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ENVIRONMENTAL EVALUATION GROUP

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EEG-3

NEW MEXICO
HEALTH AND ENVIRONMENT
DEPARTMENT

RADIOLOGICAL HEALTH REVIEW OF THE DRAFT ENVIRONMENTAL IMPACT STATEMENT (DOE/EIS-0026-D) WASTE ISOLATION PILOT PLANT, U. S. DEPARTMENT OF ENERGY

Robert H. Neill, James K. Channell, Carla Wofsy,
Moses A. Greenfield, Editors

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

August 1979

ENVIRONMENTAL EVALUATION GROUP

LIST OF REPORTS

EEG-1 Goad, Donna, A Compilation of Site Selection Criteria Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, June 1979.

EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volumes I and II, December 1978.

EEG-3 Neill, Robert H., et al, (eds.) Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U. S. Department of Energy, August 1979.

EEG-4 Little, Marshall S., Review Comments on the Report of the Steering Committee on Waste Acceptance Criteria for the Waste Isolation Pilot Plant, February 1980.

EEG-5 Channell, James K., Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, November 1980.

EEG-6 Geotechnical Considerations for Radiological Hazard Assessment of WIPP. A Report of a Meeting Held on January 17-18, 1980, April 1980.

EEG-7 Chaturvedi, Lokesh, WIPP Site and Vicinity Geological Field Trip. A Report of a Field Trip to the Proposed Waste Isolation Pilot Plant Project in Southeastern New Mexico, June 16 to 18, 1980, November 1980.

EEG-8 Wofsy, Carla, The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Doses from WIPP, September 1980.

EEG-9 Spiegler, Peter, An Approach to Calculating Upper Bounds on Maximum Individual Doses From the Use of Contaminated Well Water Following a WIPP Repository Breach, September 1981.

EEG-10 Radiological Health Review of the Final Environmental Impact Statement (DOE/EIS-0026) Waste Isolation Pilot Plant, U. S. Department of Energy, January 1981.

EEG-11 Channell, James K., Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, January 1982.

Radiological Health Review
of the Draft Environmental Impact Statement (DOE/EIS-0026-D)
Waste Isolation Pilot Plant, U. S. Department of Energy

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*The notation (5) refers to Chapter 5 in the DEIS.

APPENDIX

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is no environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department — the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and other organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

Robert H. Neill

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Director

INTRODUCTION

These comments are limited to the radiological health and safety and environmentally related aspects of the Draft Environmental Impact Statement (DEIS), Waste Isolation Pilot Plant (DOE/EIS-0026-D) and the background material used by DOE, with the primary focus of the comments on those aspects that have potential effects on the State of New Mexico.

While the Environmental Evaluation Group (EEG) recognizes that some later data have become available and that there may be significant changes in the mission of the WIPP, the review has been confined to the DEIS WIPP Reference Case (1-2; 6).* In those cases where options on WIPP are still open or data was not provided, final evaluation will await that information.

This evaluation includes:

(1) checking the calculations in the DEIS with the assumptions and methods used;

(2) checking computations by alternate (usually simplified) approaches;

(3) evaluating the assumptions and methodology used;

(4) considering possible omissions;

(5) evaluating conclusions reached; and

(6) recommending additional actions to be taken.

Alternative locations to the proposed WIPP site have not been evaluated since they are beyond the scope of EEG's mission.

Several meetings were held with the DOE and it's contractors to clarify some of the assumptions, input parameters, and numerical procedures used in various analyses.

*The notation (1-2; 6) refers to Chapter 1, page 2, paragraph 6 of the DEIS.

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SUMMARY

General

The Department of Energy is to be commended for making a major effort to determine the environmental impact of WIPP.

This review of radiological health considerations contains a number of concerns, questions and recommendations that should be addressed by the Department of Energy in the final Environmental Impact Statement (EIS).

Using the assumptions contained in the Draft Environmental Impact Statement (DEIS), the EEG calculated a number of radiation doses and the results were found to be in general agreement with those presented in the DEIS. The doses resulting from the operational and long-range releases from WIPP to the general population are no more than a fraction of existing radiation doses to the public. However, there are a number of technical considerations in the assessment of radiation exposure that were not adequately evaluated in the DEIS. They are discussed in this review.

A number of additional dosage estimates have been identified that need to be calculated by both DOE and EEG.

As the DEIS did not contain estimates of the amounts of radioactivity to be permanently located in the repository, it was necessary to calculate these amounts.

Estimated Plutonium Inventory in TRU Wastes*

Radionuclide	Activity (Curies)
Pu-238	35,000
Pu-239	480,000
Pu-240	120,000
Pu-241	1,200,000

*after 30 years of repository operation

It is apparent from our analyses that additional information and evaluations will be necessary in the future if the WIPP project ceeds. Consequently, the DEIS and its review are only the beginning of the health and safety evaluations that need to be performed.

The DOE stated in the DEIS that the WIPP repository should be licensed by the Nuclear Regulatory Commission (NRC). Recent developments suggest that the WIPP may not be licensed by that organization. EEG recommends that the proposed facility be subjected to the full scrutiny of health and safety considerations afforded by the licensing procedures of the NRC.

Health Effects

The DEIS did not estimate health effects to people from either the expected or potential radiation exposure but used dose as a presumptive index of hazard. Although not as informative as health effects, it has been a common practice in radiation protection work. Various radiation standards-setting organizations such as the International Commission on Radiological Protection (ICRP), United Nations Scientific Committee on Effects of Atomic Radiation (UNSCEAR) and the Biological Effects of Ionizing Radiation Committee (BEIR) of the National Academy of Sciences have developed models for mortality risk coefficients from ionizing radiation. In order to do expected mortality calculations, it is necessary to know not only the magnitude of the radiation exposure but the size of the population exposed as well as the probability of such an occurrence. DOE should address the issue of health effects in the final EIS. EEG will generate those estimates when the required information has been developed for the various population groups from both normal and accidental exposures.

Transportation

The equations used in the DEIS calculations of radiation dose from the normal transportation of the radioactive wastes were derived by the EEG and the calculated doses were found to be in agreement with those presented in the DEIS. These exposures to the general population are small additions to those from natural background and other man-made radiation sources. However, a critical evaluation of the assumptions used on potential accidents in the DEIS raises the following issues.

Radiation exposures from deliberate acts of sabotage in the transportation of radioactive materials could be considerably higher than those from traffic and rail accidents but the DEIS assumed there would not be a difference.

Some of the DEIS assumptions for accidents may not be conservative. Examples are:

1) A fire occurring during a rail accident involving contact-handled transuranic wastes (CH-TRU).

2) Leakages of remote-handled transuranic wastes (RH-TRU) from a container following a rail accident.

3) Ingestion of radioactive material following an airborne release.

Consideration should be given to shipping all the radioactive waste by rail wherever the calculations show that the actual and potential radiation exposures to people will be reduced. This is consistent with the concept in radiological health that all unnecessary radiation exposure be avoided and exposures kept as low as reasonably achievable (ALARA). Consideration should also be given to restricting shipments in icy weather.

Waste Acceptance Criteria

A full evaluation of the radiological consequences of operations and accidents cannot be completed until the waste acceptance criteria are developed by the DOE Waste Acceptance Criteria Steering Committee. DOE has been furnishing that material to EEG for review as it becomes available. There are a number of criteria that must be specified such as the degree of combustibility of the wastes, the amount of gas that can be generated through decomposition of organic materials, the amount of pyrophoric material, and the amount and type of non-radioactive hazardous material to be stored.

Site Characterization

There are uncertainties regarding several geologic and hydrologic aspects of the area surrounding the WIPP site. DOE is continuing to gather and analyze data relevant to these features and processes. The final EIS should include a more detailed analysis of the following:

1) Brine reservoirs, apparently large and under high pressure, which have been encountered in at least 7 wells within 9 miles of the periphery of the WIPP site.

2) Deep dissolution; i.e. dissolution of lower and intermediate levels of the salt beds.

3) Breccia pipes, which may be localized deep dissolution features, starting in the lower portion of the salt beds and migrating upward.

4) Variations and uncertainties in ground water flow rates and flow paths.

5) The effect of the presence of impurities (e.g. clay, anhydrite, and polyhalite) on the physical, hydrological, thermal and strength characteristics of rock salt from the repository horizons.

Site Selection Criteria

In the absence of regulatory standards by the Nuclear Regulatory Commission and the Environmental Protection Agency for the permanent disposal of radioactive wastes, reliance has been placed by the Department of Energy on establishing criteria that a repository should meet.

In light of this fact, we recommend that the Department of Energy formally request the involved federal agencies and other bodies of technical expertise to comment on the reasonableness and adequacy of the site selection criteria so that a consensus can be achieved. In this manner, any allegation that the criteria were unilaterally established by DOE can be avoided.

A failure of the proposed repository to meet a given design criterion does not in itself mean there is a hazard. It does identify or flag those areas that need to be thoroughly analyzed to determine whether or not the consequences of failure could result in radiation exposure to people.

Operational Exposure

The information on occupational radiation exposure is incomplete in the DEIS and presumably will be covered in more detail in the Preliminary Safety Analysis Report (PSAR).

The operational accident scenarios evaluated in the DEIS appear to be fairly complete in scope and the EEG calculations agreed with the DEIS when the same assumptions were used. Some of the assumptions may underestimate the amount of radioactivity released from damaged containers.

It is also unclear whether the exhaust air from the underground waste handling facility will pass through the HEPA filters before being released to the environment.

From the information in the DEIS, there is a question whether the non-radiological Ambient Air Quality Standards of New Mexico will be met in Zones II, III and IV. A more detailed analysis is necessary to determine the control measures that will be required.

Experimental Waste Program

It is recognized that the experimental high level radioactive waste program will provide empirical evidence for many of the theoretically derived geological parameters. However, in order to evaluate the potential radiation exposure to workers and the public it will be necessary to know the radionuclides involved, the amounts of radioactivity, the waste form, the details of the experiments and the plans for retrieval of the radioactive material. The experimental waste program could contain 9 to 90 million curies of radioactivity if the full-sized commercial high level waste canisters are used.

Long Term Radiation Releases

The DEIS considers a number of scenarios which could lead to release of radioactivity after the repository has been sealed. Based on the assumptions used in the DEIS analyses of long-term release scenarios, EEG's results are in reasonable agreement with dose rates and radionuclide migration times presented in the text. Except for the drilling scenario, the dose rates are small. However, the scenarios considered were limited and the EEG has identified additional scenarios and calculations which should be considered such as the potential contamination of well water or the role of pressurized gas in bringing radioactive material to the surface. EEG has considered the ranges over which some of the parameters relevant to the movement of radioactivity in ground water can vary and the effects of these variations on the DEIS results. Therefore, EEG recommends that the detailed sensitivity analysis currently being conducted by DOE should be included in the final EIS.

Retrievability

It is essential that the ability to retrieve the radioactive wastes be examined in detail as to criteria, procedures, logistics, canister integrity, hazards to workers and hazards to the general population.

Decommissioning

Decommissioning options are discussed in satisfactory detail in the DEIS. However, the related issue of the degree and longevity of site control after decommissioning must be addressed. This is important since an uncontrolled site would be subject to various human actions, especially drilling, that could violate site integrity. The advantage and feasibility of site control for periods greater than 100 years should be evaluated.

HEALTH EFFECTS

The DEIS neither estimated nor discussed health effects from the potential radiation exposure to the population but used doses instead as an index of hazard. In the definition of risk in the glossary, the DEIS defined "consequence" of exposure as "population dose" and not "health effects". Although this is not as informative as health effects, it has been a common practice in radiation protection work.

Estimated health effects from WIPP should be included in the final EIS. It is recognized that there are uncertainties associated with such estimates that include the anticipated size of the future population at risk from WIPP, the probability of accidents and the frequency distribution of those accidents, the magnitude of the population dose for various conditions and indeed the basic applicability of a linear correlation of health effects with doses at such low dose rates. EEG plans to undertake these calculations in the future and to also include comparisons with presumed deaths from natural background and other radiation sources in the environment.

EEG intends to use the following approach. ICRP (Publications 26, 27) has developed a set of risk coefficients for various somatic biological end points and tissues that are based on currently available data (Ref. 1, 2). For a uniform whole-body irradiation (averaged over both sexes and all ages) their report indicates a mortality risk coefficient of approximately 10^{-4} rem^{-1} (a probability of 1 death per 10,000 person-rem). In 1977 UNSCEAR gave more detailed information on the basis for this numerical value and pointed out that such coefficients are obtained for mortalities induced at doses in excess of 100 rads (Ref. 3, p. 414). There is disagreement over the numerical values of the risk coefficients and their applicability for different types of radiation and for different population groups and the results should be considered as approximations. Table 1 indicates the steps in developing risk estimates.

As indicated in the first column, populations at risk of 10^4 (10,000) and 10^6 (1,000,000) are assumed. In column 2, the uniform whole-body equivalent dose received by each member of that population is indicated to be either 10^{-6} (0.000001), 10^{-4} (0.0001), or 10^{-2} (0.01) rems. These ranges of values generally cover the estimated average dose equivalents received and the population sizes according to the calculations contained in the DEIS. It is assumed for purposes of this table that these dose equivalents are received throughout the body of each of the persons in the populations. The products of a value in column 1 and the value in column 2, for a given line, gives the population dose equivalent in person rems indicated in the third column. If the risk coefficient is assumed to be 10^{-4} deaths/rem, the product of a numerical value in the third column and 10^{-4} gives the number of deaths that are presumed to occur as a result of the irradiation. One needs to remember that these are the number of deaths throughout the lifetime of the individuals involved. It is seen that for a population of 1 million persons, uniformly exposed to a dose equivalent of 0.01 rem, one would estimate 1 death from radiation induced cancer during the entire lifetime of all members of that population.

Table 1

Illustration of Method to Calculate Radiation Induced Deaths*

If Population is	and Dose Equivalent is (rem)	Population Dose Equivalent (person-rem)	Presumed Deaths
10,000	0.000001	0.01	0.000001
10,000	0.0001	1	0.0001
10,000	0.01	100	0.01
1,000,000	0.0001	100	0.01
1,000,000	0.01	10,000	1

*The numbers used for this example are for illustrative purposes only and are not directly applicable to WIPP.

Comparison with Natural Background

In the absence of information on health effects, it is customary to compare man-made radiation exposure to that which occurs from natural background and the DEIS has done this. Dose commitments from ionizing radiation are presented in the DEIS for time periods ranging from a few days to one year and fifty years. These dose commitments are compared to the dose equivalent from natural background over a few hours, one year, fifty years and seventy years. In some cases, the DEIS inappropriately used dissimilar time periods.

Doses in which the radiation is absorbed over one year should only be compared to natural background radiation over a similar time period. Similarly, doses from radiation that occur over fifty years can be compared to fifty years cumulative total from natural background radiation exposure. Examples where this has not been done include Tables 9-18, 9-19, 9-25 and in the discussion of Table 6-13.

