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December 29, 1994

Mr. George E. Dials
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Dear George:

Enclosed are comments prepared by this office concerning the Compliance Status Report DOE/WIPP 94-019 ("CSR"). We request that these comments be taken into account in the SPM-2 phase of the Systems Prioritization Method review. We are available to explain any aspects of these comments, if desired.

Please advise whether a revised version of the CSR is to be issued, and, if so, on what schedule.

Thank you for considering these comments.

Best regards,

Lindsay

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COMMENTS ON BEHALF OF THE
ATTORNEY GENERAL OF NEW MEXICO
CONCERNING COMPLIANCE STATUS REPORT

The following comments are submitted on behalf of the State of New Mexico by the Office of the Attorney General.

The Compliance Status Report, DOE/WIPP 94-019 ("CSR"), must be appraised on the basis of its stated purposes. It is understood that DOE is not now in a position to demonstrate compliance with 40 CFR Part 191 or 40 CFR §268.6. The CSR has the following stated purposes:

1. To describe the approach to be taken by DOE in future compliance applications.
2. To detail DOE's current understanding of the repository's performance with respect to 40 CFR 191 and 40 CFR §268.6.
3. To focus project resources on the areas necessary to ensure complete, accurate, and timely compliance applications. (ES-1).

Our comments therefore are stated in light of these purposes.

1.0 Introduction

This chapter provides background information. It should be noted that the NAS study cited (NAS-NRC, 1957, cited at 1-3[1]) proposed that a salt site be employed if regulatory issues were resolved before the site is developed (Id. 4).

There is a description of the WIPP site selection process (at 1-4). No citation is provided. It is not appropriate in a document prepared for scientific and legal purposes to omit citations in support of factual statements.

There is a statement that favorable features of the site are expected to offset enhanced risks of human intrusion associated with resources. (at 1-5). There is neither citation nor elaboration. How this judgment was made must be explained so that compliance with 40 CFR §191.14(e) may be determined.

The discussion in §1.2.1 of the test phase no-migration determination refers to "precedents that will likely be applicable and appropriate for future compliance decisions." The CSR should be specific as to what is meant.

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[1] References in abbreviated form are to the materials cited in the CSR.

2.0 Site Description/Site Characterization

This chapter ought to contain the critical data about the proposed repository's performance which will be employed in creating and validating models for performance assessment. Thus, this chapter may be the most important one in the CSR. However, the discussion varies markedly in the depth of treatment of different aspects of the site. Presumably, the discussion of geologic features (e.g., 2-1 through 2-10) is offered as general background. Occasionally, specific detail is furnished (2-11 through 2-21), sometimes without citation, sometimes with (see 2-21). However, the text fails to convey the extent of uncertainty and conflict on critical issues and largely consists of conclusions rather than supporting data (Id.). If the purpose of the CSR is to enable the reader to assess the status of scientific data on points relevant to compliance, it does not help to mask questions of data sufficiency and interpretation by stating summary conclusions.

2.1.2.6.2 Culebra Member: There is a conundrum in that hydraulic conductivity varies by six orders of magnitude across the WIPP site, and the controls on this variability are not understood. The CSR does not bring out the problems presented by the data. Neither the dissolution model proposed by Snyder (1985) nor the sedimentological model proposed by Holt and Powers (1988) explains the available data, as noted in Beauheim (1987) and Brinster (1991). No model is mentioned which will describe the distribution of variations in hydraulic conductivity within the Culebra. The CSR notes the relationship between conductivity and fracture fillings but does not pursue the question of possible dissolution of fracture fillings. See the attached paper by R. Y. Anderson.

2.2.1 Physical hydrogeology of the shallow flow regime: There is extended narrative description of alternative models (confined-aquifer and groundwater basin) but no concrete presentation of either, and no choice among them is stated. The CSR also states that a physical transport model is necessary (2-30). Clearly so, but it would advance study of the compliance status to set forth with citations the most current relevant data, rather than paraphrasing without citation.

The CSR fails to express the current state of uncertainty about Culebra flow and transport. Large-scale pumping tests in the Culebra have shown the heterogeneity of the transmissivity of the rock body. The local-scale flow model is based on calibrated transmissivities using various data sources, as recently explained in the May 3-5, 1994 meeting with EPA. This model is based on limited borehole data and calibration to observed undisturbed and transient data. DOE must defend the sufficiency of the borehole data to characterize transmissivity in light of the observed heterogeneity of that rock body. DOE must also set forth in detail, and justify, the calibration methods. There is a question whether existing data are sufficient to describe the size and

characteristics of the apparent high-transmissivity zone in the area of boreholes H-15, DOE-1 and H-11.

Culebra transport issues are inadequately discussed. Double porosity behavior may characterize transport in the present-day Culebra, and such behavior may be controlled by fracture spacing, in large part. Whether transport models are based on data of sufficient density about fracture spacing is not known; this issue should be addressed.

More basically, it is not yet certain that double-porosity behavior is the nature of transport in the Culebra; the INTRAVAL analysis indicates the possibility of channel behavior.

The May 4, 1994 presentation by Sandia to EPA brought forth shortcomings in the current transport models (heterogeneous and anisotropic), including their inability to match hydraulic and tracer data, inability to reflect horizontal and vertical variability, inability to validate the conductivity tensor, limitations of the slug injection technique, and failure to study problems of scale. These issues seem to require further data, possibly tracer test data. Whether the proposed single well and multiwell tracer tests themselves can satisfactorily identify and characterize double porosity behavior is uncertain. The data generated will pertain only to a specific portion of the area of interest. Extrapolation remains an unanswered question. Parts of the area display heterogeneity or anisotropy in different behavior for different transport paths.

The CSR does not say much about the data on radionuclide retardation factors in the Culebra. The May 6, 1994 EPA-DOE technical meeting outlined experiments whereby data will be obtained to address these issues, but test results were not available. From these recent presentations, a few basic questions arise:

1. How will the described lab tests (mechanistic and rock-column) develop data applicable to the domain of interest, given the questions of scale, heterogeneity, and coupling of phenomena?

2. Are sufficient data available now to characterize the Culebra rock for purposes of modeling?

3. Are data required as to the Culebra fracture spacing to complete the retardation model? If so, how and when are such data to be obtained?

4. What are the screening experiments for potential colloids, and when will their results be available?

5. What brines will be used in evaluating the possible precipitation of actinides occurring upon the mixing of Castile, Salado, and Rustler brines?

6. How will results from examination of individual phenomena be compared with the results of the examination of integrated phenomena in column tests?

7. As to analyses of integrated phenomena (e.g., intact rock column experiments), can they contribute to the resolution of problems of scale and heterogeneity? What is the basis for extrapolating data generated from studies of a limited number of cores across the entire area of interest?

2.2.2 Chemical hydrogeology of the shallow flow regime: The CSR discusses the Rustler chemical hydrogeology and indicates several unanswered questions. It has been observed that the concentrations of dissolved solids in the Culebra aquifer are inconsistent with the direction of groundwater flow indicated by measured potentiometric heads. (Ramey 1985, at 21, 23-24). Areas of lower transmissivity would be expected to contain higher amounts of dissolved solids, but the reverse is shown by the data. Flow paths shown by transmissivity data conflict with the data on total dissolved solids in that same direction.

The CSR offers a model in purported explanation, citing Lambert (1989), which model hypothesizes that the flow direction has changed from easterly to southerly since recharge took place (CSR 2-40). The CSR cites four data sources, none of which is persuasive:

Hydrogen and oxygen isotopes in groundwater are said to differ from those of known modern meteoric waters, indicating that no modern recharge has taken place. (Siegel et al. 1991) (§2.2.2.2). However, Chapman (1986) shows that isotopic data from Rustler waters correspond to modern waters, suggesting recent recharge.

Radiocarbon dating of groundwater is said to establish a minimum age of 10,000 years (§2.2.2.3). No reference is given; presumably Lambert (1987) is meant. However, that work rejected 12 of 16 sampled values on the basis of supposed modern contamination, which was not established.

The CSR interprets the stratified distribution of Strontium ratios in the Rustler to reflect a lack of vertical flow, but such conclusion is not inconsistent with recharge more recent than 10,000 years (§2.2.2.4).

Finally, the CSR relies upon uranium-isotope disequilibrium data to postulate a recharge source and an ancient west-to-east flow pattern in the area of Nash Draw (Lambert and Carter, 1987) (§2.2.2.6). Such hypothesis is inconsistent with potentiometric

data and must be doubted. The CSR states that the conceptual model derived from such data is "hydrologically improbable." (§2.2.2.6). Thus, the model advanced by the CSR is unsatisfactory, and there is no indication of plans to resolve the situation. We note that comments by the Environmental Evaluation Group ("EEG") dated November 22, 1994 criticize the use of uranium-isotope disequilibrium data in some detail. These points require a reply.

2.2.3 Physical hydrogeology of the Salado/Castile flow regime: This section of the CSR fails to express the uncertainties concerning the hydrology of the Salado. Gas generation by the waste in disposal rooms is heavily dependent on brine availability. Estimates of the available brine depend on the conceptual model of Salado hydrology. The flow model appropriate to Salado halite is still unknown. Although Darcy flow is said to be observed through natural fractures in anhydrite and in impure halite near the repository, the existence of Darcy flow in other situations is not established. Near-field flow may be induced by excavation effects. Competing Darcy flow and DRZ drainage models for halite have been postulated. Depending on which model is valid, the amount of brine available to flow into each waste-storage room varies widely (see 4-46).

Beauheim et al. (1991) acknowledges the insufficiency of data about the hydraulic characteristics of the DRZ (e.g., at 123) and anhydrite response to excavation (at 124, 129). Beauheim et al. (1993) observes the insufficiency of data about changes in hydraulic conductivity induced by excavation (at 140). Further, it concludes that the applicability of Darcy's law to flow under the low gradients naturally existing in the Salado Formation remains uncertain and the presence or absence of hydraulic anisotropy in halite is likewise uncertain. (at 141). A third report is anticipated. (at 142). These observations support the need for additional data to model brine flow properly.

Currently, Sandia is gathering data for core tests of various Salado components. Porosity, intrinsic permeability, threshold pressure, capillary pressure, relative permeability, and rock compressibility are to be measured under various stress conditions. Test cores are to be taken from certain WIPP shafts and rooms. Test results will have to be justified, inter alia, with respect to the heterogeneity of the rock bodies examined and the sufficiency of data as bases for extrapolation over a wider area of interest.

The CSR states that the Castile brine reservoir "highly permeable portions" are "limited in extent" and that about 5% of the overall brine volume is stored in large open fractures (2-42). There is no statement about the areal extent of such reservoirs.

For assessment of compliance status, certain further points which came out at the May 3-5, 1994 technical exchange should be stated in the CSR. The origins and controls on the distribution of

brine reservoirs are not well understood, and data about them are limited; thus, their frequency, location and characteristics are not well known. Their placement in section is not well known either. Their occurrence in vertical fractures makes well data unreliable as a guide to distribution. Observed brine reservoirs appear isolated and hydrologically and geochemically distinct. Performance assessment has assumed that reservoirs have hydrologic and geochemical characteristics of the reservoir intercepted by the WIPP-12 drill hole, but such assumption is not well-founded. Further, the data about the areal extent of such reservoirs are so uncertain that the only defensible assumption is that any well penetrating the Castile intercepts such a reservoir.

