to the design will be provided to EPA for review.

PRACTICABLE PASSIVE INSTITUTIONAL CONTROLS

Permanent Markers

To minimize future vandalism through removal of monuments and other significant message caring structures, the design of the Permanent Marker System avoids the use of small components. As a result the monuments, information center, and the buried rooms all use granite components weighing several to tens of tons. Several quarries were contacted in determining the limitation regarding the size and weight of granite components which could be provided. In addition, the Santa Fe Railroad was also contacted to determine the practicality of shipping heavy granite components to the WIPP. The responses received from quarries and the railroad guided the final design of the message carrying features of the marker system. The following quarries were contacted in determining the size and configurations of large granite monoliths which can be quarried.

Rock of Ages Corporation	Barre, VT
Everlasting Granite Company	Elberton, GA
Harmony Blue Granite Company	Elberton, GA
Premier Granite Company	Llano, TX
Texas Granite Corporation	Marble Falls, TX
Keystone Memorials Incorporated	Elberton, GA
Valley Marble & Slate Corporation	New Milford, CT
Fletcher Granite Company	North Clemsford, MA
Cold Springs Granite Company	Cold Spring, MN
Olympic Granite Company	East Barre, VT

In discussions with quarry representatives it was determined that rectangular components were much easier to fabricate, when considering such large sizes, than are curved components. This information guided the design which uses only rectangular features in the monuments and for the information center and buried room components.

The technology for engraving messages is straight forward and does not require highly sophisticated techniques or equipment. The process includes preparation of the granite surface, the preparation of a stencil of the information to be engraved, and the use of grit blasting to remove material. The following discussion is provided to expand upon this short process description.

The engraving surface is ground flat as the initial step in preparing the granite for engraving. The text material, graphics material, and any other information to be engraved is prepared on a rubber stencil about 1/16 inch thick. The stencil preparation is either computer controlled or cut manually. For text material, a number of different language fonts are available. However, the unavailability of a computer compatible font does not prevent manual stencil preparation. The craftsmen preparing the stencil only need to be provided a quality document for use as a guide. For the graphics used in the Permanent Marker Design, all of the stencils will need to be cut by hand. With the stencil available, a filler material (glue) is applied to the flat granite surface and the rubber stencil applied to the filler. After the filler has set up, exposed granite material is removed by grit blasting. At some quarries grit blasting is a computer controlled operation to the extent that the computer program includes the appropriate text material. At other quarries the grit blasting is a manual operation. Grit is normally aluminum oxide. Upon completion of the grit blasting, the stencil is removed and the residue of the filler material is cleaned from the granite surface. Final cleaning concludes the engraving process.

The seven different languages used in the text material vary in the number of required characters. The minimum size of the characters, with the exception of Chinese, that can be engraved is 5/8 inches. For Chinese the minimum size is 1 inch. The number of characters included in each translated text intended for the Information Center and the Buried Rooms varies from approximately 12,000 to approximately 16,000 with the Chinese translation at the lower end of this range. There is sufficient room on each message carrying wall to accommodate the message in a single translated version at a character height and width of up to 1 inch with 3/16 inch spacing between characters. There is ample surface area available on the monuments for the much smaller number of characters in monument messages even though the character size is significantly larger than the Level IV message characters.

Publishers and Map Makers

Grolier Publishing Company of Danbury, CT was contacted regarding their willingness to publish information about WIPP's location, purpose, hazards, and the need to maintain its integrity. The Vice President Publisher, Grolier Educational, is responsible for publishing three encyclopedias-the Encyclopedia Americana, the Encyclopedia Academic America, and the New Book of Knowledge. After discussing the WIPP and the DOE's effort to make information regarding WIPP as widespread as possible, the VP confirmed that upon receipt of text developed for inclusion within the three publications, his editorial section would edit the material and include it where appropriate within those publications.