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References

1. International Commission on Radiological Protection. Recommendations of the International Commission on Radiological Protection (ICRP Publication 26), 1977.

2. International Commission on Radiological Protection. Problems Involved in Developing an Index of Harm (ICRP Publication 27), 1977.

3. United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and Effects of Ionizing Radiation, 1977.

INVENTORY OF RADIOACTIVITY

(DEIS Chapters 2, 6, 9, E)

TRU Waste Inventory

The DEIS stated that: "The quantities of waste stored at various storage locations are not precisely known; that is, the estimations of these quantities...have large uncertainties associated with them. In addition, it has not yet been decided which locations will actually be shipping waste to the WIPP reference repository" (6-11;3). EEG recognizes DOE's difficulty in obtaining an accurate inventory of TRU waste to be stored at the WIPP. The calculated inventories used by EEG are based on information in the DEIS. If this information is incomplete or incorrect on the quantity or isotopic composition, then the dose and concentration estimates will also be in error.

Activity Estimates

Since the DEIS did not include estimates of the total volume or activity of transuranic (TRU) waste, EEG has prepared estimates of the amounts to be located in the repository (see Tables 2, 3 and 5) and the inventories for truck and rail shipments (see Tables 3 and 4) and recommends that such information be included in the final EIS.

EEG's estimates are based on information in the DEIS, particularly waste volume and shipment projections in Chapter 6 and radionuclide concentrations in Appendix E. The period of repository operation was taken to be thirty years, because of the DEIS statement that "...the plant is designed for a useful life of at least 30 years" (1-4;8). Details of the calculations appear in Appendix 1.

Radionuclide Concentrations

It is recognized that the amounts of radionuclides present in containers of a given type differ greatly, making it difficult to get an accurate inventory. However, there are inconsistencies in the DEIS. The average plutonium content listed in Appendix E is 8 grams per box and 13 grams per drum for CH-TRU waste (Tables E-1, E-2, pp. E-2,3), whereas Table 9-43 (9-103) in the DEIS leads to higher estimates. This table gives projected CH-TRU waste isotopic concentrations (in Ci/liter and g/liter) 100 and 1000 years after burial. The DEIS notes that "the inventory listed in these tables is not precisely the same as that shown in Appendix E" and states that "actual assay data from the Idaho National Engineering Laboratory" were used (9-102). The data in Table 9-43 appear consistent with results of an INEL assay reported by Bingham and Barr (SAND 78-1730).

Table 6 summarizes the differing actinide concentrations obtained from Tables E-1, E-2 and 9-43. Box concentrations obtained from Table E-2 are an order of magnitude lower than drum concentrations obtained from Table E-1. The INEL assay concentrations are slightly higher than the Table E-1 drum concentrations. Does this mean that new data suggest higher box and drum concentrations than those given in Tables E-1 and E-2?

Spent Fuel Inventory

The spent fuel inventory in the DEIS agrees with other published inventories (references 1, 2, 3). The computer program used to derive these inventories was ORIGEN (ref.4). ORIGEN has been evaluated, tested and distributed by the U. S. Department of Energy, Radiation Shielding Information Center (ref. 5) and is being used worldwide as an accepted inventory code by the nuclear field. Correlation between measurements and calculations has generally been good (ref. 6).

EEG notes that the activation product Carbon-14 was not included in the spent fuel inventory. It will be present in greater quantities than I-129 (ref. 7), has a half-life of 5730 years, and is very mobile in the environment. It has been projected to cause the major part of the population dose from nuclear reactors (ref. 8). This omission should be explained.

Table 2

Estimated 30-year Repository TRU Waste Inventory*

Isotope	Activity (Ci)
Plutonium-238	3.5×10^4
Plutonium-239	4.8×10^5
Plutonium-240	1.2×10^5
Plutonium-241**	1.2×10^6
Americium-241**	5.5×10^4

*These estimates include the effects of decay and ingrowth.

**Plutonium-241 (half-life = 13 years) is a beta emitter which decays to Americium-241 (half-life = 460 years).

Table 3

Inventory of Radioactivity*

CH-TRU

Isotope	Repository Total (Ci)
Pu-238	4.0×10^4
Pu-239	4.7×10^5
Pu-240	1.2×10^5
Pu-241**	2.8×10^6
Am-241	7.7×10^3
Total	3.4×10^6

RH-TRU

Isotope	Repository Total (Ci)	Activity in a rail shipment (Ci)	Activity in a truck shipment (Ci)
Sr-90/Y-90	2.8×10^6	2100.	420.
Co-60	1.7×10^4	13.	2.6
Ru-106/Rh-106	2.5×10^4	18.5	3.7
Cs-137/Ba-137m	1.4×10^4	10.5	2.1
Eu-152	3.6×10^3	2.7	.53
Eu-154	1.4×10^4	10.5	2.1
Th-232	8.0	.006	.001
U-234	6.5×10^{-2}	(4.9×10^{-5})	(9.7×10^{-6})
U-235	2.7	.002	(4.1×10^{-4})
U-238	6.0×10	.044	.009
Pu-238	7.4×10^2	.55	.11
Pu-239	8.7×10^3	6.5	1.3
Pu-240	2.0×10^3	1.5	.3
Pu-241**	5.2×10^4	39.	7.8
Am-241	1.4×10^2	.11	.02
Cm-244	3.6×10^4	27.	5.3
Total	3.0×10^6	2.2×10^3	4.5×10^2

*30 years of new production are added to the backlog (see DEIS Tables 6-2, 6-6). The effects of decay and ingrowth are not included in these estimates.

**Beta emitter with a 13 year half-life.

Table 4

CH-TRU Shipment Inventories

Isotope	Ci/drum (Table E-1)	Ci/box (Table E-2)	Ci/rail shipment of drums	Ci/truck shipment of drums	Ci/rail shipment of boxes	Ci/truck shipment of boxes
Pu-238	4.1×10^{-2}	6.5×10^{-2}	4.9	1.7	1.6	.52
Pu-239	4.8×10^{-1}	7.5×10^{-1}	58.	20.2	18.	6.0
Pu-240	1.2×10^{-1}	1.8×10^{-1}	14.	5.0	4.3	1.4
Pu-241	2.9	4.6	350.	120.0	110.	37.
Am-241	7.8×10^{-3}	1.2×10^{-2}	0.94	0.33	.29	.10

CH-TRU Shipment Volumes*

Mode	Container	Volume of container (ft^3)	Containers per shipment	Waste volume per shipment (ft^3)
Rail[a]	Box	112	24	2700
Rail	Drum	7.4	120	930
Truck[b]	Box	112	8	900
Truck	Drum	7.4	42	310

[a] ATMX railcar assumed for rail shipment.

[b] Type B container for truck shipment assumed to hold 8 boxes.

*DEIS, Table 6-3(6-12).

Table 5

TRU Waste Volumes (ft.^{3}): 30 Year Repository Totals

Type of Waste	Containers	Backlog*	New waste production per year*	New waste production in 30 years	Backlog + 30 year production
CH	Boxes	7.0×10^5	9.0×10^4	2.7×10^6	3.4×10^6
CH	Drums	2.4×10^6	1.5×10^5	4.5×10^6	6.9×10^6
RH	Canisters	7.7×10^4	6.9×10^3	2.1×10^5	2.8×10^5

* DEIS, Tables 6-2, 6-6 (6-12,6-14).

Table 6

CH TRU Radionuclide Concentrations

Isotope	Half-life (yrs.)	Radionuclide concentrations (μCi/l) From Table E-1,* in drums	From Table E-2,* in boxes	From INEL assay SAND 78-1730 (p. 87)	From Table 9-43 at 100 years
Pu-238	8.8×10	2.0×10^2	2.0×10	2.4×10^2	1.1×10^2
Pu-239	2.4×10^4	2.3×10^3	2.3×10^2	2.8×10^3	2.8×10^3
Pu-240	6.5×10^3	5.8×10^2	5.6×10	6.8×10^2	6.7×10^2
Pu-241	1.3×10	1.4×10^4	1.4×10^3	1.7×10^4	---
Am-241	4.6×10^2	3.8×10	3.8	4.6×10	4.7×10^2

*Calculated by dividing the expected activities (Ci/drum and Ci/box) in Tables E-1 and E-2 by the container volumes (208 liters for a drum and 3.2×10^3 liters for a box), and multiplying by 10^6 μCi/Ci.

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References

1. U.S. Nuclear Regulatory Commission. Draft Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel (NUREG-0404), March 1978.

2. U.S. Energy Research and Development Administration. Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle (ERDA-76-43), May 1976.

3. U.S. Environmental Protection Agency. Significant Actinide Activities in the LWR and LMFBR Nuclear Fuel Cycles (EPA-520/3-75-006), 1974.

4. Bell, M.J. ORIGEN - The ORNL Isotope Generation and Depletion Code (ORNL-4628), 1973.

5. Oak Ridge National Laboratory. Radiation Shielding Information Center. ORIGEN. Isotope Generation and Depletion Code - Matrix Exponential Method (CCC-127), October 1978.

6. Industridepartment Energikommissionen. Disposal of High Active Nuclear Fuel Waste. A Critical Review of the Nuclear Fuel Safety (KBS) Project on Final Disposal of Vitrified High Active Fuel Wastes.

7. U.S. Department of Energy. Management of Commerically Generated Radioactive Waste (DOE/EIS-0046D), Draft Environmental Impact Statement, April 1979.

8. U.S. Nuclear Regulatory Commission. Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light Water Cooled Reactors (NUREG-0002), 1976.

WASTE ACCEPTANCE CRITERIA

(DEIS Chapter 5)

Major Conclusions

1) Since the waste acceptance criteria are under active development by the DOE, they are not in the DEIS. However, DOE has been furnishing EEG with material on the criteria as they are being developed by the Waste Acceptance Criteria Steering Committee for review.

   Until such time as waste acceptance criteria are defined, the radiological consequences of operations and accidents cannot be fully analyzed. Three major concerns of both the DOE and the EEG are the presence in the TRU waste of:

   a) gas from organic decomposition

   b) combustible materials; and

   c) respirable particles.

2) Some interim criteria on RH-TRU waste in Table 5-1 are less stringent than criteria for CH-TRU waste.

3) It is essential that the retrievability of the radioactive wastes be examined in detail as to criteria, logistics, procedures, integrity of containers, hazards to workers, and hazards to the general population.

CH and RH-TRU Criteria

The review of the interim waste acceptance criteria for CH and RH-TRU waste (5-4, 5-5) led to several concerns:

1) Combustibility. A limit has not been placed on the amount of combustible materials which may be placed in individual containe or collectively in the underground storage rooms. EEG is

concerned since fire is listed among the possible accidents.

2) Gas Generation. Gas-generating materials in CH-TRU waste are limited to 10% by weight in any single storage room. No limit is given for RH-TRU waste. The 10% limit shown would not provide meaningful guidance to the individuals packing the containers. How much gas-generating waste will be accepted? How much gas and what type can be generated? What will be the long term effects of gas generation? On pp. 9-133 to 9-136, gas generation and its possible effects on the repository are discussed. These problems are being investigated by the DOE. Calculations have been carried out which indicate that gas pressures in the repository "might exceed lithostatic pressures at the repository depths" (9-136; details are not given).

   The statement is made that "To insure that evolved gases will not fracture the rock overlying the reference repository, the waste acceptance criteria will limit the amount of gas-producing material in the waste accepted for burial" (9-136;3). Gas generation criteria should be very specific and should be supported by evidence of their adequacy. Detailed guidance should be provided to waste-generating facilities in order to help them meet the criteria. It is not clear how waste-generating facilities will determine the content of gas-producing materials in previously stored wastes.

3) Pyrophorics. EEG believes criteria should specify the amounts of pyrophoric material permitted in both CH and RH-TRU waste.

4) Hazardous Material. What non-radioactive hazardous materials must WIPP be prepared to handle, and in what total quantity? What criteria will the WIPP operator use in authorizing such material? (See the reference to "Hazardous materials" in Table 5.1). What calculations have been done on the potential reentry of these materials to the biosphere? Some of them could be hazardous for periods longer than the radioactive wastes.

5) Thermal Power. A criterion of 0.1 W/ft^3 is given for color coding and identification for the CH-TRU waste. A criterion should be given for RH-TRU as well.

The explanation given for not restricting combustibility, gas generation or thermal power for RH-TRU waste is that "quantities [of RH-TRU waste] are insignificant, and processing will probably not be available" (5-4). The DEIS refers to RH-TRU waste as constituting "a small fraction (about 2% by volume) of the TRU waste generated by the DOE complex" (5-6;1), and goes on to state that "Even if all the RH-TRU waste were gas-producing or combustible, there would probably not be enough to cause significant problems at the WIPP reference repository" (5-6;2). EEG's estimates of total respository TRU wastes volumes (see Table 5, p. 20) are 1.0×10^7 cubic feet of CH-TRU and 2.8×10^5 cubic feet of RH-TRU. If this amount of RH-TRU material is to be considered insignificant, calculations in the final EIS should support this conclusion. Furthermore, EEG estimates the average level of radioactivity of material in a shipment of RH-TRU waste to be 2.2×10^3 Ci/rail shipment and 4.5×10^2 Ci/truck shipment (see Table 3, p. 18). The degree of mobility and combustibility of wastes will be a factor in determining the consequences of a transportation accident.

Previously Stored TRU Wastes

To what extent will previously stored TRU waste be re-examined, treated as may be necessary (incineration, immobilization of ash, etc.) and repackaged prior to shipment to WIPP? Some of the wastes proposed for WIPP may have been in storage as long as 20 years. The characteristics of the wastes and the containers could have changed substantially in that time, rendering either the wastes, the containers, or both unsuitable for storage at the WIPP. According to reference 16, it is doubtful that 17C drums would meet the leak test requirements of the ANSI standard 14.5, particularly after a decade of storage. The integrity of the drums without polyethylene liners is particularly suspect. Is the no-leak requirement of ANSI 14.5 or the requirements of 10

CFR 71.42 (b) applicable to the packages to be shipped to the WIPP?

Information in reference 11 indicated that there was non-uniformity among the various suppliers of the TRU wastes in the way in which wastes were stored and data recorded. The waste acceptance criteria should clearly establish uniform practices which are consistent with the needs of WIPP. For example, reference 22 indicated that all Pu-238 contaminated waste in drums which have been previously stored for significant time periods should be considered potentially explosive until individual drum analyses are conducted. This would imply that such drums would not meet a criterion prohibiting explosive material in CH and RH-TRU waste containers.

Impacts of Processing

Processing of CH-TRU waste by slagging pyrolysis was presented in the DEIS as a strong possibility (5-9). This raises certain questions. Would slagging pyrolysis facilities be set up at all sites from which waste would be sent? Would pyrolysis take place only at INEL? In this case, would waste from other locations be sent to Idaho for processing or would the waste acceptance criteria be relaxed for waste from other locations? Will some of the waste be processed at the repository site? This would have implications in the area of transportation and operational exposures.