2.3 Resources: The CSR refers to the FEIS for estimates of the volume and location of potash, oil and gas resources. This information is important and should appear in the CSR itself. DOE should specify the resource data which it deems most appropriate for use in compliance determinations. We understand that New Mexico Tech has been requested to perform a study; this arrangement should be described.

It would be helpful to include a description of administrative practices governing drilling within and adjacent to the land withdrawal area. It would also be helpful to include an account of current drilling practices in the Permian Basin as they may arguably be pertinent to characterization of future human intrusions.

2.5 Climatology and meteorology: There is no discussion of the range of past climate variability or the methods used to select the range of projected future climate variability for PA modeling. Whether projected future climate variability should stay within the limits of Pleistocene variation is debated and should be discussed. Further, it has been pointed out that "the hydrologic model developed for the Culebra Member, from data based on the present climate and hydrology, <u>even if the average rate of precipitation is increased</u>, is not valid for the moist conditions and climatic pulsations..." R.Y. Anderson, submission to EPA, March 16, 1993, at 2. See the discussion below concerning Karst and dissolution.

2.6 Natural processes and events: The discussion of Karst topography, shallow dissolution, breccia pipes, and deep dissolution (which is not discussed at all) requires much more detail before it can be assumed that such scenarios have been correctly discounted. For instance, it should be stated why breccia pipes can be regarded as limited to the Capitan Reef area. See the further discussion of this issue in reference to Chapter 6. The discussion of igneous activity is entirely too conclusory to evaluate this scenario. There should be discussion of geologic factors limiting the potential for igneous intrusions.

2.7.1 Gas generation: This section states that two different gas-generation models are in various stages of development, but they are described only in general terms. There is not enough information from which to identify further data needs. There is no citation to any source which describes the models, their assumptions, and further data needs. The presentation should be compared with the much more detailed one by Larry Brush at the July 1993 technical meetings with EPA in Albuquerque. At that meeting Brush explained the progress of his reaction-path model and future steps. He explained that anoxic corrosion of aluminum and hydrolysis of cellulosics are omitted. Uncertainties as to waste inventory and brine availability must be resolved. There are further uncertainties as to how the conceptual model should deal with equilibrium behavior, possible methanogenesis, and the effect of pressure on microbial action. The CSR does not state how these issues may be addressed. The CSR does state that hydrologic and geomechanical models will be used in conjunction with the gas generation model to characterize brine, gas, and volume within the repository. The timing and elements of that effort should be further described.

2.7.2 Brine and gas flow processes: This section discusses in general the processes of brine flow and gas generation and flow, but there are few particulars, and the reader is not able to find out what parameters are considered sensitive and what additional data should be obtained. In §2.7.2.1 it is not stated whether residual saturation is a known quantity. Factors affecting flow in the DRZ are mentioned in §2.7.2.2 but not quantified; data needs are left uncertain. The discussion of the Salado Formation in §2.7.2.3 acknowledges the competing Darcy flow and DRZ consolidation models of the Salado halite but does not state how the issue will be resolved. Certain factors bearing on gas migration (the stratigraphic dip, layering, other nonuniformities) are identified, but how their effect will be measured is not stated. It is stated that heterogeneous properties may lead to a preferred direction of gas migration, but how this prospect will be investigated is not stated.

2.7.3 Brine chemistry processes: The discussion of brine chemistry processes and the actinide source-term program merely relates some of the issues in general terms, such as that gas generation affects the chemistry of disposal room brine. What is said is undoubtedly true in a broad sense, but the statements do not report the modeling assumptions or experimental design so that one can appraise the need for the experiments and the likelihood that they will make a contribution. The discussion omits to explain how any model developed from the actinide source term tests will be validated. Again, no citation is provided.

2.7.4 Room closure processes: The material on the disposal room performance model (§2.7.4.1) and waste compaction (§2.7.4.2) merely relates the general processes and does not adequately

describe the available data or the current status of modeling efforts. Compare the detailed presentation by Fred Mendenhall at the July 1993 DOE-EPA technical exchange. The section on waste compaction refers to the difficulty of modeling corrosion or decomposition of waste but does not state the importance of this problem or what is to be done about it.

The generalized treatment of drill cuttings, erosion (cavings), and spalling (§2.7.4.3) likewise raises more questions than it answers. The CSR should mention the status of modeling of these processes, the experimental work planned, and the importance of these processes to PA. The particular problems involved in modeling compacted decomposed waste should be mentioned. (see Berglund, 1992, at 3-40, 3-41, 3-48, 3-50).

2.7.5 Room pressurization processes: The discussion of room pressurization is also very general. From the text, it would seem that DOE has not yet succeeded in quantifying or modeling this process. The fracture modeling discussion outlines alternative conceptual models but contains almost no citation to data sources or model descriptions. It says that sensitivity studies are underway but does not give the current thinking about the compliance measures to which the fracture model may be important or how the fracture model may be developed.

2.7.6 Coupling between processes: It is not news that the processes of gas generation, brine and gas flow, brine chemistry, room closure, and room pressurization are interrelated processes and that preliminary efforts to depict such coupling have been made in the PA process. The CSR refers to the porosity surface used in PA and the possible use of deterministic coupled codes, such as PHENIX. The 1992 PA says, however, that the PA department plans to examine sensitivity to closure. (1992 PA, v. 2, 7-5). It is not stated what has been done along those lines or what role the SANCHO code will have in representation of room deformation.

2.7.7 Potential release pathways: This section summarizes various release scenarios but contains almost nothing about the sensitivity of various parameters, compliance status under 40 CFR Part 191 or §268.8, models, or experimental plans. It is difficult to see the utility of discussion at this general level.

3.0 Facility description

This chapter deserves only brief comment. The information that it contains is largely extracted from statutes, regulations, and DOE Orders or is entirely conclusory (e.g., "The configuration of the WIPP facility is controlled by written procedures and policies") without citation and without data support. Such material is of little use in evaluating the status of compliance.

3.4 Engineered barriers: The CSR contains no discussion of most of the work to date on engineered barriers. There should be a summary of the work of the Engineered Alternatives Task Force and a description of the extent to which various alternatives were expected to reduce the severity of radionuclide releases. Such information is plainly necessary for the Systems Prioritization Method phase of the compliance process.

Certain statements concerning the shaft sealing system should be corrected. The CSR states that "crushed salt components, emplaced with sufficient precompaction, will sufficiently reconsolidate within 100 years after emplacement to meet performance requirements." (at 3-11). The cited work (Van Sambeck et al., 1993) in fact declares uncertainty as to the critical requirement as to the length of reconsolidated salt above the shaft station (at 96), notes unresolved concerns about the use of bentonite (at 72), crushed salt (at 76), compressed-salt blocks (id.), concrete (at 77), and quarried-salt blocks (at 85), and concludes that "a fully defensible recommendation of any of the presented alternatives cannot be made." (at 97).

At present the performance assessment assumes a range of 3.3 x 10^{-21} to 3.3 x 10^{-20} m^2 for lower shaft seal permeability (1992 PA v. 3 at 3-14) and does not, in effect, model the performance of shaft and drift seals. (see Performance Assessment Review Team's Independent Review of WIPP Performance Assessment Activities, Feb. 1994, at 6-23). Incorporation of models which reproduce water flow from overlying aquifers, the DRZ around the shafts and drifts, the reconsolidation of the DRZ salt, and Salado brine inflow in addition to the permeability and compaction of seal materials is necessary to identify the appropriate seal design parameters and to determine whether they can be met.

It should also be noted that the projection of room closure in 100 years, contained in the discussion of system performance (§3.6), assumes no gas generation. With gas generation closure is projected to require far longer and ultimately to reverse itself (Davies et al., 1991).

3.6.3 Passive controls: There is no plan for passive institutional controls. Such a plan must be part of a compliance demonstration.

3.6.3.2 Active controls: Same comment as with respect to passive controls.

4.0 Waste description

The CSR suffers from the omission of information presented to EPA at the June 14-15, 1994 EPA-DOE technical exchanges. At that meeting DOE explained (1) the plan to prepare a Baseline Inventory Report ("BIR") to group wastes with similar physical and chemical

properties into a series of "waste-stream profiles," (2) that the BIR will be based on the Federal Facility Compliance Act Mixed Waste Inventory Report ("MWIR"), the Integrated Data Base, and the 1988-89 Nonradionuclide Inventory Database ("NID"), (3) that the BIR will employ MWIR Waste Matrix Codes as the basis of WIPP Waste Profile Groups, which are in turn subdivided into 229 Waste Stream Profiles for each TRU waste stream in the MWIR. These BIR data, largely based on process knowledge, are planned to be the basis of the System Prioritization Method and performance assessment calculations.

The use of process knowledge clearly raises questions as to the accuracy of such information. Neither the CSR nor the June 14-15 presentation contains data supporting the accuracy of the BIR inventory data.

Likewise, the CSR fails to explain the plans to use the System Prioritization Method to develop performance-based Waste Acceptance Criteria ("PBWAC"), as was set forth in the June 14-15 exchanges. The CSR does not contain the current schedule under which the draft TRU Waste Characterization Quality Assurance Program Plan ("QAPP") was issued in July 1994 and will be revised, the Waste Characterization Program Plan ("WCPP") was to issue in October 1994, and generator sites will institute development of Quality Assurance Project Plans ("QAPjP's"). Thus, there is no explanation of how the PBWAC developed in the SPM will be integrated into the development of the QAPP, WCPP, and QAPjP's.

Further, the CSR has no explanation of the development of the QAPP and the Sampling and Analysis Guidance Manual, as was presented at the June 14-15, 1994 technical exchange, and thus there is no defense of the statistical sampling methods proposed for that purpose.

Questions raised at the June 14-15, 1994 session may also be addressed to the CSR. How, for one thing, will "process knowledge" be used to characterize future decontamination and decommissioning waste? When will the second data call for the MWIR be completed, given the deficiencies of the interim MWIR? What will be the accuracy of the BIR inventory data? How will such accuracy be established?

We also have EEG's comments on the preliminary draft BIR, which was made available to EEG, and note that the following issues raised by EEG seem to deserve response:

1. When will the "expanded" inventory information required for the MWIR be furnished to DOE headquarters?

2. What is the status of the "NID"; is it still preliminary? What quality control measures are planned?

3. What changes will be incorporated in the scheduled March 1995, December 1995, and December 1996 submissions?

4. What data will PA use to support the use of "process knowledge" in preparing the BIR? How will inventory uncertainty be estimated and dealt with in generating uncertainty and sensitivity analyses?