In determining how WIPP related information can be included in college and/or high school level texts, McGraw-Hill Publishing Company's Engineering and Science Editorial Division was contacted. The company's representative stated that the inclusion of information would need to be determined by each individual author. The company can provide a list of texts which they publish and from that list a selection can be made and then the individual authors contacted. It is then at the discretion of each author whether or not WIPP related material would be included in any planned reprintings or revisions of the particular publication. A very similar policy was confirmed for the publisher, John Wiley & Sons. This policy is not unexpected. Considering that major publishers publish numerous authors for the academic community it is only reasonable that some percentage of the authors will be receptive to the idea of including relevant WIPP operating, location, and hazards information in the texts. The time to do this however, is after some history can be developed regarding the actual emplacement of waste in the WIPP during its operational period. The DOE will initiate such an effort at the time of sealing the last shaft.

A number of map publishing and informational organizations have been contacted to ensure that at least some members of the cartography industry will support the DOE's effort to provide WIPP location and hazards information to the public and to technically focused sectors of the society. The American Automobile Association (AAA) Cartography Division identifies locations on the maps provided to its members provided the location meets certain criteria. In discussing the WIPP and the planned Permanent Marker System with a representative of the AAA Cartography Division, Mr. Dave Meany. Mr. Meany stated that as a tourist attraction the WIPP would certainly meet AAA criteria for inclusion on its maps. In addition some detail regarding the waste disposed of at WIPP and the need to ensure that human intrusion be prohibited could be included in the AAA Tour Book for New Mexico.

(M)

Rand-McNally annually publishes a Road Atlas that has wide usage throughout the U.S. The Director of Marketing Communications for Rand-McNally stated that locating the WIPP site on the Road Atlas would only require that the DOE provide the company with a detailed map of the WIPP location. The map detail should include road designations in the area off of the main highways.

Midland Map Company of Midland, Texas is a major supplier of maps to the oil and gas exploration industry in West Texas and Southeastern New Mexico. The Manager and President of the company committed to providing WIPP location information on the maps provided to his customers. To initiate the identification of the WIPP site on Midland Map's products, the DOE need only submit a legal description of the WIPP location.

Tobin Data Graphics information is used by 97%-98% of the oil and gas industry in the U.S. according to the Vice President of the company. The company provides hard copy and digital mapping data which includes location information. Within its digital mapping products is the capability to pull up attribute information by simply clicking on the appropriate location. After some discussion, he stated that for WIPP this information could include warning against drilling in the location and the hazard associated with a drilling operation. His response was very positive to the idea of providing this information for his customers.

Petroleum Information Dwights Company provides digital and hardcopy information to the oil and gas industry. The information includes data for every oil and gas well in the U.S. according to the company's senior vice president. Location information is available on a hardcopy land grid and on a digital land grid. The company also has an environmental division which tracks the location of waste sites. WIPP location information and associated hazards information would be made available on products sold by both the oil and gas division and the environmental division. Upon receipt of WIPP information, the company would edit the material and place it in the various data bases they have available.

Several geographical and cartographical organizations were contacted to determine their willingness to support the DOE in its effort to inform the public about the WIPP and to preserve that information in society's memory. The Executive Director of the American Geological Institute declared a genuine interest in publishing an article in the Institute's *Geotimes* monthly. The magazine has 10,000 subscribers and an estimated readership of 30,000-40,000. In addition the Institute has a Bibliographic Data Base, *GeoRef,* with over 2,000,000 topics. A recent check identified 340 articles and reports referencing the WIPP. *GeoRef* is a logical database for information about the WIPP and the need to protect it from intrusion. The Executive Director committed to including in *GeoRef* additional information that the DOE might send.

The Director of the American Geographical Society expressed a willingness to provide WIPP information to its members. DOE information would be retained in the Society's archives as well. In the course of discussing the matter, the Director suggested that the curator of the American Geographical Society Collection (Library) at the University of Wisconsin also be solicited for support of DOE's effort for widespread promulgation of WIPP information. The Collection is the premier center for geographical information in the U.S. A subsequent conversation with the curator confirmed that WIPP information would be accepted and included in the Collection's archive.