The statement on page 5-7;3 that "the waste-acceptance criteria finally selected will produce smaller impacts than the impacts calculated from the assumed criteria" seems premature.

Detailed Comments

5-3, 5-4 What is the rationale behind "Large suppliers must observe another limit: the surface-dose rate of their shipment averaged over 3 months, must be no higher than 10 mrem/hr" (5-3:7)? What is the limit for small suppliers? Also, what are the surface contamination limits (Ref. 49 CFR 143.398)?

5-4 Have criteria been developed for spent fuel and High Level Waste?

5-5 Surface Contamination Criteria reference should be 49 CFR 173.398 instead of 49 CFR 73.398 in Table 5-1.

5-4,5-7;4 Table 5-1 stated that small quantities of pyrophoric material will be acceptable. Page 5-7 stated that environmental impacts were assessed under the assumption that no pyrophoric material would be accepted.

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20. "Comments on Proposed Interim Waste Acceptance Criteria for Contact-Handled TRU Waste," a letter from D.E. Large to H.H. Irby, October 5, 1978.

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22. "An Interim Summary of Experimental Programs for the WIPP TRU Waste Acceptance Criteria," (Draft), January 1979.

23. U.S. Department of Energy. Project Overview. Waste Isolation Pilot Plant (WIPP-DOE-21), January 10, 1979.

TRANSPORTATION

(DEIS Chapter 6)

Major Conclusions

1) The equations used in the calculations of radiation doses from the normal transportation of the radioactive wastes have been derived by the EEG and the calculated doses were found to be in agreement with those presented in the DEIS. EEG has made a critical evaluation of the assumptions used in order to determine the validity of these dose estimates. These doses would represent small additions to the general population radiation exposure in comparison to other man-made radiation sources and natural background.

2) EEG has identified a number of additional dosage calculations to be performed and these are listed on pages 90-92.

3) Radiation exposures from deliberate acts of sabotage in the transportation of radioactive materials could be considerably higher than those from conventional traffic and rail accidents. The DEIS assumed there would not be a difference.

4) Some of the assumptions for accidents may not be sufficiently conservative. The following possibilities were not included in the DEIS calculations.

   a) A fire occurring during a rail accident involving contact handled transuranic wastes (CH-TRU).

   b) Leakage of remote handled transuranic wastes (RH-TRU) from a container following a rail accident.

   c) Ingestion of radioactive material following an airborne release.

5) Consideration should be given to shipping all the radioactive waste by rail wherever the calculations show that the potential radiation exposures to people would be reduced. This is consistent with the concept in radiological health that all unnecessary radiation exposure be avoided and exposures kept as low as reasonably achievable (ALARA). Consideration should also be given to restricting shipments in icy weather.

6) The maximum dose to people from atmospheric dispersion can be closer than the 0.5 miles calculated in the DEIS if the plume does not rise to a height of 20 meters at the time of release or if more unstable atmospheric conditions occur.

Radiation Doses from the Normal Transportation of Radioactive Wastes

The radionuclide inventories for truck and rail shipments of both CH-TRU and RH-TRU wastes were calculated by EEG and are shown in Tables 3 and 4. Derivations of the equations used in the calculation of radiation exposure from the normal transportation of radioactive wastes are shown in Appendix II.

Comparison of calculated doses in Table 7 and 8 show substantial agreement between the annual doses in the DEIS and those calculated by the EEG using NUREG-0170. These exposures represent small additions to normal background radiation and man-made radiation exposure.

The doses given in the DEIS are population doses. No information was presented on potential doses to individuals. Projections of maximum individual doses during normal transport should be provided.

TABLE 7

Calculated Radiation Doses from Normal Transportation of CH-TRU Waste

Origin and Mode	Annual Population Dose (man-rem)											
	Population surrounding route while moving			Passing Motorists			Population surrounding route while stopped			Crew		
	EIS	EEG	EIS/EEG*	EIS	EEG	EIS/EEG*	EIS	EEG	EIS/EEG*	EIS	EEG	EIS/EEG*
INEL(box) Truck	.096	.14	.68	.049	.044	1.1	.16	.16	1.0	2.4	2.6	.92
Rail	.34	.21	1.6				.007	.007	1.0	.01	.009	1.1
INEL(drum) Truck	.59	.88	.68	.31	.27	1.1	.99	.99	1.0	15	16	.93
Rail	2.1	1.3	1.7				.04	.04	1.0	.08	.05	1.6
Hanford Truck	.52	.75	.69	.27	.24	1.1				13	14	.92
Rail	1.6	1.0	1.6							.06	.04	1.5
LASL Truck	.15	.22	.68									
SRP Truck	.06	.09	.67									
Rail	.16	.10	1.6									

*Ratio of EIS Dose to EEG Dose.

TABLE 8

Calculated Radiation Doses from Normal Transportation of RH-TRU Waste

Origin and Mode	Annual Population Dose (man-rem)		
	Population surrounding route while moving		
	EIS	EEG	EIS/EEG*
INEL			
Truck	.29	.44	.66
Rail	.26	.37	.70
Hanford			
Truck	.16	.25	.67
Rail	.13	.19	.68

*Ratio of EIS Dose to EEG Dose.

Radiation Doses from Transportation Accidents

According to the DEIS, the barriers limiting the release of radioactivity to the environment following an accident result in only 0.004% of the radioactive material being respirable following a rail accident with CH-TRU wastes (6-23) and 0.015% following a truck accident (6-24). The only radioactive material that would be released in a rail accident involving RH-TRU waste would be 0.1% of the Cs-137 activity (6-25). The references from which the values of these barriers were selected in many instances do not show the basis on which they were derived. Empirical evidence needs to be developed under experimental conditions to confirm the reasonableness of many of these values.

Consolidated calculations for atmospheric dispersion coefficients (χ/Q) are to be found in Appendix V and are in reasonable agreement with those presented in the DEIS when the same assumptions are used.

If the plume in an airborne release does not rise to a height of 20 meters, then larger χ/Q values can be obtained and the maximum dose can occur at distances closer than 0.5 miles.

The following calculations were performed for a rail accident with spent fuel, using the assumptions shown in the DEIS. The results obtained were in substantive agreement with those in the DEIS.

Table 9

Dose to an Individual[a]

	Dose Commitment, (rem)		
Organ	DEIS	EEG	DEIS/EEG
Bone	1.2	1.2	1.0
Lung	0.3	0.2	1.5
Whole Body	1.1	0.9	1.2

[a]Maximum dose to an individual one-half mile from the accident. Details are shown in Appendix II.

Although the CH and RH-TRU doses to the general population from normal transportation are not considered to be of public health significance in comparison to other radiation sources in the environment, serious consideration should be given to shipping all the radioactive waste by rail, wherever the calculations show that the actual and potential radiation exposures will be reduced. This is consistent with the concept in radiological health that all unnecessary radiation exposure be avoided and exposures kept as low as reasonably achievable (ALARA).

The approximate total distance to be driven by the trucks will be: (600 shipments/year) x (1000 miles/shipment) x (30 years) = 18 million truck-miles. Calculations of injuries and accidents unrelated to radiation should be performed for rail and truck shipments. Consideration should also be given to restricting shipments in icy weather.

The following need to be clarified:

1) Who is responsible for accident response?

2) What response capability exists now and is planned for the future?

3) What state and local assistance is required?

4) Who equips, trains and funds the people?

5) Who pays for deployment, if required?

6) Who assumes financial risk for accidents?

Additional Dosage Estimates

There are a number of additional dosage estimates that need to be calculated:

1) Radiation exposure from acts of sabotage in the transportation of radioactive waste materials. The amounts of radioactivity released could be greater than those released in accidents. Are there any sabotage scenarios that could produce criticality? (Occupational, General Population)

2) Radiation exposure to emergency workers such as police and firemen following a transportation accident. (Occupational)

3) Exposure to a person stopped in an automobile next to a radioactive waste truck at a red light or in a traffic jam. (General Population)

4) Exposure from shipments of retrieved radioactive waste following the completion of the high level waste experiments. Containers could be bent, damaged or under pressure from gas generated by decomposed organic material. (Occupational, General Population)

5) Ingestion from contamination of a water supply or crops following an airborne release. (General Population)

6) Material resulting from decommissioning and dismantling of weapons production facilities in Hanford. While the DEIS assumes that none of the 5 to 95 million cubic feet of material will be shipped to WIPP, it notes that the WIPP will have the capacity to receive some of this TRU waste (2-22;2). (Occupational, General Population)

7) Consideration of a diffuse source of radioactivity rather than a point source in transportation calculations.

8) Population dose estimates were provided in man-rems. They do not identify the maximum dose to an individual.

Detailed Comments

6-4 Consideration should be given to limiting truck shipments during icy weather from sites such as LASL.

6-7;5 According to the DEIS (5-7), the shipping containers will not contain pyrophoric material. Can depleted uranium be pyrophoric under certain circumstances?

6-8 The interaction of the pyrophoric material permitted on page 5-4 and the hydrogenous material layered in the cask construction is not addressed in the transportation fire scenarios.

6-9 Will DOE or the carrier select the routes to be taken? Are there always two drivers or could the shipment be left unattended during stops?

6-12, 6-14 No information is provided on waste used in HLW experiments such as:

- radionuclides
- amount of radioactivity
- type of container
- form of material

What quantity, types, configuration of non-radioactive wastes are expected to be shipped as a contaminant in the radioactive waste?

6-17;2 The last line should read "from natural background" and the time period should be one year.

6-18;1 The numerical value (1.0 person-rem) does not agree with the value shown in Table 6-10, and unit "person-rem dose" is inappropriate. We are not able to confirm the figure of 0.02%.

6-18 Tables of doses include values for occupational and general population. They should be separated since different criteria apply to them.

6-23 What is the basis for assuming no ingestion of radioactivity from an airborne release following a transportation accident? Also, a body of water could be contaminated.

The assumptions for meteorology coupled with a release height of 20 meters for the aerosol result in a maximum dose occurring 0.5 miles downwind. Other assumptions can produce larger exposures at closer distances.

6-23;4 What is the basis for the assumption that contaminated food would immediately be taken out of distribution? Such administrative action has not always been possible or necessary.

6-23;5 The hypothetical rail accident involving CH-TRU waste calculates that only 0.004% of the radioactive material in the shipment would be airborne and respirable in a release. What is the basis for each of the factors in the calculation?

6-24;2 The 1978 Shefelbine reference is not adequate to justify the assumption that 10% of the waste is in powder form.

6-25, 6-26 Would radionuclides other than Kr-85 and Cs be volatilized in the fuel element accidents involving fire?

6-25;3 The hypothetical rail accident of a violent wreck with a fire for one hour involving RH-TRU waste assumes that only 0.1% of the Cs-137 would be released. No other radionuclide listed in Table E-3 on page E-4 would be released to the environment. What is the basis and rationale for these numerical values?

6-25;5 The hypothetical rail accident of a violent wreck with a fire for one hour involving spent fuel waste assumes that only 30% of Kr-85 and 0.1% of Cs-134/137 would be released. No other radionuclide listed in Table E-3 on page E-4 would be released to the environment. What is the basis for these statements?

6-26	The hypothetical accident involving the shipment of spent fuel only considers cesium and krypton being released; but the operational accident for spent fuel on 9-37;1 otes that tritium, Krypton-85, and Iodine-129 are easily released.
6-26, 6-23	It was assumed that there was no route of exposure except inhalation for the accident. Administrative control cannot be relied upon in this type of incident and other routes of exposure must be considered.
6-26	The assumptions that many nuclides including tritium, Iodine-129 (and others) are released from a damaged spent-fuel assembly in the WIPP above ground facility, are different than the assumptions discussed on 6-26 for a rail accident. These differences should be resolved.
6-26, Tables 6-14,6-15	We were able to reproduce the spent fuel bone dose of 4200 man-rem shown in Table 6-14. We were unable to reproduce the population dose commitments in Table 6-15.
6-27	Drums were considered in the scenarios involving transportation accidents but boxes were not. An explanation is needed. Surface contamination tests upon arrival at the repository are needed.
6-27, Table 6-3	Using the assumptions of the spent fuel transportation accident outlined in the DEIS, calculations by EEG were in general agreement with the dose to individuals given in Table 6-3.
6-27, 6-18	The various radiation exposures from the shipment by truck are greater than by rail (annual man-rem doses from transportation of CH-TRU, RH-TRU and spent fuel, pp. 6-18 and 6-19). The same is true for accidents (p. 6-28). Consideration should be given to transporting all the

radioactive wastes by rail which would reduce the expected and potential radiation exposure in accordance with the ALARA (as low as reasonably achievable) concept.

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SITE CHARACTERIZATION

(DEIS Chapter 7)

Major Conclusions

The EEG has evaluated the Geological Characterization Report (GCR) Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico (SAND 78-1596), December, 1978, which is the source of most of the geological and hydrological data in the DEIS; the complete review is in Appendix III. Conclusions and summary statements in the DEIS, as well as in the GCR, did not take into account certain important problems related to geologic and hydrologic factors. The following is a summary of EEG's major concerns:

1) Seven wells within nine miles of the periphery of the WIPP site have encountered brine reservoirs under artesian pressure. The origin, evolution, frequency of occurrence and size of these high pressure brine reservoirs were not adequately addressed in either the DEIS or the GCR.

2) There is at least one confirmed occurrence of a "chimney... with clay cemented brecciated rock", commonly called a breccia pipe, approximately seven miles from the WIPP site (Mississippi Chemical Corporation potash mine). Several other possible breccia pipes are under various stages of investigation. The origin, evolution and frequency of occurrence of these features must be better understood. They may be localized deep dissolution features which originate in the lower portion of the evaporites and migrate upward. Such localized dissolution features could now exist or develop later beneath the proposed site.

3) The DEIS and the GCR assumed that surface or shallow dissolution is the dominant process of salt removal from the evaporite beds. However, deep dissolution may be causing a preferential removal of the salt horizon which is proposed for the repository.

4) The lithology of the repository horizons is described on page 7-24 of the DEIS and parts of the lithologic log of the ERDA-9 hole are shown in Figures 1 and 2 of this section (from Fig. 4.3-3B of the GCR). These sections of the logs describe the lithology of the repository horizons for CH and RH zones as shown on Figure 4.3-3A of the GCR. The logs show the presence of clay, anhydrite and polyhalite in addition to halite, as the constituents of both repository horizons. The presence of these impurities should be taken into account in evaluating physical, hydrological, thermal and strength characteristics of "rock salt" from the repository horizons.

5) The values of hydrologic parameters (e.g. hydraulic conductivity, distribution coefficients, and effective porosity) can vary over a large range and the DEIS provides such information. In addition, potentiometric surface maps, hydraulic gradients and flow paths have been constructed on the basis of limited data. In some cases (e.g. hydraulic conductivity) the DEIS gives a range of measured values. Ranges should be assessed in all cases, particularly for distribution coefficients. The distribution coefficient (K_d), which affects the speed with which a given radionuclide is transported in groundwater, can be affected by rock type, extent of fracture permeability, water quality characteristics, competing ion effects, and the chemical form of the radionuclide of interest. Values obtained for a given nuclide in a given rock formation have been observed to vary by several orders of magnitude.