5. What inventory data will DOE use in support of the disposal no-migration petition?

6. What characterization information is needed for PA? Will the answer emerge only when the SPM gives rise to PBWAC?

7. Will pre-1970 waste be listed in the BIR? Will such waste be unearthed and classed as "newly generated" waste?

8. How will process knowledge and expert judgment underlying the BIR be validated for PA purposes?

9. What support exists for statistical methods used in preparing the BIR?

Further, at the July 21, 1994 State-DOE quarterly meeting, a DOE presentation by Jeff Williams stated that data generated in site characterization activities pursuant to QAPjP's now in development would be fed back into the BIR to revise its characterization information. The scope and timing of this effort must be set forth.

We note too that a version of the BIR has now been made available, and there are certain conflicts with the CSR. For example, the list of generator sites is different from the list in the CSR (at 4-2).

4.1.5 Radionuclide inventory: The CSR does not state the date at which the Curie content of the radionuclide inventory should be determined in calculating permissible releases. In a similar context DOE said that the curie content should be determined at 100 years after disposal. See Final Supplement to EIS, 1990, v. 2, at 18-19.

There is considerable uncertainty as to the radionuclide inventory, especially in light of the possible use of WIPP to dispose of decontamination and decommissioning waste (4-22). Will consideration be given to treating inventory as a variable parameter in the PA?

4.2.1 Performance-based waste envelope: There is only a skeletal explanation of the concept of performance-based waste acceptance criteria. The CSR states that PA may provide "insight" (4-22) as to the sensitivity of specific parameters and may call

for new or increased waste characterization beyond what was previously planned or performed. The CSR should contain DOE's plan to employ the PA or SPM to define and apply ranges of acceptability as to various criteria.

4.3 Waste characterization: It is not clear what further waste characterization efforts will be undertaken to establish compliance. The Experimental Program Plan (DOE/WIPP 94-008) refers to characterization efforts (at 3-38, 4-14), and the Disposal Decision Plan (March 23, 1994) states that DOE will "provide supplemental inventory data to PA based on waste characterization plan" in December 1995. These efforts should be referred to in the CSR.

The CSR says that physical waste form parameters of interest will be presented based on the average content of the total TRU waste inventory and not on a drum-by-drum basis (at 4-40). It also suggests that the parameters have not yet been determined. DOE has not yet demonstrated the adequacy of characterizing waste--including characterization according to undetermined parameters--on a repository-wide basis. Waste-repository interactions will certainly not take place on that basis. If there are substantial departures from "average" conditions in various repository regions, probability distributions of waste parameters will be put in doubt. How such probabilities should be projected as to waste placement factors, which are within DOE's control, is a further question.

There is reference to possible "local management alternatives" on a panel and room scale (4-41). How such plans could be achieved in the context of inventory-wide averaging as to physical parameters is not explained. The CSR also states that DOE will be in a position to control the types and quantities of waste forms generated in the future. How such control will be employed is not stated.

The CSR description of RCRA-related waste characterization raises several questions. How will DOE establish TRU waste baseline inventory based on "maximum allowable physical waste form parameters that will not result in the migration of hazardous constituents above health-based limits" (4-41)? How will DOE show that headspace sampling and analysis reflects the content of inner layers? What practice will generator sites use to determine whether waste is hazardous? There is reference to process knowledge; what demonstration will be made to support its sufficiency? What sampling and analysis procedure will be used for solid process residues? (4-41, 4-42).

It is said that the QAPP for the test phase is currently being revised for the disposal phase (4-42). This document is now available in draft; what is the schedule for its completion? What is the schedule for approval of waste characterization programs at individual generating sites? How were the one-year and per-batch

sampling frequencies established? What will be the method for statistically sampling retrievably stored waste, and how will upper-90% confidence limit values be identified?

When will the WIPP Sampling and Analysis Guidance Manual be revised (4-43)? Does the reference to "performance standards specified in the QAPP" (Id.) refer to the revised QAPP?

The CSR states that the FFCA Interim MWIR will be used to assess the available waste repackaging and treatment capabilities (4-43). Does this mean that the IMWIR will project treatment capabilities for WIPP-destined waste, and, if so, on what basis will such capabilities be identified in that report?

The discussion of "analytical data" (4-44) is obscure and leaves the reader wondering what waste characterization data will be included in a compliance demonstration. What exactly is meant by "analytical data" here, and what data will be included from which sites?

4.4 Waste transformation processes in the repository environment: There is a general-level discussion of corrosion, microbial action, and radiolysis. What is necessary is a report, with citations, of the current status of experimental work and modeling efforts. Only such information will enable one to assess the proximity of a compliance demonstration and the further work needed to approach that point. The widely varying estimates of brine flow (4-46) imply a need for refinement of data, but no statement of plans is made. The source of the estimate of 150,000 liters of brine in 200 years should be given. Further, what plan exists to explore the effect of radiolysis in enhancing biodegradation (4-47, 4-48)?

5.0 Monitoring

The long-term monitoring program is not set forth because it does not exist. The only reference to a plan to develop such a program is a citation to DOE/WIPP 93-029. The CSR should contain at least an outline of the current view as to how such a program will be developed and should note how EPA's compliance criteria will be integrated into the effort. The subsidence monitoring program (5-8) should be described and a reference supplied.

6.0 Test programs

It is difficult to comment definitively on the asserted "resolution" of various compliance-related issues, because the importance of a given issue may depend upon the scenario, assumptions, models, and so forth underlying a final compliance demonstration, and we do not yet have those. With that caveat, we comment:

6.1.1 Geological/geochemical compliance issues

A. Breccia pipes: If breccia features are to be discounted, a compliance demonstration must justify the conceptual model which would confine such features to areas underlain by the Capitan Reef and demonstrate that such model is supported by sufficient data. There are indications that breccia structures occur in areas not underlain by that limestone. See Anderson, 1981; Anderson and Kirkland, Dissolution of salt deposits by brine density flow, Geology 8, 66-69 (1980). If the CSR is considered a paradigm for the presentation of compliance issues, it is inadequate in its present form for lack of supporting data and explanation.

B. Borehole and shaft plugging: These are correctly stated to be an open issue.

C. Brine reservoirs: The text (at 6-3) correctly says that brine reservoirs are an "open" issue. The table (at 12-4) says that DOE is evaluating standard drilling procedures to see whether a driller would "stop drilling operations prior to encountering a Castile Brine Reservoir." How the driller could do so is not explained. How DOE would incorporate the results of an analysis into an assessment of human intrusion probabilities is also unexplained.

D. Brine weeps and seeps: The text says only that "a number of approaches" have been pursued to quantify brine inflow, and the issue is "open." The Table says, however, that recent testing of repository-level sediments "appear adequate for modeling purposes." (12-4). No information is given about such tests. What tests are referred to, and is this issue still considered open?

E. Dissolution: Lambert (1983) concludes that deep dissolution is not a significant threat to the underground facility. Also, after the drilling and analysis of DOE-2 in 1987, EEG was able to conclude that there is no issue of a threat to the integrity of the repository from advancing dissolution at depth (Letter, Neill to Tillman, Sept. 9, 1987). (Such dissolution may be distinguished from the question of karst drainage features in the Rustler (see G) and from the issue of more subtle transmissivity variations caused by dissolution.) Most basically, for DOE to discount all possible effects of dissolution at depth, it should set forth much more fully the data and models which DOE considers accurate so that EPA and the stakeholders can evaluate DOE's position.

The attached paper by R.Y. Anderson highlights the interrelated problems of dissolution, climate change, and the modeling of Culebra flow. As Anderson relates, Nash Draw is an obvious karstic dissolution feature, and the occurrence of dissolution within the Rustler even closer to the WIPP site is not excluded by the absence of surface effects. Nash Draw itself was formed in the most recent 500,000 years. Extending northeast from Nash Draw is a high-transmissivity "finger" characterized by rapid

movement of tracers, relative absence of gypsum in fractures, and halite dissolution above the Rustler. Pre-Culebra strata at the WIPP site show enlargement by dissolution. The Culebra itself shows wide variations in transmissivity.

Further, as Anderson notes, "[p]roblems related to site stability and hydrology are different in character and more acute in a region of soluble strata that continues to be affected by changes in climate." (at 6). Nash Draw itself is a product of recent moist climate intervals containing pulses of even heavier precipitation. Recharge is indicated (at 10-11). The finger of high transmissivity will be the site of further dissolution during the next moist period. Dissolution of Nash Draw took place during episodes comprising only 10,000 to 50,000 years. Thus, "the time available for active dissolution and the development of Karst, in the vicinity of the site, is within the same time frame as the time interval for which prediction is required." (at 10) Gypsum precipitated in Culebra fractures will then be subject to dissolution, bringing "active dissolution to the center of the WIPP site shortly after a major change in climate" (at 8) and altering the flow and transport characteristics of the Culebra in ways not contemplated by the existing hydrologic models.

Thus, a model which purports to reflect climate change simply by altering recharge values without affecting other Culebra characteristics does not predict the response of the aquifer. "Such models assume no change in the condition of the aquifer and cannot be used to predict adjustments in the aquifer (e.g., fracturing and channelization) under different climatic conditions." (at 9). Further, due to the complexity of the interrelated processes, there is little hope that a model could be developed to represent the response of the aquifer to climate change.

F. Igneous activity. The CSR puts igneous activity in the "resolved" category based on certain conclusory statements. The 1991 PA states that the observed dike was not followed by similar occurrences in the Pliocene and Pleistocene and that, therefore, "a change in the geologic processes at this location has occurred." (1991 PA, v. 1, 4-23). Further explanation is required beyond such conclusions.

G. Karst: There has been debate about the occurrence of Karst features at the WIPP site, as the text notes (6-6). The issue is said to be resolved, however, based on citations to the Bachman (1985 and 1987) and Lappin, et al. (1989) studies. The CSR should make a fuller factual explanation of the exclusion of this scenario. Bachman (1987) in fact notes the occurrence of numerous Karst features of greatly varying ages.

More importantly, the impact of Karst formations on the effort to model the Culebra is not accounted for. See the discussion of dissolution above and the attached report by R. Y. Anderson.

H. Natural background radiation. Resolved, as noted.

I. Paleoclimate and climatic changes. The CSR states that paleoclimatic studies contained in Swift (1992) were used to develop a reasonable expectation as to future climate variation. It is not stated what that expectation is. Since it has been pointed out that the past 10,000 years have been extremely dry in comparison with the average of the past 800,000 years and that the Culebra hydrologic model, which is based on present-day climate and hydrology, is not valid for moist conditions and climate pulsations even if the precipitation rate is increased (See the discussion of dissolution above; see also Anderson comments to EPA, March 16, 1993), it would not be appropriate to deal with climate variations simply by limiting the recharge "expectation" to the range of variation seen in the past 10,000 years.

J. Resources: The CSR text says this issue is "closed," but the table says it is "open." (6-9, 12-7). The issue of the frequency and nature of human intrusions is plainly open. We inquire whether the quantity of oil, gas, and potash resources have been established for the site insofar as such information is part of the process of estimating future human intrusions. Until that issue is decided, the issue is open. A recent EEG report, Silva, Implications of the Presence of Petroleum Resources on the Integrity of the WIPP, EEG-55 (1994), illustrates that DOE has selectively endorsed or rejected resource calculations in past PA analyses. Reference should also be made to the plan to obtain a further study by New Mexico Tech.