The Headquarters Director of the Society of Women Geographers commented that information regarding the WIPP site location and hazards associated with the waste falls well within the Society's charter of geographical education. The Society would certainly be receptive to disseminating WIPP information among its members, many of whom are in the academic arena. Although the society does not have a published journal or magazine, it does have a Serve List (restricted E-mail) through which it provides information to its members.

The President of the Cartography and Geographic Information Society explained that the Society is one of four organizations within the American Congress on Surveying and Mapping (ACSM). The other three organizations are:

The National Society of Professional Land Surveyors
The American Association of Geodetic Surveys
The Geographic and Land Information Service

Some of these organization have their own journal. ACSM publishes bi-monthly a bulletin which the President stated would be a logical medium for providing WIPP information. When contacted, the editor of the bulletin was supportive of publishing WIPP information to assist in DOE's effort for informing the public.

Although not every publisher, map-making company, or professional organization has been contacted with regard to accepting DOE's request to assist in promulgating information regarding the WIPP location and hazards, it should be noted that of those contacted there was not one refusal. Based upon this limited sample, it is reasonable to assume that the DOE will meet with some success in obtaining the goal of widespread information dissemination about WIPP.

Archives and Record Centers

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In Appendix PIC the DOE has identified in excess of 200 archives, record centers and libraries for consideration in receiving information related to the WIPP project. Recognizing that such an undertaking is a major commitment of resources and desiring that emphasis be placed on where the effort is likely to provide the most benefit, the DOE will conduct the negotiations with planned recipients on a priority basis. The driving motivation for widespread dissemination of WIPP information is to ensure that the WIPP's location and associated hazards are not lost in society's memory. Therefore the program for distributing relevant information will focus on locations that are likely to be sought as sources of information when researching the Delaware Basin for oil, gas, and mineral resources; national locations which are likely to be sought by individuals doing oil, gas, and mineral resource investigation in the southwestern portion of the U.S.; and international locations in countries whose stable economic condition is conducive to the development of a cadre of individuals with the financial incentive to search for natural resources worldwide. Priority will also be given to countries with a nuclear industry who may also be engaged in nuclear waste disposal. Within this prioritization bases, the DOE will focus on the following international archives to establish working agreements for them to accept WIPP information:

Canada	Belgium	Japan	Russia
Britain	France	Germany	South Korea

Taiwan	China	Australia	Saudia Arabia
Venezuela	Mexico	Norway	Kuwait

Nationally the archival prioritization will be:

- National Archives-Washington, D.C.
- National Archives-Southwest Region
- National Archives-Rocky Mountain Region
- New Mexico State Archives
- Texas State Archives
- Zuni Indian Archives

Record center prioritization will include the following locations;

- The Hobbs, NM and Artesia, NM offices of the New Mexico Oil Conservation Division (OCD)
- The local Carlsbad offices of the Bureau of Land Management
- The local Carlsbad office of the Bureau of Reclamation
- The City Libraries of Carlsbad, Artesia, Hobbs, and Roswell
- The New Mexico State Library
- The Texas State Library
- The Library of Congress
- The University Libraries at New Mexico Tech, New Mexico State University, University of New Mexico, University of Colorado at Boulder, Texas Tech University, and Texas A&M
- The Denver Public Library

Mapping organizations receiving location and hazards information will include:

- The New Mexico State Highway Department Planning and Research Division, Cartography Section
- Rand-McNally
- American Automobile Association
- Midland Map Company
- Tobin Data Graphics Company
- Petroleum Information Dwights Company
- U.S. Geological Survey
- Defense Mapping Agency
- Federal Highway Administration

Publishers and Professional Organizations receiving WIPP information include:

- Grolier Publishing, Grolier Educational Division
- American Geological Institute
- Society of Women Geographers
- Cartography and Geographic Information Society
- American Geographical Society
- American Geographical Society Collection