6) More information should be given in the final EIS on surface water hydrology in the region surrounding the WIPP site.

Items 1, 2 and 3 have been discussed in detail in Appendix III (EEG's Review Comments on the GCR). No new information on these items is presented in the DEIS. The DEIS concluded that there was no evidence of brine reservoirs or ongoing deep dissolution at the WIPP site. EEG questions the basis of these conclusions in the Review of the GCR.

Lithology of Proposed Emplacement Horizons

According to the DEIS (7-21;4), the repository horizons were selected due to the presence of relatively pure salt layers. When the NAS-NRC Committee (Ref. 2) recommended salt as the most likely geologic medium for radioactive waste disposal, it placed strong emphasis on the "purity" of a bedded salt formation so that its thermal and physical properties could be predicted. The presence of impurities can affect the properties of bedded salt. Examples are:

1) Argillaceous (clayey) layers in bedded salt may provide conduits for the migration of water to and from the repository. While some of the impurities found in bedded salt have lower permeabilities than halite, a path for migration of water may be created along the contact between two layers of differing lithology.

2) A subgroup of the Interagency Review Group on Nuclear Waste Management commented on salt formations: "The hydrologic regimes in which anhydrite occurs are characterized by flows along bedded planes, but locally channeling (cavern formation) occurs in anhydrite similar to that in limestone and gypsum" (Ref. 1).

3) The chemical reactions which may take place in the vicinity of high level waste, accelerated by elevated temperatures and high pressures become more complex and unpredictable when the host rock is heterogeneous.

4) Because thermal conductivities of clays and polyhalite are very different from that of halite, the dissipation of heat resulting from the high level wastes will not be uniform around the waste. This may result in cracking, parting of seams and uneven concentration of moisture.

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These potential problems are not discussed in the DEIS, although the lithology of the repository horizons is presented as follows: "The basic mineral of both repository horizons is halite. Also present are anhydrite, polyhalite, quartz and a suite of clay minerals (illite, chlorite, talc, serpentine, and expendable clays). Halite beds within the emplacement horizons are about 97% halite. Most of the remainder is anhydrite" (7-24;5). Note that the last line quoted refers to 97% halite in halite beds and not in the total repository horizon. The lithologic log for the CH repository horizons (Figure 1) shows anhydrite beds which are 0.2, 0.7 and 0.9 feet thick and most halite layers are "argillic and polyhalitic". The RH repository rocks are mostly "anhydritic and argillic halite" (Figure 2). The bottom 20 feet of the RH zone is primarily "dense anhydrite".

Unidentified Structures

A lamprophyre dike or a series of en-echelon dikes were reported within six miles of the periphery of the WIPP site. If associated igneous bodies underlie the WIPP site, they could affect the integrity of the salt beds. The cross-section on Figure 4.4-5 in the GCR shows faults in the Castile directly below the WIPP site and the contour map on Figure 4.4-6 shows confined faults on top of the Castile. These should be explained.

Surface Water Hydrology

There is not enough information given on surface water hydrology in the region around the site to enable one to adequately evaluate the effect of the site on local water resources. Since surface runoff is a potential pathway to spread contamination, it needs to be evaluated in much more detail. This evaluation should include runoff from floods with a 100-year and 1,000-year return period. The fate of this runoff water after it reaches Nash Draw (or elsewhere) needs to be evaluated. A description of existing and planned water resource development in the area (including irrigation withdrawal, canals, irrigated lands, and return flows) would make it possible to evaluate the effect of the project on present and future surface water resources. Also, it will be necessary to describe water use downstream from Malaga Bend into Texas in order to evaluate the transport and concentration of radionuclides released to the Pecos River from the long term breach scenarios.

Ground Water Hydrology

The ground water data was largely obtained on the Rustler and deeper aquifers and was used to evalute the role of these aquifers in transporting radionuclides away from the site. Another pathway of exposure would be from wells drilled into the Rustler, Santa Rosa Sandstone or other shallow lenses near the site, and used for individual water supplies, gardens or stock watering. More information is needed on present and potential well water use, quantities of water available, effect of surface recharge, and potential for the well water to be contaminated by the Bell Canyon or Rustler aquifers.

Climatic Changes

Based on the evidence presented on page H-62 and H-63 of the DEIS, the present interglacial period may last another 4,000-5,000 years followed by a cooling trend culminating in another glacial age. In that case, the climate near the WIPP site may be significantly cooler and wetter in 10,000-15,000 years. EEG recommends that long range modeling take into account plausible future climatic changes in hydrological regime.

Figure 1

From GCR, Figure 4.3-3B
CH repository horizon from 2074 to 2176 feet

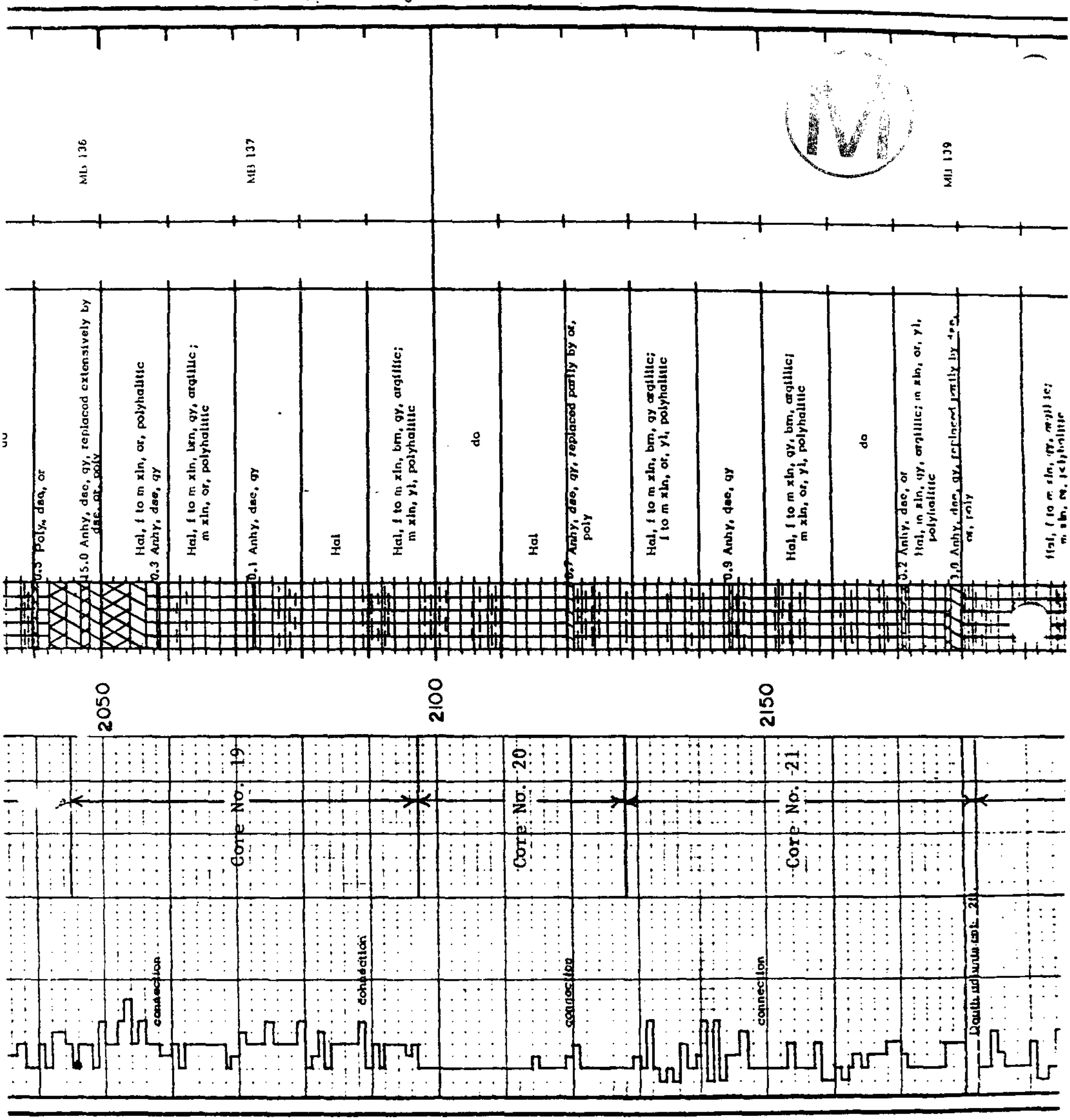
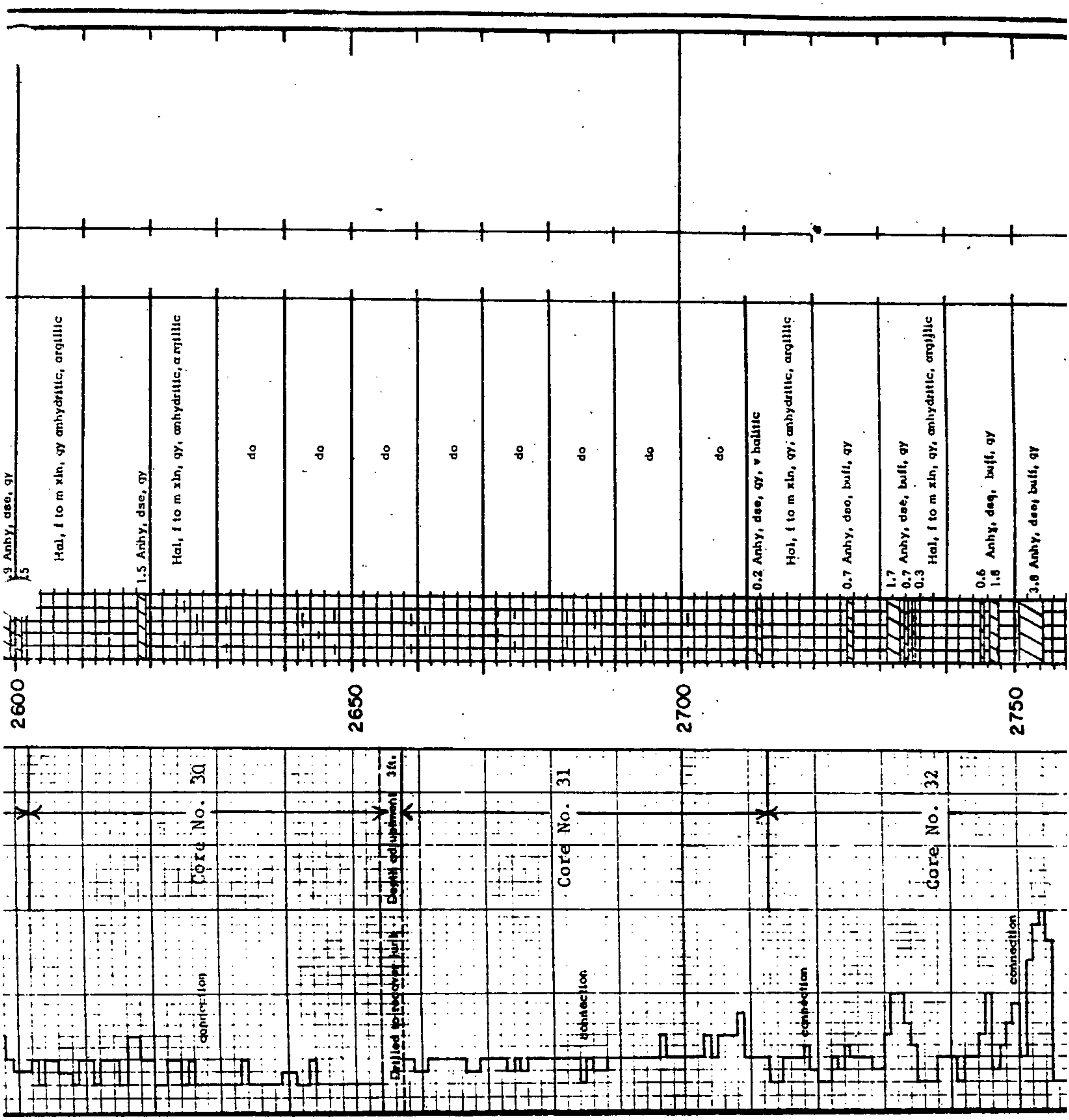


Figure 2

From GCR, Figure 4.3-3B
RH repository horizon from 2620 to 2730 feet



7-17;2 Section 17, T22S, R31E is in control Zone III.

7-26;7 What is a "depositional-growth fault" and what is its significance?

7-30;9 What is the status of the investigation of these faults?

7-47;3 It should be "approximately 3300 square miles" instead of "1 million sq. mi." (See Fig. 7-17).

7-65;1 A map and a cross-section showing locations of brine pockets encountered and their stratigraphic locations should be included in the final EIS.

7-65;4 Why has the model assumed a flow path in the Rustler directly to Malaga Bend to the Pecos River. (See Fig. K-5). Couldn't the water seep out in Nash Draw since the top of the Salado is exposed in Nash Draw?

7-69;1 Why is it assumed that the water will come out at Malaga Bend? Why not Laguna Grande de la Sal? What is the origin of the water in Laguna Grande de la Sal?

7-72;6 What is the basis for the assumption of the origin of water for Laguna Plata and Laguna Gatuna?

7-74;1 "Weaver Pipe" could be an example of a breccia pipe which has no surface expression. Could there be such breccia pipes at the WIPP site which have no surface expression?

7-75;3 Late Pleistocene (Wisconsin) was from 40,000 years to 15,000 years B.P. Such climate changes can occur in the future as well.

7-75;7 The GCR (August 1978) referred to current and future studies to evaluate deep dissolution (6-46;1). The EIS (April 1979) concluded "In any case, deep dissolution does not occur near the site". Have these studies been conclud

References

1. Interagency Review Group on Nuclear Waste Management, Subgroup for Alternative Technology Strategies. "Isolation of Radioactive Waste in Geologic Repositories: Status of Scientific and Technological Knowledge," Subgroup Report on Alternative Technology Strategies for the Isolation of Nuclear Waste (TID-28818 Draft), Appendix A, October 1978.

2. National Academy of Sciences-National Research Council. Committee on Waste Disposal. The Disposal of Radioactive Waste on Land (Publication 519), April 1957.

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OPERATION OF THE REPOSITORY
(DEIS Chapter 8)

Major Conclusions

1) Present plans would permit public access to Zones II, III and IV during operations. Also, there is private land 2.8 miles downwind (northwest) of the center of the site where building could occur. Consideration should be given to the radiological air quality and noise environments at these locations in addition to those at the James Ranch.

2) Calculations of radionuclide releases from routine operations agree with those in the DEIS when the same assumptions are used. However, several assumptions used in estimating the amount of radioactivity released are unverified.