K. Salt deformation: The text acknowledges that deformation in the Salado has been related to the occurrence of brine reservoirs (6-9). We have previously noted that the origins and controls on the areal distribution and stratigraphic location of brine reservoirs are not well understood (pages 5-6). Insofar as this issue relates to brine reservoir occurrences, it remains open.

L. Seismic activity: This office is not now in a position to assess the seismic data. If the data are accurate, it would seem that the design value exceeds the expected value for 1,000 year acceleration. It must be kept in mind that compliance is tested over a 10,000 year period. It should be explained why the 1,000 year value is relevant.

M. Specific site geological characteristics: salt depth, thickness, purity, etc: It is difficult to determine what is included in this issue. The CSR should state exactly what characteristics, and what quantities, are specified. In any case the statement in the table that the "WIPP facility is adequately

characterized" (12-9) is overbroad, as shown by the ongoing efforts to characterize the Culebra, Salado, Castile, etc.

N. Subsidence: The issue is correctly deemed open. Subsidence related to mining is correctly said to be a subject for further modeling. Such mining is not properly limited to mining outside the WIPP site; mining within the WIPP site should also be considered.

O. Tectonic stability/faulting: The information about tectonic stability is set forth mostly without citation to data sources. Until data can be supplied the enumerated issues must be regarded as open.

P. Identification and quantification of chemical processes that retard radionuclide transport in the Rustler Formation, particularly the Culebra Member: As the CSR states, this is an open item. An agreement between DOE and the State requires that DOE present the State with experimentally justifiable values for retardation factors and consult with the State before selecting the range of K_d values which is "based on the lowest reasonable values experimentally obtained." (1988 Modification to the Working Agreement of the Consultation and Cooperation Agreement at 9). DOE has not initiated the process of consultation with the State; therefore, this issue must remain open.

6.1.2 Issues in rock mechanics

A. Thermal expansion. Our office has not yet reviewed the cited material but after doing so may be able to concur that this issue is closed.

B. What is the best approach to simulating salt creep?

1. We cannot yet concur on the validity of the modeling approaches. Once our office is equipped with expert assistance we may be able to concur in the stated resolution.

2. We have not had a chance to review the cited materials and to obtain expert assistance in this area and cannot yet agree that the constitutive model and material properties of salt are adequately described. Further, any model which omits fracture behavior of salt is inadequate to describe the room closure process.

C. Rock Mechanics concerns in seal performance: These issues are properly deemed open.

6.1.3 Issues related to WIPP hydrology

A. Focus on the Culebra dolomite: We agree that the Culebra must be thoroughly investigated. However, the investigation of other units should not be suspended. The CSR itself says that the Dewey Lake Redbeds could be important under disturbed-performance scenarios which include wetter climates. It also says that the PA is looking at conditions involving geohydrological characteristics of rock units other than the Culebra. In this situation the analysis of other rock bodies is not to be excluded, and the issue should remain open.

B. Reconciling present-day distribution of solutes with Culebra flow direction: This issue is recognized as unresolved (see pages 4-5, above).

C. Rustler formation recharge: This question is also open.

D. Model for Culebra flow and transport: This question is also open. The CSR refers to plans to conduct non-sorbing tracer tests, which we have not had the opportunity to review.

E. Transmissivity variation in Culebra dolomite: The CSR notes the sparsity of data and the need to quantify the uncertainty of interpolations. We agree on the need.

F. Brine content of Salado evaporites: The issue, properly stated, includes identification of the relationship between permeability and pore pressure as affected by inflow and stress release resulting from excavations. It is another open issue.

G. Effects of gas generation: This is a major issue and is properly described as open. The CSR refers to several experimental plans, which we have not had an opportunity to study.

H. Effects of groundwater below the Salado and Castile Formations: The CSR refers only to the dissolution issue. See our comments above (page 15). It is not stated whether Delaware Mountain Group groundwaters may play a role under any other scenario.

6.1.4 Performance Assessment (PA)

A. CCDF confidence bounds: The CSR correctly notes that this issue is open and will be addressed in compliance criteria.

B. Scenarios: The CSR discussion involves only the use of a logic diagram procedure to construct combinations of events. It may be considered resolved that scenarios can be constructed in disregard of the order of events, but the various possible orders of events still must be considered in analyzing scenarios.

C. Complexity and realism of PA models: It is unclear what is said to be "resolved," and therefore we cannot agree. The entirety of the codes and models cannot be deemed resolved.

D. Uncertainty in radionuclide solubility and retardation: The issue is correctly listed as open. The CSR says that uncertainty in actinide concentrations and retardation will be reduced by replacing expert judgment values with experimental data (6-26). This statement oversimplifies the process and may be inaccurate. In fact, it has been said that data from the actinide source term program will be used somehow to validate or enhance confidence in a model. This validation or enhancement process needs to be described in detail.

E. Human intrusion: This issue should not be listed as resolved. As the CSR states, this issue will be reopened by 40 C.F.R. Part 194. Further, several questions remain about how the expert elicitation was conducted and the results incorporated into the PA. See comments by this office in the 1992 PA, submitted on April 8, 1994, pp. 11-13.

F. Climate change: The climate change issue is correctly shown as open. We do not agree that climate change is correctly dealt with in the 1992 PA, in that the range of prospective climate change is unduly limited. See also our comments at pages 15-16 above. It is not clear from the CSR (at 6-27) whether the planned regional flow model will be incorporated in PA.

G. Two-phase flow and gas generation: The need to include two-phase flow in PA is resolved.

H. Transmissivity of the Culebra: We agree on the need to enhance data representing the spatial variability of transmissivity in the Culebra. A question exists as to the density of the data as to transmissivity.

I. Displays of uncertainty: The CSR discussion mentions only uncertainty as to conceptual models of waste form and radionuclide transport (6-28). The CSR concludes that alternative conceptual models can be evaluated if they can be described by parameter variations in existing models. This is almost a tautology but leaves open the larger question of alternative conceptual models which cannot be so described.

J. Coupling of models: We concur that representation of the disposal room will require the coupling of creep closure with gas generation and brine flow modeling and that this issue is therefore open.

K. Fracture modeling: The CSR correctly notes that the adequacy of the representation of how anhydrite fractures are opened or generated is unresolved.

L. Confirmation of the adequacy of two-dimensional models: The described verification process confirms that this issue is open.

M. Events/process screening: The described review process confirms that this issue is open.

7.0 Quality assurance/quality control program

The CSR states that quality assurance will be governed by forthcoming Quality Assurance Requirements and Description, which will cover both future-generated and existing data. Thus, the compliance status of QA is a state of flux, and there is little object in commenting at this time.

It should be noted that the discussion of waste characterization QA states that site characterization programs are reviewed and approved by the WACCC; DOE recently stated during a technical exchange with EPA that this practice had been discontinued. The NTPO may have functions in this area and, if so, they should be described.

The CSR should state that the Waste Characterization Program Plan, Quality Assurance Program Plan, and Quality Assurance Project Plans are in the process of being rewritten.

Further, the entire subject of quality assurance must be deemed open, because it will be addressed by EPA in 40 C.F.R. Part 194.

8.0 Compliance analysis

The discussion in this chapter largely reproduces the 1992 PA, and we refer you to our April 8, 1994 comments on that subject. In addition:

8.1.2.1 Model validation: The CSR treatment of methods of model validation is conclusory and does not explain how models may be validated -- or confidence can be provided -- in specific instances.

8.1.2.2. Model verification: The CSR states that complete verification of all PA codes has not been completed; thus, this is an open item.

8.1.4.5.2 Inadvertent human intrusion: The CSR refers to matters to be examined in future PA's (e.g., at 8-21, 8-24, 8-42). Since annual and biennial PA's are no longer contemplated, the CSR should state what PA analysis will deal with such issues.

8.1.4.6 Scenarios evaluated for 40 C.F.R. §268.6: DOE does not have good grounds to exclude human intrusion from consideration

under RCRA. It is particularly unjustifiable to do so where EPA and DOE are addressing the likelihood of such intrusion for purposes of 40 C.F.R. Part 191.

8.1.5.1.1 40 C.F.R. §191.13: The CSR says that to demonstrate compliance DOE will use a single CCDF determined as the mean of the family (E-26). Previously, DOE has said that no single curve adequately presents the compliance issue (1992 PA, vol. 2, at 3-9). The CSR also says that "replications" of Latin hypercube sampling will be used; there should be an indication of the number of such replications. The theoretical basis for the choice of a particular CCDF curve or number of replications must be set forth. In addition, this issue will be addressed by EPA in 40 C.F.R. Part 194.

8.2.1 Role and use of expert judgment: The CSR fails to note that expert judgment is also employed in numerous phases of the PA process, such as in experimental design and in assessing the sufficiency of data.

8.2.2 Treatment of uncertainty associated with alternative conceptual models: The CSR states that a formal process will be adopted. It should be borne in mind that, if the process involves expert judgment, special safeguards should be incorporated. The text should refer to the work of the Conceptual Model Uncertainty Group and explain what further plans exist for that group.

9.0 Regulatory compliance assessment

This chapter raises the implicit question of the process whereby DOE will make its own determination of the sufficiency of a compliance demonstration prior to its submission to EPA and also the decision to operate WIPP after a compliance certification. The CSR should outline these processes or at least indicate when and how they will be developed.

Much of the general discussion of compliance demonstration is responded to in our comments on the 1992 PA, sent on April 8, 1994. In addition:

9.2.1 40 C.F.R. 191: The CSR relies upon the Appendix C guidance concerning human intrusion. While this guidance has not been withdrawn, EPA has said that the regulatory treatment of human intrusion will be considered afresh in the compliance criteria. Thus, it is unrealistic in a report on compliance status to fail to recognize the forthcoming changes in the applicable rules.

9.2.2 40 C.F.R. §268.6: The CSR recounts a purported EPA position that the likelihood of human intrusion need not be considered in projecting compliance with the no-migration rules. The CSR fails to note that EPA has stated in its draft guidance for the presentation of no-migration petitions that performance

assessments must account for such intrusions. (EPA 1992(b), at 34).

9.5.1 Active institutional controls: CSR should acknowledge that no long-term plan for active institutional controls yet exists.

9.5.2 Monitoring: No long-term monitoring plan exists. That issue will also be dealt with in 40 C.F.R. Part 194.

9.5.3 Passive institutional controls: No plan for passive institutional controls exists. Further, it is not possible to estimate the effectiveness of such controls in the absence of a plan. Again, 40 C.F.R. Part 194 will address these issues.

9.5.4 Multiple barriers: The CSR does not state any clear plan on DOE's part to implement the engineered barrier requirement. With the compliance criteria in flux and the SPM in its early stages, it seems that DOE does not have a concrete plan.

9.5.5 Resource characteristics evaluation: This issue will also be reopened based on the content of the compliance criteria, 40 C.F.R. Part 194. We have noted that the issue of on-site resources is open.

9.5.6 Waste removal: The compliance criteria will address this issue. DOE should be required to present a plan for the removal of waste during a period of 50 years after closure.