The DOE believes that these locations and organizations will be receptive to receiving WIPP related information for the following reasons:

Nationally it has been found that those archives, record centers, publishers, and map making organizations which have been contacted in the course of researching information in developing the Passive Institutional Controls design and program have been receptive to supporting the DOE's intent of preserving WIPP information. There may be differences in the quantity of material acceptable to individual locations but at least some material will be acceptable to all. Internationally the DOE believes that the national interest in nuclear waste disposal and providing detailed WIPP design information to the individual country's nationals will serve as an incentive for foreign archives to accept at least technical if not all the legal information available. When considering that the DOE would provide at least some of the material translated into the particular country's technical language or finance the translation as defined in any agreement reached, there are strong arguments for accepting information.

During the course of obtaining agreements for this initial set of recipients, the DOE will develop a second level of priority based upon experience gained in the initial round of negotiations and determine the list of locations to focus on at this level. All other locations will be addressed upon completion of the second round of negotiations. The DOE will provide the second priority list in its sixth recertification application prior to completion of site restoration.

The feasibility of including remaining archives, record centers, and professional organizations identified in Appendix PIC which are not included in the first and second prioritization will be investigated and a determination made on their participation. The DOE will provide the EPA with a final listing of all participants at the conclusion of site restoration.

SUMMARY

In developing the Permanent Marker System design, a number of quarries were contacted to obtain order of magnitude cost estimates for the fabrication of components used for monuments, storage rooms, and the information center. In addition, inquiries were made of the availability of riprap and caliche in the local area. It was assumed that the required soil and salt would be obtained from excavation activities associated with construction of the trench forming the base of the berm and from excavation of the planned repository panels. In addition fabrication time estimates and berm construction time estimates have been determined and fall within a range permitting the final construction of the Permanent Marker System within a three year period. An order of magnitude cost for the system if fully constructed today is $75,000,000. This expenditure will be spread over a number years. For example, the base of the berm should be prepared during the operational period as the salt is excavated from the repository. This will provide decades for the salt to consolidate into a supportive foundation. The fabrication of the granite components will be initiated prior to construction of the berm with delivery coordinated with berm construction so that access to the footprint is not inhibited by the berm for installation of monuments, storage rooms, the information center, and the buried markers.

The National Archives-Washington, D.C., the Library of Congress, the National Archives-Rocky Mountain Region, the New Mexico State Archives, the Zuni Indian Tribe Archives, local libraries in Carlsbad, NM and Roswell, NM, and the offices of the New Mexico Oil Conservation Division in Artesia, NM and Hobbs, NM are representative of the organizations contacted in obtaining information with respect to internal operations of archives and record centers. From these inquiries it was recognized that the DOE must develop a filing system for the information submitted to the archives. It was also determined that individual agreements will need to be obtained since all international archives have unique aspects of their operation related to capacity, environmental control, and retrieval processes. This individual uniqueness exists even though all archives conduct their operations in a reasonably similar fashion. In the course of developing these contacts it was also determined that a summary document would add significantly to making WIPP information available to researchers, mineral prospectors, and the general public. Information obtained from this research also emphasized the need to use archival quality paper as the most effective long term storage media and to exercise caution in using electronic systems which could and no doubt will become obsolete over the regulatory timeframe.

The DOE recognizes that the design of Passive Institutional Controls represents a significant cost to society. However, meeting the intent of the regulation that "Disposal sites shall be designated by the most permanent markers, records, and other passive institutional controls practicable to indicate the dangers of the wastes and their location" [40 CFR §191.14(c)] in the context of a 10,000 year regulatory period of interest requires a major effort. Historical analogues which to date have survived thousands of years (but not 10,000 years) are those which cost the constructing society significant resources. The design developed by the DOE meets the requirements of the regulations and provides a reasonable expectation that it will endure for the regulatory period of interest.