3) Radon emissions from natural radioactivity in the repository have not been measured in soil, mined rock, and the proposed waste horizons. Radon should be measured to see if levels might be high enough to be a problem for underground workers and a source of radiation exposure to the public from the excavated salt.

4) Other than radon, the present radiological monitoring program appears satisfactory for the next several years.

5) From the limited information provided in the DEIS on the high level waste experimental program, 9-90 million curies of radioactivity may be involved in the experiments with full-size canisters. In this case, the experimental waste could be the most significant factor in the analysis of potential radiation exposures during the operational phase of the repository. This was not considered in the DEIS calculation of radiation doses.

6) All high level waste used in experiments is scheduled to be retrieved and all TRU waste and spent fuel elements are to be in a

retrievable condition. The DEIS does not address such important items as the criteria for retrieval, the hazards to workers, and hazards to the public. More information is needed before the feasibility of retrievability can be evaluated.

7) The options of decommissioning are adequately covered for the present. The advantage and feasibility of control for periods greater than 100 years should be included in this evaluation.

8) From the material presented in the DEIS, one could conclude that Ambient Air Quality Standards may be violated in Zones II, III, and IV, unless certain measures are taken to insure that the standards are met.

9) There will be some degradation of the noise environment due to repository operations and the traffic related to it. More attention needs to be given to mitigating noise.

10) Due to WIPP-induced population growth in surrounding communities, there will be some impact on water quality, water supply, and solid and hazardous waste conditions. The EEG agrees with the DEIS conclusion that, with proper planning, the existing systems are adequate to absorb the increase.

The Site and Its Environs

The entire area of the site and much of the land immediately outside of Zone IV are owned by the Federal or State government. The James Ranch, located 3 miles south-southwest of the site center, is privately owned and occupied and was used to calculate the maximum individual exposures to radioactivity and noise in the DEIS.

However, it may not be conservative to assume that this is the location of the maximum exposed individual, for the following reasons:

1) Private land is located just outside the northwest boundary, 2.8 miles downwind from the site center. From the atmospheric

dispersion coefficients given in Table H-36, calculations of concentrations of airborne effluents would be about 5 times higher than at James Ranch.

2) Plans indicate public access to parts of the site for ranching, recreation and resource extraction. Consequently, people may be as close as one-half mile from the site center.

Analysis of the effects of repository operation on individuals in the population should consider these locations where people will be permitted to live or visit as well as where they live now.

Normal Radiation Releases

Radon Emissions

Radon, a naturally occurring radioactive noble gas is contained in air exhausted from underground mines. Because radon concentrations could be high enough to be a hazard to some underground workers and could result in measurable off-site exposures, the concentrations should be measured.

The DEIS recognized that radon will be present in exhaust air but did not consider the radon from the mined rock storage pile on the surface. Radon concentrations in the DEIS were based on concentrations reported in the Nuclear Regulatory Commission's Final Generic Impact Statement on Mixed Oxide Fuels (GESMO).

Appendix IV contains a more detailed discussion of the possible radon exposure and calculates dosages to the bronchial epithelium as well as the pulmonary lung dose at 0.5 miles, 2.8 miles (NW) and 3.0 miles (SSW). These calculated doses (which are average, rather than upper-bound limits) suggest that potential radon exposures are high enough to require direct measurement at the site to determine actual concentrations.

Operational Releases of Radioactivity

Starting with the assumptions used in Chapter 8, the radiation releases to the environment were calculated by EEG and they agreed with the results listed in the DEIS (Table 8-6). Agreement was also obtained with the quantity of radioactivity collected on HEPA filters reported in Table 8-7.

However, one area of potential disagreement relates to the calculation of releases of radioactivity from underground storage of contaminated containers. The EEG calculations assumed a 4-year accumulation of boxes and drums that were releasing 1% per year of their remaining surface contamination. The EEG calculated release was approximately four times the quantity of released TRU wastes listed in Table 8-6. Was the calculation in the DEIS based on one year's accumulation of containers?

It is not clear from the description in the DEIS what becomes of spilled material from damaged drums and boxes. The DEIS, assumed that 1.47 curies of TRU waste would be spilled per year and 0.1% would become airborne. The remainder is unaccounted for. The quantity of TRU wastes on ion exchange resins reported in Table 8-7 was only 0.04 curies per year.

Assumptions for Release

A number of factors are involved in the chain of events that must occur before radioactivity is released at the site. Most of the factors that are used to calculate the release of the CH-TRU waste are assumed (surface contamination, non-fixed surface contamination, number of boxes and drums damaged, percent of the surface area that is cracked). Is there a data base for the surface contaminated or damaged drums and boxes that have been packaged, shipped and stored over the years? It is difficult to determine if the assumptions are conservative based on the following information presented in the DEIS:

1) The DEIS assumed that one spent fuel assembly and its canister are damaged in a four-year period (8-32:1) as described in the NRC's Reactor Safety Study, 1975. A more recent report reviewing the history of spent fuel assembly accidents by Johnson (Ref. 1), presented data which suggest that one or more accidents per year might be more realistic.

2) All calculations assumed an average percentage of powder and average radionuclide concentration in each drum. Calculations should also be made using boxes, which contain more waste than drums and have higher levels of radioactivity.

3) Specific data are absent on design, testing and experience with remote handled TRU waste casks and canisters.

Due to the ranges of possible values of factors involved in a potential release of radioactivity, a sensitivity analyses should be performed to determine their effect on potential doses.

High Level Waste Experiments

The DEIS did not state the amount and types of radionuclides that will be brought into the repository for these experiments. Twenty to 200 bare waste experiments are to be conducted (8-47). The number of full sized canisters emplaced was estimated to be between 20 and 200 (8-48), but "...these numbers, like the estimates of bare waste reaction chambers may change by as much as a factor of 2" (8-48;2). "The source of the waste to be used in these experiments is not as yet defined" (2-24;3). The possibilities of using laboratory produced commercial reactor wastes, aged defense HLW or wastes fortified with Strontium-90 or Cesium-137 are then discussed.

Even with these few details it is apparent that the quantities of radioactivity brought into the repository in the experimental program could be large if one assumes that the full sized canisters described on page 8-48 are the same as the high level waste canisters described for commercial high level waste in Table E-4 on page E-5. The estimated amount of radioactivity in a high level waste canister is about 460,000 curies (Table E-4) which would give a total of 9-92 million curies from the canisters alone.

Retrievability

Present plans are to retrieve all high level wastes (HLW) experiments after completion and to have the ability to retrieve contact-handled and remote-handled TRU wastes and spent fuel. The periods of retrievability are apparently 10 years for TRU wastes and 20 years for spent fuel (the times are reversed in the statements on 2-18;7 and 2-19;1). Container life for TRU wastes is designed for 10 years so it can be retrieved (5-4). A possible need for repackaging retrieved containers is recognized (9-52;5) and apparently it is planned to do this underground. Another reference (9-49;2) stated that accidents during retrieval are expected to be no worse than could occur during emplacement.

The DEIS did not provide guidance on the criteria for retrieval of TRU and spent fuel wastes. Details were not provided on how retrieval would be conducted and on the contamination and exposure problems that are expected. The retrieved containers could be damaged during emplacement, storage, and retrieval. Also, chemical action of the salt environment for periods of 10 or 20 years could produce deterioration in the integrity of the canisters. Retrieval of high level waste experiments will be further complicated by bare wastes and contaminated salt.

While retrieval is possible, the removal of radioactive waste from the repository will involve more problems than emplacement. The extent of this difference has not been adequately addressed in the DEIS and should be expanded upon in either the final EIS or PSAR (Preliminary Safety Analysis Report).

EEG believes that retrieval will be a complex operation with the potential for significant radiation exposure to workers and for possible releases to the environment. It is necessary for retrievability to be evaluated in detail for procedures, logistics, and criteria before conclusions can be drawn about its feasibility.

Decommissioning

The discussion on decommissioning of the WIPP site repository (8-53 to 8-57) covers various alternatives and contains adequate detail at this time. Any of the alternatives listed on page 8-54 should be acceptable if carried out properly. There are two issues that have the potential to increase the probability of long-term problems:

1) administrative control over the site; and

2) borehole plugging.

Possible industrial use of the site is indicated (8-53;3). The land area is expected to be returned to its natural state in several decades unless the mothballing option is taken (11-1). Also, Scenario 5 (9-124) assumes administrative control is lost after 100 years and unregulated drilling can occur. This scenario results in a high dose to well drillers. A detailed evaluation should be made of the degree of control needed at the site after decommissioning and should include:

1) the possibility of control for periods longer than 100 years;

2) the long-term controls over shallow-well drilling in Zone III and resource extraction in Zone IV; and

3) details of the long-term radiological monitoring program.

Radiological Monitoring Program

Pages J-24 to J-41 of Appendix J of the DEIS describe the present radiological monitoring program, the tentative pre-operational monitoring program, the proposed operational monitoring program, and the post-operational monitoring program.

While it is realized that these future programs are necessarily tentative, the following comments are offered.

Present Program

This program appears adequate for several years, with one exception. Measurements of radon and its short-lived daughter product concentrations are needed from the soil, from mined rock, and in the underground mine.

Radon monitoring should be done as soon as possible because the presence of high levels could influence the design of underground ventilation.

It will be necessary to obtain sufficient samples and analyses before operation to insure that the variations in the background (naturally occuring and from weapons testing fallout) levels of actinides, tritium, Carbon-14 and fission products are adequately known. These values are needed in order to be able to detect contamination from site operations.

Pre-operational Program

It is noted that no air particulate station is planned for Hobbs. Since it is a major population center, with a calculated long-term χ/Q only 10% lower than at Eunice, this omission should be reconsidered. Also, the three days per week of sampling should be randomized in order to measure levels on work days, and non-work days.

Consideration should also be given to monitoring radioactivity in rainfall and runoff (when it occurs) at the site as well as surface water and biota in Nash Draw. Several additional shallow wells, whether presently used for human consumption or not, should also be sampled on an annual or biennial basis.

In several cases in Table J-4 (Appendix J), the types of analyses are not specific enough. Gross analysis is useful as a screening mechanism for detecting significant contamination. However, it usually will not detect trace migration of radionuclides. All media being sampled should have periodic analyses of the actinides, tritium, Carbon-14 and long-lived fission products. Consideration should be given to developing and maintaining a capability of measuring Iodine-129 in case of accidents (J-27;2).

Operational Monitoring Program

The same considerations expressed for the pre-operational program are applicable for the operational program. No further comments are offered at this time.

Post-operational Program.

The outline of a post-operational program presented in Table J-7 appears reasonable. However, the borehole radionuclide analyses should be for specific radionuclides rather than gross alpha and beta for the reasons discussed above.

Non-Radiological Hazards

Air Quality

The EEG analyzed the data presented in the DEIS to determine if a potential exists to exceed the Ambient Air Quality Standards at the Reference Site. It was concluded that standards for several of the criteria pollutants could be violated during construction and operation of the WIPP. This conclusion, which differs from that implied in the DEIS, is due to the following factors:

1) When calculating ambient concentrations, it is appropriate to consider locations where the public has access rather than county-wide averages. The distance from the WIPP site may be less than 0.5 miles.

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2) Appropriate allowance must be made for the number of shifts that will operate at the site. There is a discrepancy in the DEIS. Table 8-9 assumes only one shift operation, whereas page 2-19 and 8-27 mention three-shift operation to calculate radiation releases.

3) For three shift, five-day per week operation, the nitrogen oxide and sulfur dioxide concentrations at 0.5 miles were calculated to exceed the annual average concentrations permitted by the State of New Mexico if the χ/Q values in Table H-36 are used. The annual nitrogen dioxide Standard would also be exceeded during construction.

4) During construction, the fugitive dust emissions shown on page 9-8 would exceed the permissible 24-hour level at a distance of two miles when the background concentration of approximately 30 $\mu g/m^3$ is added.

5) Particulate emissions during the operating phase are dominated by releases from the salt pile and from the salt drying unit. The magnitude of salt pile emissions has a range of uncertainty. Experience with the potash industry suggests that the pile emissions will be negligible except for the periods when salt is being reclaimed for drying and use as backfill. Emissions from the salt drying unit (other than from combustion) were not estimated in the DEIS. This source has been found to be significant in the potash industry.

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Although the EEG analysis concludes that construction and operation of the site will violate the New Mexico Ambient Air Quality Standards, experience with the potash industry suggests that it should be possible to meet these standards with proper engineering controls, elevated releases, and other mitigating measures.

A more detailed analysis of the air quality aspects needs to be performed. This analysis should include one-hour and three-hour analyses as well as 24-hour and annual values. A more precise estimate of emissions from the salt pile and dryer is needed. The analysis should consider such factors as elevated releases, non-point source emissions, cloud depletion, control technology, and other mitigating measures that will be taken. The final EIS should contain the results of this re-evaluation and indicate the measures that will be provided to insure that Ambient Air Quality Standards are not exceeded.

<u>Noise</u>

The DEIS makes predictions on the noise levels from construction and operation at the WIPP site. For the most part these projections appear reasonable. However, the conclusions emphasize the fact that ambient levels will still be well below various standards and suggest there is no problem. Actually, the noise environment will be degraded both during the construction and operating phase and some residents, off-site and near transportation arteries, and users of Zones II, III and IV will be exposed to more noise than at present. Furthermore, while the DEIS makes reference to measures that could minimize noise exposure, no commitments are made to implement specific measures.

Several items in the DEIS requiring clarifications are:

1) Traffic noise impact from WIPP-related commuter and truck traffic cannot be estimated without knowing the projected traffic volume (of both trucks and autos) with and without the project. This needs to include the effect of night-time traffic which will be present during three-shift operation and construction.

2) The assumption of a peak dBA of 84 at 50 feet from diesel trucks is optimistic since the Federal standard for Inter-State trucks permits 90 dBA and many intrastate trucks cannot meet this standard.

3) References on pages 9-4 and 9-27 imply that noise levels of about 45 dBA will be inaudible at the James Ranch. Actually, if the ambient is 26-28 dBA, sound pressure levels of less than 35 dBA will be clearly audible.

4) It is unclear from the description of the mined-rock storage just what noise sources are included and how they might vary with time.

5) Operational noise near the site would be expected to alter the present mix of wildlife species. The conclusion that this would be minor and insignificant should be documented.

The final EIS should include more precise analysis of just how much the noise level is expected to rise from site construction and operation. Also, consideration should be given to mitigating measures such as:

1) busing of workers to drastically reduce auto traffic;

2) muffling of construction equipment and use of low noise products where available;

3) a requirement that all trucks meet the Federal noise regulations required for Inter-State Commerce; and

4) housing of various equipment and operations.

Water Quality

Several aspects of the WIPP site operation may have an effect on water quality. Primary impacts (on site) could occur from:

1) the sewage plant effluent and sludge;

2) reclaimed water use on-site;

3) runoff and leaching from the salt pile; and

4) general site runoff.