9.9 Waste acceptance/waste compliance: This section does not describe DOE's current plan, as outlined in the June 14-15, 1994 DOE-EPA technical exchange, to rely upon the Baseline Inventory Report for the characterization data underlying a compliance demonstration and to develop performance-based waste acceptance criteria ("PBWAC") through the SPM process to govern the receipt of waste. It is important to explain these new approaches and, notably, the prospect that PBWAC may change and DOE may seek to broaden the range of admissible waste through recertification proceedings.

10.0 Future test programs

10.1 Summary of future experimental activities necessary to support a compliance demonstration: The discussion of present and planned experimental work is of little value. It disregards the ongoing SPM process whereby experimental plans are being reevaluated. It contains almost no citations to supporting documents, and therefore the broad narrative statements in text cannot be clarified or checked.

11.0 Other Federal Laws

The discussion of the Resource Conservation and Recovery Act (§11.9) erroneously states that the facility has obtained interim status under the New Mexico Hazardous Waste Act. This matter is in litigation in the United States District Court for the District of Columbia, and the State's position has been presented in briefs to that court.

Appendix A: Regulatory interpretations

Certain of the interpretations contained in Appendix A contain errors. The following should be noted:

Regulatory interpretations pertaining to 40 C.F.R. 191:

6. The statement appears that the repository/shaft system includes the underground workings, emplaced materials, and altered zones. It should be stated that the emplaced materials include the waste, backfill, seals, and engineered barriers.

7. The term "encapsulating or stabilizing matrix" (part of the definition of "waste form") is not intended to include drums or boxes of the sort currently planned for emplacement of TRU waste. Such containers do not have a significant lifetime and do not inhibit movement of waste for any substantial time.

12. This definition would be better if it cited the authorities given to EPA pursuant to the WIPP Act and listed in 40 C.F.R. §191.12. Further, the reference to a DOE compliance determination raises the questions of the process, DOE participants, public participation, rules, and form of decision of that DOE procedure. They have not been adequately outlined to date.

15. Whether the "reasonable expectation" standard can be compared with courtroom measures of proof is dubious. We are dealing with a scientific and technical process and one which projects future events. "Reasonable expectation" should be described in terms which emphasize the statistical measures of assurance and encourage the reduction of the subjective component of the assessment. Insofar as an agency's general "expertise" is a factor, that expertise must be documented.

22. It is inappropriate to exclude from PA processes and events with a probability less than 10^{-4}. Any event or process may be narrowly defined to meet that criterion.

26. There is reference to a DOE "formal review process," but no description of it. What is the process, and when does it take place?

31. The description of active institutional controls should include means to control access to a site, e.g., by

surveillance and security measures. See the definition in 40 C.F.R. §191.12.

35. The term "substantial and detrimental deviations from expected performance" appears in 40 C.F.R. §191.14(b), not in Appendix C. It is not clear what the stated definition means. Given the complexity of the PA process, it is best to focus monitoring on factors to which the PA seems to be sensitive and which can be effectively monitored.

38. Monitoring should not be restricted to parameters used in analysis of undisturbed performance. It should also address parameters related to disturbed performance, since disturbance of the site has a definite likelihood.

40. It is erroneous to limit monitoring to the period of active institutional control. The regulation requires monitoring to continue "until there are no significant concerns to be addressed by further monitoring." 40 C.F.R. §191.14(b).

42. Same comment as with regard to item 40.

43. The post-closure monitoring plan should be more definite than what is described here. It should be a concrete plan with methods, equipment, operations and schedule described.

45, 46. If this discussion means that passive institutional controls will not be fully planned and designed at the time of the compliance certification submission, it is erroneous. DOE is not free to make changes in a plan which is the basis for certification.

53. The interpretation which limits pertinent resources to those of current or near-term value is erroneous. The regulation speaks also of "any material that is not widely available from other sources" and "valuable geologic formations." §191.14(e).

54. The "documentation" referred to must satisfy the requirements of §191.14(e).

55. It is premature to reach the conclusions stated here. DOE should make its case as part of its compliance demonstration that wastes would be removable. Such presentation should include a plan to remove wastes. In the course of preparation and review of such a plan it may become evident that certain procedures and design features should be adopted.

61. In assessing compliance with the undisturbed-performance standards it must be borne in mind that these provisions do not state limits in terms of probabilities of stated releases; rather, they speak of releases that "shall not"

(§§191.15(a), 191.24(a)(1)) occur. Analysis must be revised accordingly.

63. The language concerning the scope of human intrusions to be considered is extracted from Appendix C, which is nonbinding guidance and is to be superseded by 40 C.F.R. Part 194.

64. This language will also be superseded by 40 C.F.R. Part 194. It cannot simply be assumed that a driller would soon detect an intrusion into a repository. Proof of that fact would be required.

65. Again, the language comes from the Appendix C guidance, which will be superseded. It is erroneous to assume compliance with drilling regulations when compliance is not the norm.

66. The language from Appendix C is not binding and, in any case, is under review in the issuance of 40 C.F.R. Part 194. Releases must be examined based on a supportable process of scenario selection, rather than being fixed a priori.

Regulatory interpretations pertaining to 40 C.F.R. §268.6:

8. The term "reasonable degree of certainty" is not clarified by analogy with courtroom standards, since the issue is specifically scientific and technical. It would be more appropriate to outline methods to reduce uncertainty in projections of performance and to enhance the quantification of factors in that assessment.

13. The length of time described as "for as long as the waste remains hazardous" is waste and site specific. EPA has cautioned that nondegradeable constituents such as metals may call for a demonstration covering many thousands of years (EPA, 1992(b) at 9). EPA has not endorsed the limit of 10,000 years for all purposes.

14. It would be erroneous to omit consideration of human intrusion for purposes of 40 C.F.R. §268.6 on the supposition that passive controls will be effective over many thousands of years, yet to decline to make that assumption for purposes of 40 C.F.R. §191.13. EPA's draft guidance directs that human intrusion should be considered:

> "In addition, likely human-induced events which may affect the isolation capability of the unit, such as disturbance of the hydrologic regime and future land uses, should generally be considered." (EPA, 1992(b), at 34).

Thus, the compliance demonstration must take account of the likelihood of human intrusion.

16. It is not clear what standard is set by the requirement that models be validated "to the extent practicable." There is obviously difficulty in validating a model which describes performance over 10,000 years. However, disposal without treatment is not legally favored, and there is no legal presumption that validation is possible at all; thus, there is no reason for an exemption based on impracticability.

28. The language should not imply that a no-migration variance petition may exclude a monitoring plan.

38. The proposed interpretation suggests that human intrusion need not be considered in the projection of repository performance. This is erroneous. See the discussion of item 14.

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14 July, 1994

Lindsay A. Lovejoy, Jr.
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Dear Lindsay Lovejoy,

This document is in response to your 30 June, 1994 request for comments regarding unresolved issues related to the WIPP Compliance Status Report (CSR, DOE/WIPP 94-019). I have examined the items in section 6 which DOE claims as "closed" or resolved. I have not examined or commented upon issues 6.1.1 F, J, K, L, M,N,O. I have prepared comments on two general areas, *Deep Hydrology* and *Surface Hydrology*. Each encompasses several of the issues that DOE has listed as resolved. A minimal number of sources of information have been cited, owing to limitations of time.

Unresolved problems related to deep hydrology are important for Performance Assessment (PA), but how they would effect the performance of the repository would depend on the results of further research and exploration which probably would not be authorized by DOE. On the other hand, what is known about surface hydrology has revealed a site that, under conditions of even moderately changed climate, because of changes in the Rustler aquifer, may not meet present requirements for disposal over a time interval of 10,000 years. Over the next 100,000 years, the certainty of significant climate change means that WIPP cannot accomplish its mission of demonstrating safe, long-term isolation of radioactive waste.

Respectfully Submitted,

Roger Y. Anderson

Roger Y. Anderson

Anderson to Lovejoy, Comments on CSR,DOE/WIPP 94-019; 14 July, 1994

"Deep Hydrology" Issues

6.1.1 A Breccia pipes (closed)
6.1.1 D Brine weeps and seeps (open)
6.1.1 E Dissolution (closed)

The report contains several inaccuracies about the distribution of breccia pipes and their relation to hydrology. Breccia pipes ***are*** found within the basin and they are ***not*** restricted to the area above the reef. The occurrence of a breccia pipe within the basin was reported by Anderson and Kirkland (1980) and a photograph of collapse breccia in that pipe was featured on the cover of the national journal which published the reviewed article. The abundant *limestone buttes* (castiles) that are exposed in Culberson County are another example of breccia pipes or chimneys within the basin. All of these vertically penetrating features have a small cross section and the statement that none occur in the vicinity of WIPP would require supporting evidence that the geophysical methods used to explore the WIPP site area were capable of identifying such features. Equally important as their occurrence within the basin, is a lack of understanding about how such collapse features formed and how they are related to the hydrology of the basin.

Other collapse structures found within the basin are Bell Lake Sink and Slick Sink, which occur east of the WIPP site and within an area of the basin where there is no evidence for regional dissolution. No one disputes that these are collapse structures but there is no information about the depth of these structures, about which geologic strata were dissolved to produce the collapse, or about the hydrologic conditions that caused the collapse. It is entirely conceivable, and in fact likely, that the collapse extends downward at least to the Rustler aquifer. The large diameter of Bell Lake Sink, a collapse structure which pre-dates the climate change of the last glacial maximum (LGM), and geochemical evidence for the upward movement of deep formation fluids (Hill, 1993), suggest that Bell Lake Sink is a deep structure. Some information on Bell Lake Sink is in a UNM MS thesis by R. Widdicombe, but the origin of this collapse feature, *within the basin,* has been largely ignored during the characterization of WIPP.

The implications of having a deep, localized collapse structure within the "undissolved" region of the Delaware Basin should not be

underestimated. For example, if the structure is rooted in the Rustler aquifer it would mean that fluids moving through the Rustler have produced localized dissolution and collapse well beyond advancing regional fronts of dissolution. Bell Lake Sink contains a high lake stand that probably reflects climate changes during the LGM. The possible renewal of localized collapse before or during the LGM has important implications for the local stability and hydrology of the site under a wetter climate regime and is therefore related to the "closed" issue of climate change. Climate issues are also related to the question of karst and surface hydrology, discussed later.

Still another question related to "deep" hydrology, is the character and origin of the west-to-east, upslope-to-downslope hydrologic communication that is known to exist within the body of Salado evaporites within the Delaware Basin. This hydrologic condition was recognized long ago by Hills (1968), evidence was presented by Anderson (1981, and in several reports to Sandia Laboratories), and EEG has confirmed the validity of the evidence. Possible consequences of having moist salt is the unexpectedly fast rate of salt creep and room closure (see issue 6.1.2 B.2) and increased brine seepage (see issue 6.1.3 F).

The repository is already built and it is too late to use information about this largely unknown hydrologic system for site selection. However, it is not too late to characterize the hydrology and to use this understanding in order to provide more reliable estimates of brine seepage and room closure, issues that are vital to PA. For the reasons cited above, I do not consider dissolution or "deep dissolution", breccia pipes, or brine weeps and seeps to be resolved issues.