Secondary impacts could occur from the WIPP induced population growth in Eddy and Lea counties. The most likely problem is from septic tank contamination in unsewered areas and is recognized in the DEIS (9-91;2). Both primary and secondary impacts appear to be manageable with proper planning.

Solid and Hazardous Waste Control

Construction, operation and decommissioning of the WIPP site will result in the generation of substantial quantities of solid waste and unestimated amounts of non-radiological hazardous wastes. There will also be some secondary impacts in Carlsbad and Hobbs due to the WIPP induced population growth.

It is not possible to evaluate the hazardous waste situation from the limited information in the DEIS. Under present New Mexico regulations, it is permissible to dispose of hazardous wastes on the site without a permit where they are generated. However, Federal regulations are expected to be in effect prior to the beginning of site construction and they will probably require regulation whether disposal is on or off-site. The types and quantities of hazardous waste expected to be generated on-site need to be determined more precisely.

Metals and discarded equipment are scheduled to be recycled with a commercial salvage company (8-35;6). An appropriate control system should be established to insure that this recycling does not lead to off-site radiological contamination.

Water Supply

Since the WIPP plant operators propose to purchase its water supply from the City of Carlsbad, the State of New Mexico would be involved in regulatory procedures only indirectly. In addition, the project could be exempted from State regulations under Part I., Section 102, Water Supply Regulations.

A portion of the population growth could take place outside of incorporated city limits. Water supplies for these families would probably come from individual wells. Local and regional governmental agencies should be aware of potential water quality problems related to the increased number of wells and their proximity to septic systems since the State Environmental Improvement Division does not regulate individual water supply systems.

8-15;3 No mention is made in the DEIS of the management or organization of the health physics program. EEG assumes this will be covered in the PSAR.

8-17;5 A contamination check should be made on empty CH waste containers before they are "reloaded onto vehicles leaving the plant".

8-23 Consideration should be given to isolating the High Level Waste experimental area from the remainder of the mine in case of accident. It is unclear how the isolation of the air flow will be accomplished from the description on pages 8-20, 8-22 and 8-23.

8-28;1 The DEIS stated that 10% of surface activity is released and becomes airborne. What data is this based on?

8-28;2 The DEIS states that 30 drums and five boxes per year may be received in a damaged condition. This is .019% of the drums and 0.21% of the boxes. Are these numbers predicated on actual experience?

8-28;3 The DEIS states that cracks generated by dropping a 55-gallon drum will be less than 1% of the total area of the drum surface. Is there a reference for this assumption?

8-28;4 The assumptions of an airborne fraction of 0.00023 per hour and a decontamination factor of 10^6 are referenced and the airborne fraction is taken from an experiment utilizing a road-like surface. Both larger and smaller fractions were observed from other experiments by the authors (Mishima and Schwendiman, 1973).

8-31;4 The DEIS assumed that one canister per year will be cracked, the crack is 1% of the area, and that the release is proportional to the crack. Is there a reference for these assumptions? Mishima and Schwendiman in BNWL-1732, 1973 do not cover these items.

8-32;1 It is assumed that one spent fuel assembly and its canister are damaged in a four-year period. From the data presented in a review of the history of spent fuel assembly accidents (ref. 1) it appears the assumed rate of one accident per 1000 assemblies handled might be too low.

The NRC's Draft Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel (ref. 2) stated that both NFS (Nuclear Fuel Service) and AGNS (Allied-General Nuclear Services) included in their safety analysis reports on underwater fuel drop accidents in which it is assumed that all of the fuel pins in a fuel assembly were ruptured. It appears that when the DEIS assumptions on released fractions from fuel assemblies are compared to other references (ref. 1 and 2) the DEIS assumptions might be too low.

8-31;5 Since experiments with high level waste are planned with bare sources, this paragraph should be clarified.

8-32;1 The assumptions that many nuclides including H-3, Kr-85, I-129, tellurium and selenium are released from the damaged spent fuel are much different from the assumptions discussed on page 6-26 for a rail accident. These differences should be resolved or the rationale explained.

In addition, C-14 has been consistently omitted from all inventories, releases and dose calculations pertaining to spent fuel. The DOE in its Draft Environmental Impact Statement Management of Commercially Generated

Radioactive Waste (Ref. 3), consistently lists C-14 in its inventory (as on page 2.1.16) and outlines the calculations for C-14 (in Appendix D).

8-34;1,3 — The DEIS stated that there are 200 HEPA filters in "parallel". This differs with statements made in 8-26;4 where it says there are two stages of filters in series. If the statement on page 8-34 is correct, then there is only a decontamination factor of 10^3 rather than the 10^6 used throughout the report.

8-34 Table 8-7 — The total radioactivity per drum in Table 8-7 totals 6.7-4 Ci, not 5.7-4.

8-36;3 — How effective will the protective action of spraying the salt pile with water be in containing the contents?

8-37;2 — 265 $\mu g/m^3$.

8-38 Table 8-9 — While the table shows the total emissions of pollutants at the site, it would be helpful to show the maximum expected emission rates and when they occur.

8-43;3 — Laboratory decontamination agents with EDTA may be present in the TRU waste. If EDTA is present, it may drastically alter the migration of actinides through the soil and effectively alter the K_d values in the long range release scenarios.

8-47;4 — Are the "reaction chambers" merely drilled holes in the salt of the mine? If so, how does one collect "gaseous samples" without having such samples contaminated by the ambient air?

8-49;7 If the canistered spent fuel assembly is placed inside a sleeved hole, can this assembly do anything more than produce a temperature gradient outside the sleeve? If not, why use a spent fuel assembly?

8-49;5 There is no reference or backup information given to substantiate the statement "Sufficient air quantities will be provided to support the mining and storage operations as well as to remove fission gases that might escape from unsealed storage rooms". Uranium mining experience indicated adequate ventilation can be difficult to provide.

8-51 The plans for retrieval have not addressed the problem of radiation protection.

8-52;2 Have the contamination limits been established, and what is "an acceptable level"? The potential contamination problem for "retrieval after backfilling" could be extremely troublesome. More information on personnel exposure control and contamination limits should be provided. Where will the radioactive waste and contaminated salt be taken?

8-55;3 The DEIS stated that the site might be used after decommissioning as an industrial site. No scenarios cover this possibility of future use.

8-57;1 The DEIS stated that the results obtained so far give the DOE confidence that newly developed plugging methods will be available in decommissioning the repository. What are the references?

References

1. Johnson, A.B., Jr. Behavior of Spent Nuclear Fuel in Water Pool Storage (BNWL-2256), 1977.

2. U.S. Nuclear Regulatory Commission. Draft Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel (NUREG-0404), March 1978.

3. U.S. Department of Energy. Management of Commer ally Generated Radioactive Waste (DOE/EIS-0046D), Draft Environmental Impact Statement, April 1979.

4. U.S. Energy Research and Development Administration. Alternatives for Managing Wastes from Reactors and Post-Fission Operations in the LWR Fuel Cycle (ERDA-76-43), May 1976.

5. Bell, M.J. ORIGEN - The ORNL Isotope Generation and Depletion Code (ORNL-4628), 1973.

6. Oak Ridge National Laboratory. Radiation Shielding Information Center. ORIGEN. Isotope Generation and Depletion Code - Matrix Exponential Method (CCC-127), October 1978.

7. Industridepartment Energikommissionen. Disposal of High Active Nuclear Fuel Waste. A Critical Review of the Nuclear Fuel Safety (KBS) Project on Final Disposal of Vitrified High Active Fuel Wastes.

RADIOLOGICAL IMPACTS OF THE REPOSITORY
(DEIS Chapter 9)

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Major Conclusions

Operational Releases

1) Atmospheric dispersion coefficients were calculated by EEG, checked with those listed in the DEIS and found to be in agreement. However, the DEIS did not use a consistent approach in calculating those coefficients for operational releases of radioactivity, air quality emissions and transportation accidents.

2) EEG obtained close agreement with the DEIS inhalation dose calculations from both normal and accidental releases to an individual at the James Ranch. Consideration should be given to inhalation doses received by transient people in Zones II, III and IV and to potential residents near the northwest site boundary.

3) The detailed assumptions used in evaluating accident scenarios may underestimate the amounts of radioactivity that could be released.

4) An accident scenario involving a methane gas pocket should be considered.

5) The assumption that contaminated food will be taken out of distribution has not always been possible or necessary.

6) The Chapter 9 assumption that exhaust air from underground waste handling and storage areas passes through HEPA filters is inconsistent with statements in Chapter 8. Since the absence of filters can result in a substantial increase in doses from particulate radioactivity, it is important to clarify this point.

7) Occupational radiation exposure has not been evaluated by EEG because of lack of necessary data in the DEIS. More information is needed on waste operations, the environmental control systems, and the health physics program. It is anticipated that this information will be provided in the Preliminary Safety Analysis Report.

Long Term Releases

1) EEG has identified a number of repository breach scenarios which also should be considered and evaluated in the final DEIS:

   a) well water becomes contaminated and is used for irrigation or stock watering;

   b) gas, generated by organic decomposition of the waste, acts as a driving mechanism in bringing waste to the surface;

   c) a connection develops between the repository, a high pressure brine reservoir and the surface;

   d) solution mining for salt takes place.

2) EEG has checked many of the DEIS dose calculations for the long term release scenarios considered, and the EEG and DEIS results are in agreement. Since the hydrologic parameters on which these dose estimates are based can vary by several orders of magnitude, the effect of parameter variation on dose estimates should be evaluated.

3) Unacceptably high radiation doses could occur to well drillers from a scenario 5 type incident. Control measures should be considered to prevent such an event.

Operational Releases

Atmospheric Dispersion Coefficients

Several key χ/Q values were calculated by a simplified hand calculation (see Appendix V for details) and compared with those used in the DEIS. The EEG model differed somewhat from the MESODIF Code used in the DEIS in not allowing the plume to be blown back over the source to contribute on a "second pass". The values calculated for the long term average χ/Q were lower than those used in the DEIS by factors of 3.3 to 4.4 (Table H-36). Lower values would be expected in the prevailing downwind direction from the model difference, although the magnitude of the difference cannot be estimated from the data available. Values calculated for the one-hour frequency $(\chi/Q)_{5\%}$ and $(\chi/Q)_{50\%}$ (H-Annex 1, Table 21) varied from 1.0-4.1 times those in the DEIS with agreement being best at 0.5 miles. EEG concluded that the short-term and long-term χ/Q values used for the site are reasonable.

The DEIS analysis did not use atmospheric dispersion coefficients to compute annual concentrations for non-radiological air pollutants other than a 24-hour value for particulates. In this case, another equation was used and an effective $(\chi/Q)_{24\ hrs.}$ of 2.1×10^{-6} s/m^3 was obtained. This is to be compared to a $(\chi/Q)_{50\%}$ of about 15×10^{-6} s/m^3 (H-Annex 1, Table 21) and an annual average of 5.9×10^{-6} s/m^3 (in downwind maximum sector from Table H-36). This calculation is inconsistent with that for site radionuclide releases.

Slightly different dispersion coefficients were used in the DEIS to compute doses from transportation accidents and an elevated release was assumed. This assumption produces lower dose estimates and is consequently less conservative than assuming a surface release. The DEIS did not explain its procedures for determining that 0.5 miles from an accident was the maximum concentration. EEG made this calculation and was in general agreement when the same assumptions were used. However, it was noted that concentrations were not negligible closer to the site and that if other atmospheric stability categories were assumed the highest values occurred closer than 0.5 miles.

Any inconsistencies in the use of atmospheric dispersion coefficients and assumptions (especially the rationale for assuming an elevated release in transportation accidents that do not involve fires, while assuming surface releases from the site) should be explained in the final EIS.

Radiological Doses to the Public

The calculated doses (Table 9-18) received by an individual at the James Ranch were checked using the releases from Table 8-6 (see Appendix VII). In all cases, the results agreed with the DEIS within 20%. The doses are small and well below existing standards that apply to other types of nuclear facilities. However, there are some uncertainties in the release fractions assumed (see Chapter 8 discussion) and in the source term.

There is a question whether the maximum exposed individual would necessarily be a resident of the James Ranch. If he were to reside on private land 2.8 miles northwest of the center of the site, he would receive an inhalation dose five times as great as at the James Ranch. Also, individuals spending some time in Zones II, III and IV would be exposed to higher concentrations while on the site. For example, average concentrations at 0.5 miles from the site center would be 16-145 times those at the James Ranch.

The assumptions on living patterns in Table 9-17 appear reasonable for the average person residing in each subsector. The calculation of a maximum dose to an individual should consider a person with a family cow that provides over 1% of his milk, or a garden that provides over 10% of his vegetables, or cattle that provide over 50% of his meat. Additionally, there may be game killed on the site and consumed by area residents. The final EIS should state the assumptions and calculate the maximum ingestion dose to an individual at both the James Ranch and at the northwest boundary. The inhalation doses should be listed separately from the ingestion doses.

Environmental Effects of Accidents During Operations

The operational accident scenarios evaluated in the DEIS (Table 9-21, pp. 9-45 to 9-48) appear to be fairly complete. However, it appears that the DEIS may underestimate the duration of fires, the number of containers involved and the clean-up time involved. An operational scenario not addressed was that of encountering a methane gas pocket during the mining operations resulting in an underground explosion involving multiple drums and/or boxes or spent fuel canisters. EEG recommends that such a severe operational accident be investigated by DOE in the final EIS.

Where referenced, estimates of release fractions (pp. 9-49 and 9-50) have been reviewed and in some cases the values used in the DEIS may be questioned. For example, it is stated (9-49;5) that Shefelbine supports a conservative assumption that 10% of the waste is in powder form and that 25% of the waste is combustible (Ref. 1). In reviewing the Shefelbine report, no mention of powder was found. The 10% powder figure might be deduced from the data indirectly. Shefelbine does reference Dieckhoner (1978) as the source of the information that 25% of the waste is combustible. In fact, Shefelbine states that "this data should be used with caution because there seems to be a consensus that, in spite of regulations, considerable mixing of combustibles and non-combustibles occurred in the past" (Ref. 1, p. 25). The presence of combustibles directly affects the severity of a postulated fire.

A second example concerns the percentage of activity which is released and respirable during accidents. It was stated that 1% was used as an intermediate value based on Mishima and Schwendiman (Ref. 2, 3). Mishima and Schwendiman described that as much as 1% of the plutonium was airborne during the combustion of flammable contaminated materials (Ref. 2, p.6). They also found that 10-40% of uranium oxide became airborne after being mixed with combustible material and ignited. Uranium oxide was used to simulate plutonium in these experiments.

In the spent fuel accident, a gap activity of 30% of the gaseous activity (H-3, Kr-85, I-129) was chosen. Although there is little information in the literature on the gap activity of fuel assemblies older than 10 years, gap activities as high as 45% have been observed (Ref. 4). Also, the quantity of Carbon-14 released was ignored.

The computer code AIRDOS-II was used in the DEIS to calculate resulting doses and dose commitments. It traces each nuclide from the point of release through the biosphere to man. AIRDOS-II is listed with the U.S. Department of Energy Radiation Shielding Information Center and has been tested and evaluated by this group prior to distribution for general use. Hand calculations by EEG using the DEIS assumptions and standard formulas gave results which generally agreed with those reported in the DEIS.

The assumed distribution of radionuclides released to the environment during operational accidents is sometimes different than the assumed releases from transportation accidents. For example, the RH-TRU waste railroad accident involving impact and fire considers only the release of cesium-137. The surface fire at the facility (Accident R-11) has cesium-137 as less than 1% of the total release. It is recommended that a consistent release fraction be used in calculations throughout the final EIS.

AIRDOS-II considers only the inhalation and external pathways of exposure. In some situations (such as surface runoff) the water pathway could be significant and should be considered. The assumption that contaminated food will be taken out of distribution has not always been possible or necessary. Existing Federal Protective Action Guides do not recommend removal of food or milk from commerce unless the projected dose commitment is 5 rem to the whole body or 15 rem to the thyroid.

Using the releases and the atmospheric dispersion coefficients (χ/Q) for accident scenario C-7 described in the DEIS, EEG calculated doses for a person living at the James Ranch. The results agreed with those given in Table 9-25 of the DEIS and are shown on the following Table 10.

Table 10

Dose Estimates at the James Ranch from Accident C7

Reference	χ/Q Type	χ/Q (s/m^3)	50 yr. Bone Dose Commitment (re	
			EEG	EIS
Table 21 p. 26	50% one-hour frequency	0.58×10^{-5}	7.4×10^{-9}	5.5×10^{-9}
Table H-36 p. H-59	Annual	0.62×10^{-6}	7.9×10^{-10}	
Table 21 p. 26	5%	0.568×10^{-4}	7.2×10^{-8}	

EEG also calculated doses from the spent fuel hoist drop accident scenario (R15) using the assumptions of the DEIS. The results, presented in Table 11, are in agreement with the DEIS calculations. The only question raised concerned the assumptions of release fractions for various accidents. The margin of error in the assumptions is not well known and EEG recommends that the basis of the assumptions be discussed in the final EIS.

The Chapter 9 assumption that exhaust air from underground waste handling and storage areas passes through HEPA filters is inconsistent with statements in Chapter 8.

Occupational Radiation Exposure

Occupational radiation exposure at WIPP is scheduled to be covered in the Preliminary Safety Analysis Report (PSAR). Therefore, no attempt will be made to evaluate it here. The following are examples of the kind of information needed to adequately evaluate occupational exposure:

1) The analysis should consider estimates of maximum individual doses, the expected distribution of doses among workers, and the population dose to the entire work force. An evaluation should be made of whether these doses are as low as reasonably achievable (ALARA).

2) Additional information will be needed on the environmental control systems, other physical facilities, and pertinent equipment, both above and below ground, so that the reasonableness of projected doses can be evaluated. More data are needed on the actual radiation levels (average and range) that workers will be exposed to from remote handled TRU waste, spent fuel assemblies and on the high level waste

Table 11

Operational Accident Scenario R-15
Hoist Drop - Spent Fuel - 6 hr. Release

Nuclide	50 year Dose Committment (rem)				
	Bone	Lung	Whole Body	Skin	Thyroid
H-3		9.54×10^{-6}	7.66×10^{-6}		0.77×10^{-5}
Kr-85		2.52×10^{-6}		7.04×10^{-5}	
Sr-90	7.43×10^{-6}	2.78×10^{-8}	0.46×10^{-6}		
Ru-106		5.97×10^{-12}			
I-129	0.02×10^{-6}		0.06×10^{-6}		4.82×10^{-5}
Cs-134		2.14×10^{-10}			
Cs-137		3.96×10^{-10}			
Pm-147	7.65×10^{-12}	2.4×10^{-13}			
Eu-154	8.22×10^{-11}	1.4×10^{-12}			
Np-237	5.89×10^{-12}	1.0×10^{-14}			
Pu-238	8.53×10^{-8}	1.0×10^{-10}			
Pu-239	1.04×10^{-8}	5.5×10^{-11}			
Pu-240	1.66×10^{-8}	8.75×10^{-11}			
Pu-241	1.49×10^{-10}	1.06×10^{-11}			
Pu-242		2.48×10^{-13}			
Am-241	1.59×10^{-8}	2.87×10^{-11}			
Am-242m					
Am-243	2.2×10^{-10}				
Cm-243	3.11×10^{-11}				
Cm-244	1.29×10^{-9}				
EEG Totals	7.58×10^{-6}	1.2×10^{-5}	8.28×10^{-6}	7.04×10^{-5}	5.59×10^{-5}
DEIS Totals*					
R-15 Spent Fuel	8.7×10^{-6}	1×10^{-5}	8.3×10^{-6}	2.2×10^{-4}	3.2×10^{-5}

*Table 9-25, page 9-56

experiments (including retrieval operations). Also, it will be necessary to describe the management organization (including health physics activities) that will be used to operate the facility and provide health and safety control.

Long-Term Releases

Five repository breach "scenarios" were analyzed in the DEIS (section 9.5.1). Scenarios 1-4 all resulted in dissolution of the waste, passage of the waste into the Rustler aquifer, and passage through the aquifer into the Pecos River. Scenario 5 involved direct access by drilling.

Dose Calculation Methodology

The radionuclide concentrations and resultant radiation doses reported in the DEIS were obtained by using large computer codes. EEG was able to check many of these computer calculations by hand. To check results of the hydrologic model used to describe nuclide transport in the liquid breach scenarios 1-4, EEG used a simpler model. To check dose calculations, EEG used standard formulas and conversion factors. The calculations are discussed in Appendices VI and VII, and the results compared with those in the DEIS. In its calculations, EEG used the hydrologic parameters, radionuclide inventory, and scenario descriptions in the DEIS. The EEG and DEIS results agree closely.

While these calculation checks tend to support the validity of the methods employed in the DEIS to calculate nuclide concentrations, ingestion doses and external gamma radiation doses, they do not provide checks on the validity of the assumptions used or the appropriateness of the situations analyzed.

Parameter Values

One must consider the key parameters that lead to the nuclide concentrations and ingestion doses calculated. They include the distribution coefficients (K_d) values which are responsible for holding back such nuclides as plutonium, neptunium and thorium, as well as the basic driving parameter, $\bar{v}$, the assumed groundwater flow velocity. The last quantity depends on hydraulic conductivity, porosity and hydraulic gradient. All of these parameters have large uncertainties associated with them because of natural variation and difficulties in measurement. Both K_d values and hydraulic conductivities can vary by several orders of magnitude. A thorough review of these uncertainties and of their impact on radiation doses must be made, and should be included in the final EIS.

EEG has done some calculations relevant to the effect of variations in K_d and hydraulic conductivity values and they appear in Appendix VII.

Flow Paths

All of the hydrologic breach scenarios assumed a flow along the Rustler aquifer and release at the Malaga Bend of the Pecos River. However, the interface between the Rustler and Salado formations is exposed at Nash Draw. A spring at the north edge of Laguna Grande de la Sal is fed by water from the Rustler aquifers. The calculated hydraulic potentials for the Rustler formation (Figure K-5, p. k-13) indicate that the shortest release path is 15 miles from WIPP to Malaga Bend. However, the measured hydraulic potential contours in the Rustler formation (Figure K-3, p. K-12) indicate that the shortest flow path is 9 miles to Laguna Grande de la Sal. The dosage calculations should take this shorter path into consideration.

Scenario 5

Dose estimates in the DEIS for both external radiation to a drill crew member (Table 9-47) and inhalation to a resident (Tables 9-48 and 9-49) were checked using the assumptions in the DEIS (see Appendix VII). EEG calculated a dose of 71 rem to a drill crew-member, compared to ∿90 rem in the DEIS. In either case the dose is high enough to warrant serious consideration of control measures to prevent such an occurrence.

Alternate Scenarios

It is not clear that the scenarios used in the DEIS are indeed upper limits or bounding cases. EEG has identified a number of scenarios which also should be considered in the final EIS:

1) well water becomes contaminated and is used for irrigation or stock watering;

2) gas, generated by organic decomposition of the waste, acts as a driving mechanism in bringing waste to the surface;

3) a connection develops between the repository, a high pressure brine reservoir and the surface; and

4) solution mining for salt takes place.

The April 1979 <u>Draft Environmental Impact Statement, Management of Commercially Generated Radioactive Waste</u> (DOE/EIS-0046D) discussed solution mining for salt as the most likely of several repository breach scenarios. The main pathway of exposure was considered to be ingestion of contaminated salt. The presence of salt contaminated with radioactive materials was not expected to go undetected for long, due to quality control checks. The DOE assumed the contamination went undetected for one year, and obtained radiation doses orders of magnitude higher than those obtained for the scenarios considered in the WIPP DEIS.

Detailed Comments

9-4 Table 9-2	The construction equipment noise levels given in Table 9-2 are achievable but will require proper equipment and noise control procedures to obtain.
9-26 Table 9-13	The Department of Housing and Urban Development Criteria for Noise Assessment given in Table 9-13 were revised in 1979 and those should be listed in the final EIS.
9-33 Fig. 9-3	The schematic diagram (Fig. 9-3) shows only the air pathway of exposure. Surface runoff from contaminated surface areas, wildlife contamination from surface lagoon, and ingestion of drinking water are not discussed. Although these pathways may not be the primary ones, they should be considered.
9-33;4	Each wedge of the study area was divided into 10 subsectors, not 14 as stated.
9-34 Fig. 9-4	According to page H-6, Figure H-1 and page H-8, Table H-4, the population size of 50 would not be within the 5 mile or 10 mile radius. There also appears to be some discrepancy with some of the other numbers. For example, the population of 230 given within the 10 mile radius in the WNW direction does not agree with the numbers given in Appendix H. Do the numbers include workers at potash mills?
9-37;2-4	The DOE <u>Draft Environmental Impact Statement, Management of Commercially Generated Radioactive Waste</u> (Ref. 6) consistently used a 70 year dose commitment instead of the 50 year dose commitment used in the WIPP DEIS. The 70 year dose commitment seems most appropriate when discussing population dose commitments.

9-37;6 Would one expect the dose from krypton to be about 25% of the total from spent fuel when one considers the whole body, lungs and bone? The krypton irradiation involves primarily submersion in the gas because little of the krypton will circulate in the blood and therefore irradiate bone.

9-38 Tables 9-18, 9-19 It should be indicated whether the tritium that seems to be included in the spent fuel group is a gaseous molecule or incorporated in a water molecule. If the tritium is a diatomic molecule, then the dose is received only from immersion, but if it is a part of a water molecule, then it has an effective half life of about 12 days (indicated in ICRP II, or in ICRP Publication 10). Since the values indicate similar doses for bone, lungs and whole body, one must assume that the calculations were for tritium incorporated in a water molecule. In this case, the values given are for dose equivalent and not dose equivalent commitment.

It is not clear what nuclides are contained within "structural materials, fission products, actinides, and spent-fuel". One can assume that the actinides are specified in Table 8-6, page 8-30; however, it is not clear how one separates the structural material, fission products and spent-fuel.

EEG questions the comparison of dose commitment and 50 year dose equivalent from natural background in assessing the acceptability of such releases.

9-38 A dose calculation was made from the actinides (largest dose contributor) using Pu-239 as the primary isotope and agreement with Table 9-18 was obtained when the information in Table 8-6, page 8-30, was used as the source term.

9-40 Table 9-20 The surface dose rate should be 10mrem/hour not per year. The 1900 mrem/year should be subjected to the "as low as reasonable achievable" (ALARA) principle.

9-40;1 The statement was made that the radiation dose to workers on the RH waste portion has not been computed. This type of waste is perhaps the source of highest individual exposures and should be carefully monitored.

9-42;5 The information for the environmental control for the rock pile is inadequate.

9-51;7 The use of filters on exhaust air from the underground storage areas to the atmosphere can reduce the radioactive concentration of particulates by a factor of 10^6. It is unclear from the following two statements whether the storage room air is actually filtered:

(1) page 8-29, Table 8-5, footnote a - "Except for underground operations, effluent treatment is provided by filters in the ventillation system (decontamination factor = 10^6)".

(2) page 8-33;4 - "Airborne surface activity in the underground storage area will be released to the atmosphere unfiltered".

Operational Accident Scenarios C13 and C22 both use 10^6 decontamination factor for the HEPA filters.

9-53 Table 9-24 The DEIS used different distributions of radionuclides released to the environment in transportation accidents and operational accidents involving RH-TRU canisters.

9-54;3 The DEIS assumed 30% of the Kr-85, H-3 and I-129 present in the fuel cladding gap were available for release. NUREG-0404 assumed that 10% of the Kr-85 and 1% of the I-129 present is in the fuel cladding gap and available for release (ref. 9, p. 4-19). A General Electric document (ref. 4) predicted that fission gas release fractions range from 20 to 45%. This report further quotes studies which report 3% of iodine found in the gas plenum and is available for release. The 45% for Krypton is somewhat higher than the 30% predicted by the Reactor Safety Study (ref. 8) used in the DEIS. The General Electric figures of 20 - 45% are also higher than ref. 2 results of 10% release of Kr-85 and 1% of I-129. The doses and dose commitments are directly proportional to the release fractions chosen for the calculations, and the DEIS value of 30% appears reasonable.

Why is the 50 percentile χ/Q used for the accidents? Would the 5 percentile value be more reasonable? The (χ/Q) 5% in NW downwind sector is approximately 16 times the (χ/Q) 50% in SSW sector used in the DEIS.

9-56;1 All calculated doses appear to be adult doses. Were the doses to infants, children and teenagers considered in the computer programs used?

9-56
9-57 One should not compare the radiation received from natural background over 50 years with doses that occur over shorter times (e.g. tritium and I-129).

9-107;3 How was the pressure difference of 7.5 psi obtained? How reliable is that pressure difference? See EEG's question in the GCR review (Appendix III) on the reliability of the head data in the Delaware Mountain Group aquifer.

9-108 In the flow calculations for scenario 1, what value of transmissivity was used for the DMG? Was it 50 $ft.^2/day$? How reliable is the value?

In the flow calculations for scenario 2, what was the basis for the assumption that the wellbore has a hydraulic conductivity K = 50 ft./day?

9-112;5 Should this reference be to figure K-5 rather than K-6?

9-114,
9-115 Table 9-45 is inconsistent with Table 9-46. The transport rates given for I-129, Ra-226, and U-235 in scenario 2 (with the upper transmissivity assumption), do not agree.