"Surface Hydrology" Issues

The remaining issues are closely related to one another and to the larger issue of karst, which DOE claims is resolved.

6.1.1 G Karst
6.1.1 I Paleoclimate and climate change
6.1.3 A Focus on Culebra Dolomite
6.1.4 F Climate change

Karst

History of the Karst Issue

In 1975, after complex structures and a pressurized brine reservoir were encountered at the first WIPP site , the project moved westward to the Los Medaños site along the eastern margin of Nash Draw. Approximately half of the halite in the Rustler Formation was missing at this site (CSR Fig. 2-8). It soon became apparent that dissolution by near-surface ground waters had removed the halite along the eastern margin of Nash Draw (Fig. 1), which borders the WIPP site on the west. Nash Draw is one of the largest karstic dissolution structures with surface expression in North America. Geologic features and surface hydrology around the site clearly are expressions of the kinds of geomorphic features and groundwater flow regimes that geologists, world-wide, refer to as karst.

The issue of surface dissolution and karst was originally investigated to determine if rates of regional dissolution and erosion were sufficient to breach the repository. Although suberosion is too slow for a breach, dissolution does pose a threat to the Rustler aquifer. The CSR separates the issues of karst and dissolution and minimizes its use the term karst in describing the processes of dissolution at the site that effect the Rustler aquifer. The CSR uses the term karst for the deep dissolution troughs that occur in the central and southern part of the Delaware Basin and which contain thick sequences of early Pleistocene Gatuña Formation.

The CSR cites the absence of visible karstic surface features at the WIPP site as DOE's main reason for closing the issues of both karst and surface dissolution. The CSR acknowledges the importance of karst, were it to exist at the WIPP site, but closes the issue by stating that "...karst formation is not a process at the WIPP site which will result in significant compliance-related consequences."

The absence of visible karstic surface features such as sink holes, however, is <u>not</u> evidence that the Rustler aquifer is unaffected by dissolution. The moderate thickness of halite and gypsum strata in the Rustler Formation precludes the development of large, visible collapse structures at the surface until late stages of dissolution. In addition, a cover of dune sand at WIPP obscures any surface expression of smaller karst features such as swallow holes. As will be discussed, there is ample evidence that dissolution is an active process at the WIPP site and the issue of near-surface dissolution(karst) is critical to the effects of climate change on the performance of WIPP.

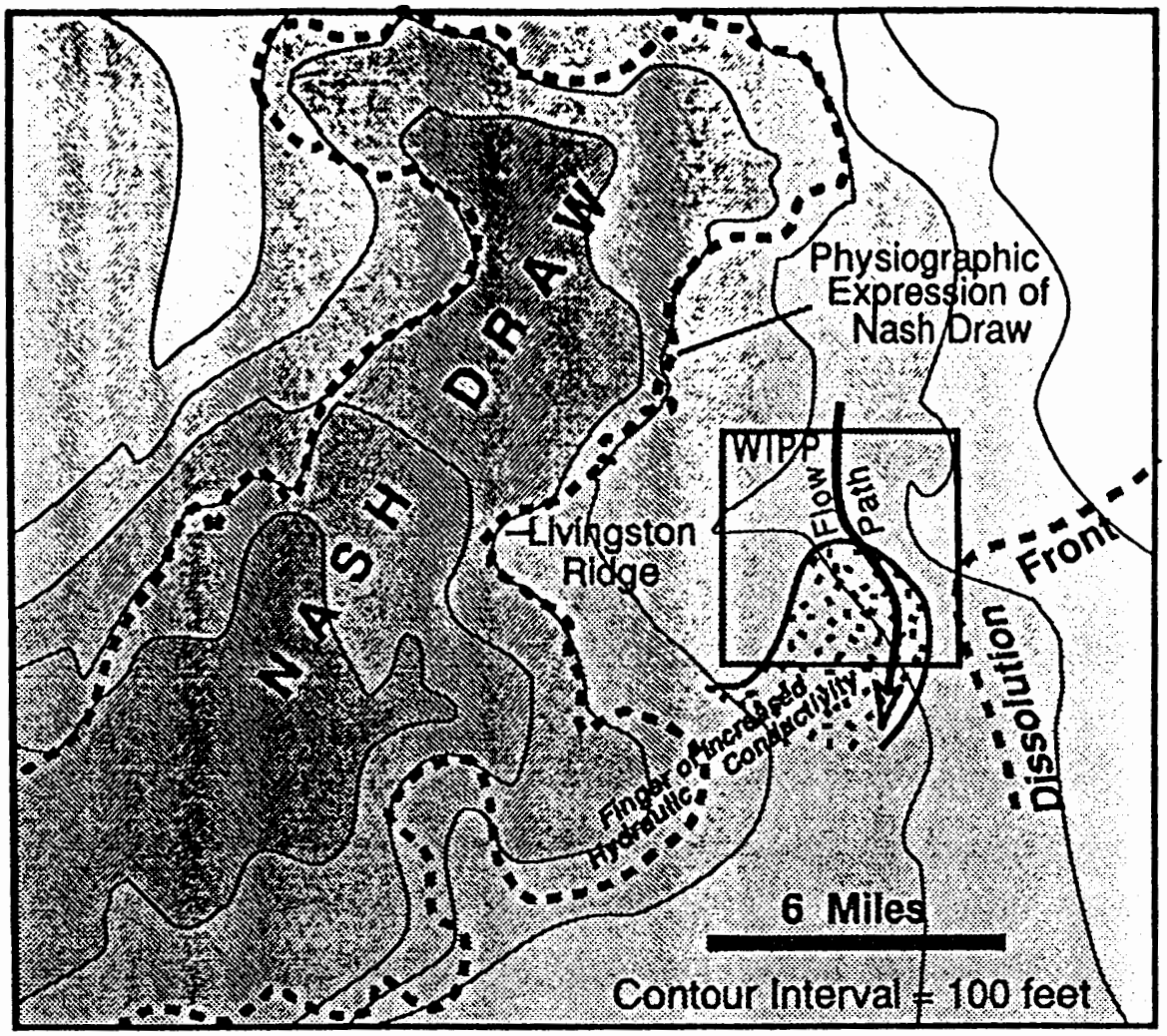

Fig. 1. Location of Nash Draw in relation to WIPP site.

Dissolution, beginning along the axis of Nash Draw, has moved about 10 miles eastward and over the WIPP site to the present position of the dissolution front. Dissolution moved eastward in a series of pulse-like episodes controlled by changes in climate (see Fig. 3).

Notice that the main flow path in the Rustler aquifer and the local area of increased hydraulic conductivity in the southern part of the WIPP site occur as a northward extension of the southeastern lobe of Nash Draw.

Subsiding and expanding topographic depressions, such as Nash Draw, are typical of karst regions and a karstic hydrology.

Age of Dissolution

Although the CSR makes little mention of the age of dissolution in the area of WIPP, other publications by DOE team members (e. g. Beauheim and Holt, 1990) make it clear that most of the dissolution, karst development, and associated fracturing of the Rustler aquifer is believed to have occurred in the Cenozoic. Nash Draw, for example, is considered to be a Cenozoic feature related to the ancestral Pecos drainage and to the deep dissolution troughs in the central area of the Delaware Basin (Beauheim and Holt, 1990). This estimate of the age of Nash Draw clearly is in error because the age of this structure has been adequately dated by tephrochronology as younger than 600,000 years (Bachman, 1974). The young age of Nash Draw is highly relevant because it offers a means for examining the effects of climate change on the progress of dissolution.

The young age of Nash Draw and its growth and development under regional hydrologic conditions that continue to the present day provide a basis for understanding and predicting future dissolution at the WIPP site. For example, Beauheim and Holt (1990) recognize that *"A high transmissivity 'finger' penetrates the southern border of the WIPP site."* This finger is a localized area of high transmissivity in the Culebra aquifer (Fig. 2A). This is the area where test wells that show rapid movement of tracers. It is also the area where groundwater is relatively fresh and unsaturated for gypsum (Fig. 2B), and where gypsum cement in Culebra fractures has been removed by dissolution (Fig. 2C). The "finger" is also the pathway for the most rapid flow in the Culebra and the local site for dissolution of halite above the Culebra (Fig. 2D). Examination of the location and orientation of this finger of high flow, fresher water, and dissolution effects, relative to the configuration of Nash Draw, shows it to be a northeastern extension of conditions that prevail within the southeastern lobe of Nash Draw.

Other geologic features and hydrologic conditions found in the finger and into the central area of the WIPP site are explainable as early stages in the process of karstic dissolution. For example, physical and photographic evidence taken from the main shaft at the center of the WIPP site reveals that fractures in soluble units below the Culebra have been enlarged by dissolution to form flow channels (see Fig. 2 in Chaturvedi and Channel, 1985). The fact that hydraulic conductivity varies by 6 orders of magnitude across the site, as well as the vertical movement of fluids through other stratigraphic units of the Rustler, are conditions that are consistent with karstic dissolution. Some wells in the finger, such as H-11, show high transmissivities and rapid movement of tracers, while other nearby wells

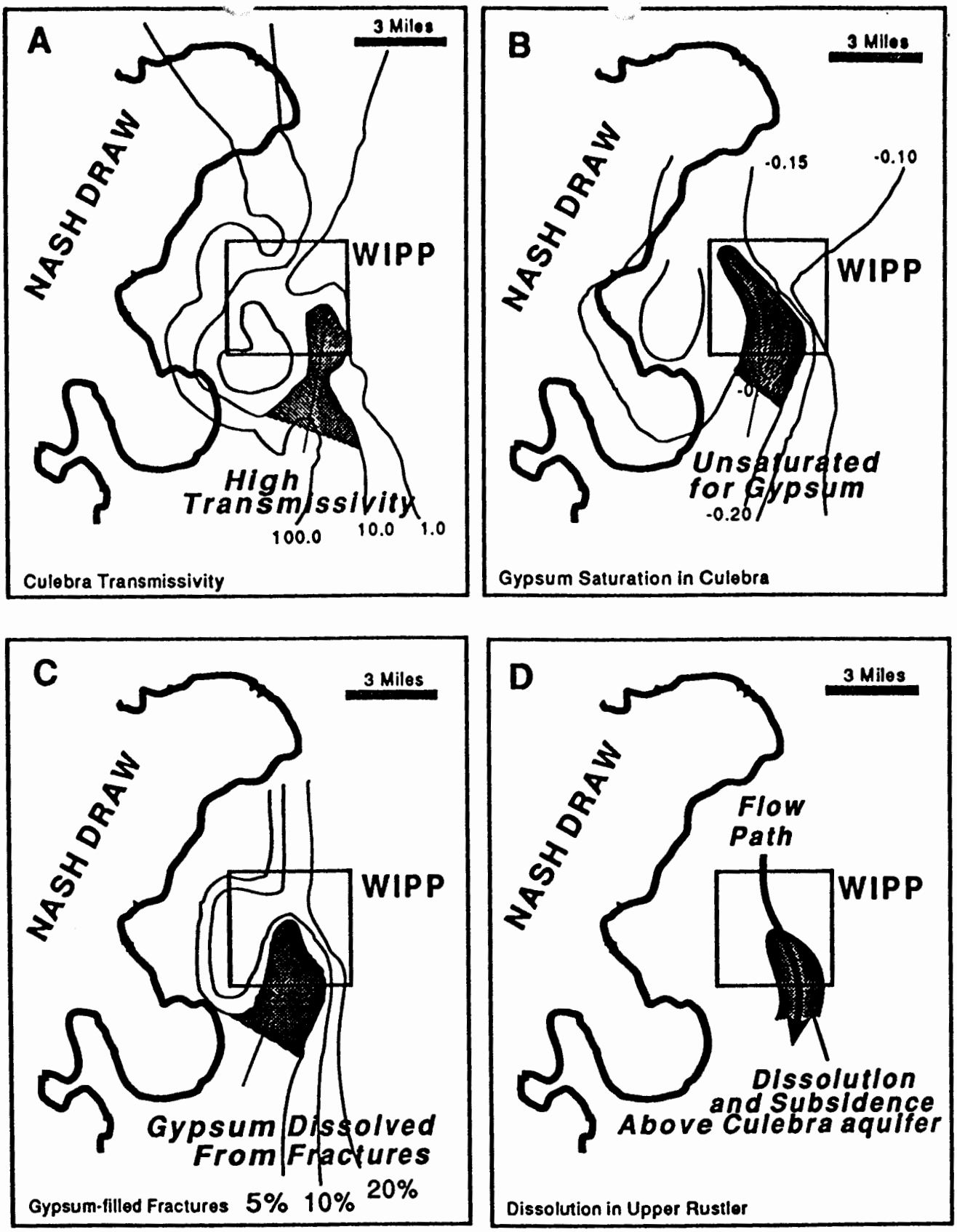

Fig. 2. Expression of active dissolution in the southern area of the WIPP site Adapted from Beauheim and Holt (1990).

have very low transmissivities. This is precisely what one would expect to find under conditions of developing karstic dissolution.

Present models adopted for the WIPP PA assume only fracture flow in the Culebra, and as will be discussed, a correct understanding of the evidence for dissolution is necessary for the development of valid hydrologic models. In this regard, it is pertinent that a team of international experts, reviewing WIPP hydrologic models, has suggested the use of alternate "fracture channeling models" (see Beauheim and Davies, 1992), thereby acknowledging that the aquifer has developed flow channels and has adjusted to an early stage of karstic development.

Interpreting the "finger" as an advancing extension of the karst hydrology of Nash Draw follows logically from the young age of Nash Draw and from its history of eastward expansion and migration during past episodes of climate change. The response of Nash Draw and adjacent areas to the effects of climate change are critical to predicting the future performance of WIPP.

Climate Change

The CSR contains a meager summary of climate issues and gives conflicting statements, saying in one section that the issue of climate change is open and in another that the issue is closed (12-7 vs 12-24).

I have emphasized the issues of karst and dissolution in because placing the WIPP in a region of developing karst carries with it profound implications for the stability of the site under conditions of variable climate. Problems related to site stability and hydrology are different in character and more acute in a region of soluble strata that continues to be affected by changes in climate.

A brief geologic history of Nash Draw illustrates the problem of long-term site stability. Nash Draw (Fig. 1) formed sometime after a thick surface-layer of soil carbonate (Mescalero "caliche") developed over the region of WIPP. The Mescalero unit is about 500,000 years old. The first stage of dissolution and subsidence was centered in the present axis of Nash Draw and during the last 500,000 years dissolution and subsidence has expanded laterally under a highly variable climate, creating the present topography and reaching the present edge of the regional dissolution front (Fig. 1). Today, the topographic or physiographic expression of Nash Draw resembles a very large dog bone (Fig. 1). In the southeastern corner of Nash Draw, dissolution and

subsidence have outflanked Livingston Ridge and the effects of dissolution have encroached upon the WIPP site from the south (Fig. 1).

Dissolution and eastward expansion of Nash Draw occurred mainly during a series of four strong perturbations in climate that occurred in the latter part of the Ice Age and Nash Draw migrated eastward during a series of dissolution episodes, each separated by dry intervals of lesser dissolution, such as the dry episode of the last 12,000 years (Fig. 3). The average amount of precipitation in New Mexico during these major climatic episodes is believed to have increased to more than double its present value. Precipitation during moist episodes also occurred in short pulse-like events of even greater precipitation (Allen and Anderson, 1992). The pulse-like character of these events may have increased the effectiveness of infiltration into karstic systems, thereby facilitating dissolution during moist episodes.

The finger of anomalous hydraulic conductivity in the southern part of the WIPP site, referred to earlier, is also the main flow path through the Culebra aquifer. One can anticipate that during the next major climate cycle of increased precipitation, dissolution will expand along the finger, advance northward, dissolve what remains of the halite in the Rustler Formation, and dissolve some fraction of the upper Salado at the interface between the Rustler and Salado salt (brine aquifer).

A precursor to the path that dissolution is expected to take in the future can be seen, as well, in the distribution of the secondary gypsum in fractures in the Culebra aquifer (CSR Fig. 2-12). To appreciate the significance of this pattern, and the importance of the effects of climate change, it is helpful to describe the process of re-solution of gypsum in stages, as follows, and as depicted in Fig. 3:

1. *Creation of a system of open fractures in the Culebra aquifer during episodes of high flow prior to 12,000 years ago.*

2. *Plugging of the open-fracture network by precipitation of secondary gypsum in fractures during a period of reduced rainfall and infiltration, and low hydraulic head in the WIPP area. This warm dry climate episode occurred in the American Southwest about ~ 8000 to 4000 years ago.*

3. *Beginning about 4000 years ago, re-solution of secondary gypsum from fractures in the Culebra aquifer occurred after the regional climate changed from dry to the moderately moist conditions of the present day.*

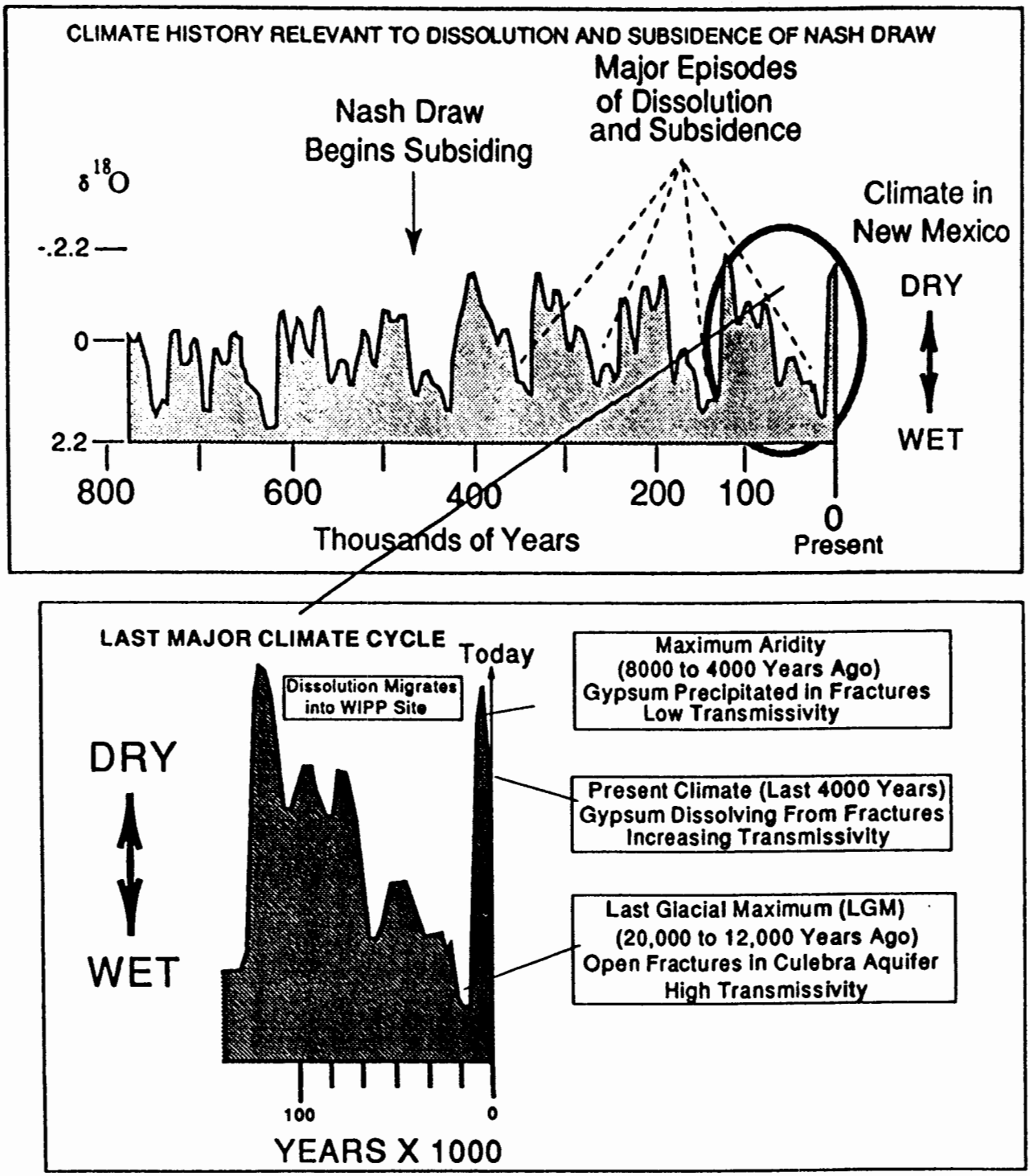

Fig. 3. Wet/dry climate cycles and their effect on the Rustler aquifer in the southern area of the WIPP site. Major climate cycles based on marine isotopic record (see Swift, 1992).

4. *Development of a localized pattern of open fractures that corresponds, approximately, with the modern flow path through the Rustler aquifer (Figs. 1, 2, and see Fig. 26 in Beauheim and Holt, 1990).*

The effects of the above climate-driven cycle of solution, deposition, and re-solution can be seen in the present-day pattern of open fractures in the Culebra (Fig. 2C, and see CSR Fig. 2-12). This localized pattern corresponds to the area of variable and high hydraulic conductivity, to the area of anomalous tracer tests, and to the main flow path (Fig. 2D).

DOE, as outlined by Swift (1992), has correctly identified a climate history for the WIPP area that is essentially as illustrated in Fig. 3. The CSR, however, does not link this history to dissolution and related changes in the Rustler Formation. The effect on dissolution by the moderate changes in climate that occurred during the last 10,000 years, as shown in stages 1-4 above and in Fig. 3, leads to several observations regarding the effects of larger changes in climate expected in the future.

1. *Adjustments of the Rustler aquifer to past changes in climate can be used as a predictor of patterns of dissolution and structural adjustments during future changes in climate.*

One can predict that the dissolution front will migrate further eastward and most if not all the remaining soluble beds will be removed from within the Rustler. More important for the performance of WIPP, however, will be the flanking movement of dissolution that extends from the southeastern lobe of Nash Draw. This route will bring active dissolution to the center of the WIPP site shortly after a major change in climate and before the remaining halite in the Rustler Formation is removed along the regional dissolution front.

2. *Changes in climate result in rapid adjustment of the aquifer to the altered climate state.*

Evidence for this observation is considered in later paragraphs.

3. ***Predictive models based on hydrologic data collected from the existing Rustler aquifer are valid only for the present climate state.***

Rapid adjustment of the aquifer due to dissolution and subsidence following a change in climate means that hydrologic models cannot accurately predict flow rates, retardation, and other measures of WIPP performance on the basis of modern hydrologic data. These adjustments range from dissolution of gypsum in existing fractures to the generation of additional fractures following the removal of soluble strata

Present hydrologic models alter climate input by changing values for hydraulic head in the Culebra aquifer. Such models assume no change in the condition of the aquifer and cannot be used to predict adjustments in the aquifer (e. g. fracturing and channelization) under different climatic conditions. A model that attempted to do so would have to consider so many unknown variables that output from the model would be of little or no value.

Inadequacy of Performance Assessment For Altered Climatic Conditions

The above observations indicate that *there is no adequate means for predicting the performance of WIPP under climatic conditions of increased moisture.* This conclusion is based on the fact that soluble material and strata adjust rapidly, through dissolution and then through subsidence and fracturing, to small increases in the supply of dissolving fluids. For example, a continuation of the increased moisture of the last 4000 years, relative to the dry interval between 8000 and 4000 years ago, will result in further dissolution of secondary gypsum from fractures in the Culebra Dolomite. With only a moderate increase in moisture and head, fractures in the Culebra will continue to widen and accommodate increased flow within a time frame of a few thousand years, thereby reducing the validity of a 10,000-year prediction based on tighter fractures. For even larger increases in moisture, as illustrated in Fig. 3, removal of soluble strata within and below the Rustler Formation will lead to further fracturing and channelized flow, making predictions even less reliable.

DOE, which has closed the issue of karst, probably will challenge the above conclusions on grounds that little or no dissolution, fracturing, or channelization of the aquifer is likely to occur during the next 10,000 years. However, such an argument cannot be based on the assumption that Nash

Draw and the associated fractures in the Rustler are old structures that developed largely during the Cenozoic or early Pleistocene.

Evidence for the on-going nature of dissolution is provided by the distribution of secondary gypsum in Culebra fractures and by the fact that the climate history of the Southwest constrains the time when re-solution and increases in transmissivity occurred (Fig. 3). Another line of evidence that helps date the pace of dissolution is the rate of migration and collapse of Nash Draw. Although Nash Draw grew to its present size during four or five major climate cycles over the last 500,000 years (Fig. 3), eastward migration was undoubtedly marked by episodes of rapid migration during wet intervals separated by cessation of dissolution and fracture filling during periods of dryness. Eastward migration means that most of the soluble materials removed from the Rustler Formation in the vicinity of WIPP were dissolved out during the last major wet climate episode (less than ~100,000 years, see Fig. 3).

Examination of this last major climate cycle at other localities in New Mexico shows that climate changed in a series of strong pulsations lasting no more than a few centuries and that these century-scale wet intervals were grouped into longer cycles of about 2000 years (Allen and Anderson, 1993). Even though the last major wet episode was sustained for more than 50,000 years, actual increases in moisture to double present values during this prolonged interval were much shorter, possibly representing as little as 10,000 years. We are left with the understanding that the time available for active dissolution and the development of karst, in the vicinity of the site, is within the same time frame as the time interval for which prediction is required.

Predictions of future flow in the Rustler under conditions of a doubling of moisture, given the short time frame of dissolution and aquifer adjustment, must deal with the problem of an altered aquifer. For example, assume that a dramatic increase in precipitation occurred 2000 years from now, a real possibility if one examines Fig. 3. Under such conditions a lag between increased precipitation/infiltration and dissolution of nearly 8000 years would be required for a prediction to be valid for 10,000 years. The evidence from the rate of migration of Nash Draw, and from the re-solution of secondary gypsum in fractures, indicates no such lag.

The question of lag effects and how soon dissolution and subsidence will follow a shift in climate depends upon the pathways and rates of infiltration from the ground surface to the Rustler and brine aquifers. Extensive dune cover over the site area has obscured any surface expression of rapid infiltration (e.g. sinkholes and swallow holes). However, a sinkhole and a test well east of Nash Draw and near the western edge of the site (WIPP

33) testify to rapid infiltration. Halite is dissolved from the strata that lie above the finger of high transmissivity, undersaturation, and rapid flow in the Culebra (Fig. 2D). Where did the brine from this dissolved salt go, if not downward and into the Culebra aquifer? Where was the source of dissolving waters? South of the finger is an unexplained decrease in total dissolved solids that provides a strong clue as to how the hydrologic system must work.

The CSR leaves the question of surface recharge of the Rustler aquifer open, stating that "recharge areas and rates remain unidentified" (CSR, p. 6-20). Even after making this unequivocal statement, the CSR concludes, remarkably, that the issues of karst and dissolution are resolved and will not have... "compliance related consequences."

An Important Question

The inability to obtain meaningful predictions of performance over the next 10,000 years raises the question of the proper interval of time for which waste isolation must be assured with acceptable consequences. A 10,000-year period of institutional responsibility was promulgated for radioactive waste disposal on grounds that predictions made beyond that period would be increasingly unreliable. It was argued that if a site could be shown to be stable for 10,000- years, then it was likely that the site would be stable for a much longer interval. Although such an argument might be valid for many geologic sites, it is not valid for the WIPP because of its history of dissolution and the certainty that changes in climate will disrupt the Rustler aquifer.

For a radionuclide such as plutonium (half life of 24,000 years) a realistic period of isolation would be at least 100,000 years. If one examines the regularity of major episodes of past climate change (Fig. 3) and considers WIPP in this context, then the Rustler aquifer would have to survive at least one complete major climate cycle. Given the previous history of Nash Draw, the soluble beds in the Rustler would be completely removed during the next major cycle and the question of retardation of radionuclide transport in the Rustler aquifer would become moot.

A Logical Question

If the existence of karst at WIPP precludes the use of predictive models for performance assessment for the next 10,000 years, how is it that the WIPP project moved forward to its advanced stage of development without recognizing so fatal a flaw?

The answer lies in WIPP history and in an examination of institutional commitments to WIPP as a disposal site. When the first WIPP site had to be abandoned, the one remaining site in New Mexico, Los Medaños, came with

several problems. One problem was proximity to potash, petroleum and other resources. For example, producing oil wells nearly encircle the WIPP site. The pattern of well spacing indicates that WIPP sits above a major oil discovery, a fact already known by 1990. The record shows that DOE officials knowingly failed to inform experts about petroleum exploration and production at the site, even though producing oil rigs were in clear view of the WIPP facility (Silva, 1994). This episode illustrates the determination of institutions to complete the WIPP mission in the face of adverse information, but, more importantly, it shows the ineffectiveness of institutional controls and the certainty that the WIPP site is a target for Human intrusion.

The other problem was that about half of the salt in the Rustler aquifer was missing. At that time the reasons for a thin Rustler were not well understood and it was believed that karstic conditions were confined to Nash Draw. Investigators were concerned with travel time for fluids in the Rustler aquifer under existing climatic conditions and profound changes in climate were considered to be mainly a feature of the high latitudes associated with glaciation.

When evidence began to emerge, before WIPP was constructed, that karstic conditions were more widespread than anticipated, this information was ignored, leaving us, today, with consequences made greater by changes in climate. This means that the effects of human intrusion may not only be amplified by the pressurized brine reservoir that is reported to occur beneath the WIPP repository, it will not be possible to predict the consequences of this compounded scenario owing to unknown responses to climate change.

The institutional track record for characterizing WIPP and for considering possible consequences warns us to be certain about having reliable predictions of performance. Therefore, specific recommendations are in order.

Recommendations

1. The discovery of petroleum resources under WIPP, and a greatly increased potential for multiple breaches of the repository, relate directly to climate issues as they effect the performance of the Rustler aquifer. The issue of resources needs to be reexamined, with all the facts on the table.

2. Previous assumptions about the age of Karst are in error, with karst development and dissolution in the site area younger and more extensive than acknowledged. There needs to be a concerted effort to determine the extent of dissolution by means of further exploration.

3. It is acknowledged in the CSR that neither the area nor the rate of recharge of the Rustler aquifer are known. Explanations for Rustler flow, recharge, and geochemistry that draw upon conjectural models of past recharge under changed climatic conditions must be replaced by actual data about the specific areas where recharge is occurring today and about rates of recharge.

4. The Rustler aquifer is progressing through stages of dissolution which may make it impossible to assure predictions of performance within the selected 10,000-year time frame. Further exploration should be directed at determining not only the extent but the history of dissolution within the context of past changes in climate

In the absence of a resolution of key issues related to climate (see recommendations 2, 3, and 4), one must conclude that present hydrologic models are not adequate for performance assessment and that the WIPP project will be unable to demonstrate compliance with EPA requirements for waste isolation.

References Cited

Allen, B. D., and Anderson, R. Y., 1993, Evidence from western North America for rapid shifts in climate during the last glacial maximum: Science, 260, 1920-1923.

Anderson, R. Y., 1981, Deep-seated salt dissolution in the Delaware Basin, Texas and New Mexico; N. M. Geol. Soc., Special Pub. 10, 133-145.

Anderson, R. Y., and Kirkland, D. W., 1980, Dissolution of salt deposits by brine density flow, Geology 8, 66-69.

Bachman, G. O. 1974, Geologic processes and Cenozoic history related to salt dissolution in southeastern New Mexico: U. S. Geological Survey, Open File Report 74-194, 81p.

Beauheim, R. L., and Davies, P. B, 1992, Experimental plan for tracer testing in the Culebra Dolomite at the WIPP site, Sandia Natl. Lab., SAND 92-9798.

Chaturvedi, L, and Channel, J. K., 1985, The Rustler Formation as a transport medium for contaminated groundwater: EEG-32, 84p.

Hill, C. A., 1993, Barite/celestite/selenite/calcite mineralization at Bell Lake Sink, Lea County, New Mexico, N. M. Geol. Soc. Guidebook, 44th Field Conf., 317-320.

Hills, J. M., 1968, Permian Basin field area, west Texas and southeastern New Mexico: *in* Mattox, R. B., (ed.) Saline Deposits, Geol. Soc. America Spec. Paper 88, 17-27.

Hills, J. M., 1968, Permian Basin field area, west Texas and southeastern New Mexico: *in* Mattox, R. B., (ed.) Saline Deposits, Geol. Soc. America Spec. Paper 88, 17-27.

Silva, M., 1994, Implications of the presence of petroleum resources on the integrity of the WIPP: EEG-55.

Swift, P. N., 1992, Long-term climate variability at the Waste Isolation Pilot Plant, southeastern New Mexico, USA: SAND91-7055, Albuquerque, NM, Sandia National Laboratories.

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14 July, 1994