	Table 9-45	Table 9-46
I-129, g/yr	2.6 x 10	3.3 x 10^{-1}
I-129, Ci/yr	4.5 x 10^{-3}	5.8 x 10^{-5}
Ra-226, g/yr	2.0 x 10^{-14}	2.9 x 10^{-7}
Ra-226, Ci/yr	2.0 x 10^{-14}	2.9 x 10^{-7}
U-235, g/yr	2.9 x 10	2.2 x 10
U-235, Ci/yr	6.2 x 10^{-5}	4.8 x 10^{-5}

9-116
9-117 The graphs appear to be incorrectly plotted. For example, in Figure 9-15 the maximum concentration of 3.1×10^{-6} should be plotted at between .5 and .6 of the distance from 1 towards 10^{-10}. Tables would provide a more accurate presentation.

9-117 The graphs terminate while the dose rate is still rising in Figure 9-16 a, d, and f. The final EIS should show the maximum dose rates and when they will occur.

9-133,
9-134 EEG agrees that the generation of gas from organic material in the radioactive waste can be important for both transportation accident and long-term storage, and the question posed in the DEIS of the gas generation effects upon the repository must be resolved. Large amounts of gas could be generated. Pressures exceed lithostatic pressure (9-136), i.e. 2000 psi.

These large pressures could cause fracturing of the overlying rocks and would possibly release gas with radioactive contaminants directly to the atmosphere through fractures or through a well drilled into the repository.

9-136;4 Will the brine migration induced by heat-emitting radionuclides cause difficulty in retrieval of sources?

9-153
Table 9-53 The probability of fire is assumed to be 10^{-3} and of a dropped container, 10^{-2}. The reasoning behind these numbers should be in the EIS.

9-154 What is the expected distribution of annual dose equivalents received by the radiation workers retrieving stored waste?

9-157 The ratio of population doses to maximally exposed persons is constant in Table 9-55, except for the whole body dose. Why?

References

1. Shefelbine, Henry C. Preliminary Evaluation of the Characteristics of Defense Transuranic Wastes (SAND 78-1850), November 1978.

2. Mishima, J., and Schwendiman, L.C. The Amount and Characteristics of Plutonium Made Airborne Under Thermal Stress (BNWL-SA-3379), October 1970.

3. ________. Some Experimental Measurements of Airborne Uranium (Representing Plutonium) in Transportation Accidents (BNWL-1732), August 1973.

4. General Electric Company. Safety Evaluation Report for Morris Operation Fuel Storage Expansion. Phase I (NEDO-20825), March 1975.

5. Oak Ridge National Laboratory, Radiation Shielding Information Center. AIRDOS-II, Estimation of Radiation Doses Caused by Airborne Radionuclides in Areas Surrounding Nuclear Facilities (CCC-304), 1977.

6. U.S. Department of Energy. Draft Environmental Impact Statement, Management of Commercially Generated Radioactive Waste (DOE/EIS-0046D), April 1979.

7. U.S. Nuclear Regulatory Commission. Draft Generic Environmental Impact Statement, Uranium Milling (NUREG-0511), April 1979.

8. U.S. Nuclear Regulatory Commission. Reactor Safety Study: An Assessment of Accident Risks in U.S. Commercial Nuclear Power Plants (WASH-1400), 1975.

9. U.S. Nuclear Regulatory Commission. Draft Generic Environmental Impact Statement on Handling and Storage of Spent Light Water Power Reactor Fuel (NUREG-0404), March 1978.

ADDITIONAL DOSE ESTIMATES

The following lists additional dosage estimates that should be considered in the final EIS.

Long Term

1) Build-up in the environment from radionuclides in water removed from the Pecos River for irrigation, incorporated into soil and plants, and cycled in food and man over long periods of time.
(General Population)

2) Generate dosage estimates using the DOE generic Waste Isolation Safety Assessment Program (WISAP) model currently under development by the Battelle Northwest Laboratories.
(General Population)

3) A connection is made between the Delaware Mountain Group aquifer, the repository and the surface.
(General Population)

4) A connection is made between the repository, a high pressure brine reservoir and the surface.

5) Effects of high pressure gas formation on the release of radionuclides to the environment.
(General Population)

Transportation

1) Radiation exposure from acts of sabotage in the transportation of radioactive waste materials. The amounts of radioactive material released could be greater than those released in accidents.
(General Population, Occupational)

2) Radiation exposure to emergency workers such as police and firemen following a transportation accident.
(Occupational)

3) Exposure to a person in an automobile stopped next to a radioactive waste truck at a red light or in a highway traffic jam. (General Population)

4) Exposures from shipments of retrieved radioactive wastes following the completion of high level waste experiments. Containers could be bent, damaged or under pressure from gas generated by decomposed organic material. (Occupational, General Population)

5) Contamination of a water supply or crops following an airborne release. (General Population)

6) Potential radiation exposure from transportation of material resulting from decommissioning and dismantling of weapons production facilities. While the DEIS assumes that none of the 5 to 95 million cubic feet of material will be shipped to WIPP, it notes that the WIPP will have the capacity to receive some of the TRU waste (2-22;2). (Occupational, General Population)

7) Calculation of individual doses as well as population doses. (Occupational, General Population)

8) Consideration of a diffuse source of radioactivity rather than a point source.

<u>Construction and Operation</u>

1) Radon-222 from the mined salt and from the walls of the underground repository. (Occupational, General Population)

2) Radiation exposure from decommissioning and dismantling of the above ground facility. (Occupational)

3) Pressurized brine breaches the mine, damages containers and flows up the shaft to the surface.
(Occupational, General Population)

4) A methane gas pocket leaks into mine and explodes.

5) Acts of sabotage at surface processing facility.
(Occupational, General Population)

6) On-site exposure.
(General Population)

7) Ingestion doses from operational releases at the site.
(General Population)

Mineral Extraction

1) Radiation exposure to workers who may bring minerals to the surface (oil drilling, solution mining) and to the public using the products.
(Occupational, General Population)

2) Exposure from burning natural gas obtained from formations below the site. Radioactive waste material could move downward as pressure is decreased with the removal of gas.
(General Population)

3) Exposure to people who may use well water from the Culebra, Magenta, or Santa Rosa sandstone aquifers contaminated with radionuclides.
(General Population)

APPENDICES

APPENDIX I

Radioactivity Inventory Calculations

Tables 2-5 in the Inventory of Radioactivity section were prepared as follows:

Volume estimates (cu. ft.), Table 5, were calculated to equal:

$$\left(\begin{array}{c}\text{backlog}\\ \text{of waste,}\\ \text{cu.ft.}\end{array}\right) + \left(\begin{array}{cc}30 & \times\ \text{new waste}\\ \text{yr.} & \text{production,}\\ & \text{cu. ft./yr.}\end{array}\right)$$

where backlog and new production volumes were taken from Table 6-2 for CH waste and Table 6-6 for RH waste.

Total repository CH and RH-TRU activities (Curies), Table 3, were obtained by adding total box, drum and RH-TRU canister activities, without considering decay or ingrowth. The total activity of a given nuclide in a given type of container was calculated as:

$$\frac{\text{(curies per container)} \times \text{(total cu. ft. of waste in containers)}}{\text{(cu. ft. per container)}}$$

where the container activities were taken from Table E-1 (drums), E-2 (boxes) and E-3 (RH canisters); single container volumes were taken from Table 6-3 and 6-5; and total waste volumes in given types of containers were taken from Table 5 of this review.

Shipment activities (Curies), Tables 3 and 4, were obtained by multiplying activities per container (Tables E-1, E-2, E-3) by the number of containers in a shipment (Tables 6-3, 6-5).

The total repository actinide inventory (Curies), Table 2, which includes the effects of decay and ingrowth, after 30 years of repository operation, was calculated as follows. The Plutonium-239 and 240 inventories are not affected by decay over a 30 year period, and these activities are found by adding the CH and RH-TRU activities given in Table 3. Plutonium-238 and 241 have half-lives of 88 and 13 years, respectively, and so these inventories decay significantly in 30 years. The activity after 30 years, A(30), is found from:

$$A(30) = A(0)e^{-\lambda(30)} + \frac{C}{\lambda}\left(1 - e^{-\lambda(30)}\right)$$

where λ is the nuclide decay constant, A(0) is the nuclide activity in the waste backlog, and C is the activity in the new waste produced each year.

Americium-241 is affected by both decay and ingrowth (from Plutonium-241) in a 30 year period. The final inventory was estimated by adding the total Table 3 Americium-241 inventory to the ingrowth term:

$$\frac{13}{460}\left[\text{Pu-241 activity in Table 3 (without decay)} - \text{Pu-241 activity in Table 2 (with decay)}\right]$$

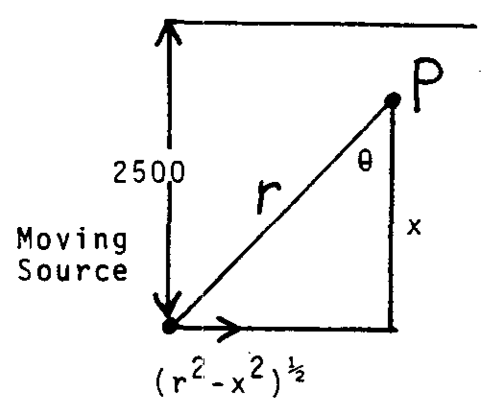
where 13/460 is the ratio of the Pu-241 and Am-241 half-lives. Then this undecayed total was multiplied by a 30-year Am-241 decay factor of .96. This method underestimates slightly the amount of Am-241, since it assumes that all of the Am-241 (from the 30 year repository inventory and from the decay of Pu-241) has been present for the full 30 years.

A more complete discussion of decay and ingrowth estimates is included in Appendix VI.

APPENDIX II

TRANSPORTATION CALCULATIONS
(Chapter 6)

To Develop An Expression For Dose To A Person At Point P From A Moving Source



(1) Dose at Point P $= \int D_r \, dt$

where D = dose (rads)

D_r = dose rate (rads/h)

t = time (h)

(2) $D = \int D_{r6} \frac{6^2}{r^2} e^{-\mu r} \, dt$

where D_{r6} = dose rate at 6 feet

r = distance (feet)

μ = linear absorption coefficient (feet^{-1})

Now $s = (r^2 - x^2)^{1/2}$. Thus:

(3) $v = \frac{ds}{dt} = \frac{1}{2} (r^2 - x^2)^{-1/2} \; 2r\frac{dr}{dt}$;

substituting (3) for dt into (2):

$$D = \int D_{r6} \frac{6^2}{r^2} e^{-\mu r} \frac{r\,dr}{v(r^2 - x^2)^{1/2}}$$

To evaluate the integral

$$\int \frac{dr}{r(r^2-x^2)^{1/2}} ,$$

The following change of variable is made:

$$\frac{r}{x} = \sec\theta$$

$$r = x\sec\theta$$

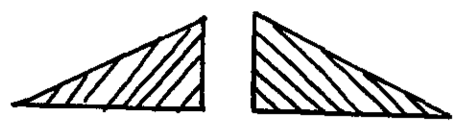
$$dr = x\sec\theta\tan\theta\, d\theta$$

$$\tan\theta = \frac{(r^2 - x^2)^{1/2}}{x}$$

$$(5)\quad \int \frac{x\sec\theta\tan\theta\, d\theta}{x\sec\theta\; x\;\tan\theta} = \int_{\theta=\pi/2}^{\theta=0} \frac{d\theta}{x} \approx \frac{\pi}{2x} .$$

Therefore,

$$D = \frac{D_{r6'}\; 36\;\pi 2}{v\;\;2x}$$

for both sides of  .

$$\text{Dose to a Person at Point P} = \frac{D_{r6}\; 36\pi}{v\;x}$$

To Calculate Total Man Rem Dose to People

$$\underset{\text{(Man-Rem)}}{\text{Dose}} = 2\,(P.D.)L \int_{Min}^{d} \frac{D_{r6}\; 36\pi\; dx}{v\;\;x}$$

$$\text{Dose} = \frac{2\,(P.D.)L\;\; D_{r6}\; 36\pi}{v}\;\; \ln\,(d/min)$$

where

P.D. = population density (people/mi^2)
L = length of shipment path (miles)
v = velocity (mile/hour)
d = distance to people (miles)
min = minimum distance (miles)

correcting for different population densities in urban (u), suburban (s) and rural (r) and velocities and using format of NUREG 0170, p. D-6, Ref. 4 and RADTRAN P. 19, Ref. 3.

$$\frac{\text{pop. dens.}}{V} = \left[\frac{f_r PD_r}{V_r} + \frac{f_s PD_s}{V_s} + \frac{f_u \ PD_u}{V_u} \quad (f_o + 1.636 f_1) \right]$$

incorporating PPS = Packages per shipment

SPY = Shipments per year

L = Distance of Shipment (miles)

TI = Transport Index (mr/h)

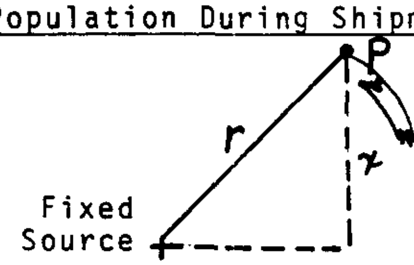
K = Dose Rate at Distance d

k = Ko (TI)

$$\text{Dose} = (TI)(Ko)(PPS)(SPY)(L)\pi \ \ln(d/\min) \ x$$

$$x \left[\frac{f_r PD_r}{V_r} + \frac{f_s PD_s}{V_s} + \frac{f_u PD_u}{V_u} \quad (f_o + 1.636 f_1) \right]$$

<u>To Develop An Expression For Dose To a Population During Shipment Stops.</u>



Annulus=2Πrdr

$$\text{Dose} = \int D_r \, dt$$

$$= Ko(TI)\Delta T(\text{Pop. Dens.}) \int \frac{2\Pi r dr \ e^{-\mu r} \quad B(r)}{r^2}$$

$$= Ko(TI)\Delta T(\text{Pop.Dens}) \int_x^d \frac{2\Pi e^{-\mu r} \ B(r) \ dr}{R}$$

Evaluating the integral

$$\int_{r=x}^{r=d} \frac{e^{-\mu r} B(r)\, dr}{r^2} = \ln (d/x) - \ln(d-x) - \frac{(\mu t)^2}{22!} - \frac{(\mu r)^3}{33!} + \frac{(\mu r)^4}{44!}$$

$$= 3.845$$

$$= (Q_1) Ko(TI)(Shipments/y) \left[\Delta T_r (PD)_r + \Delta T_s \; PD_s + \Delta T_u \; PD_u \right]$$

<u>To Develop An Expression for Dose To Crew</u>

$$Dose = D_r \, \Delta t$$

$$= Ko(TI)S \; N_c \; \frac{e^{-\mu d} B(d)}{d^2} \; \Delta t_{shipment}$$

where N_c = Number in crew
d = Average distance to crew (feet)
FM = Distance/shipment (miles
Δt = Average time for shipment (hours)
S = Shipments/year

$$\Delta t = \left[\frac{f_r}{V_r} + \frac{f_s}{V_s} + \frac{f_u}{V_u} \right] FM$$

$$Dose = Ko(TI)S \; N_c \; e^{-\mu d} \, B(d) \left[\frac{f_r}{V_r} + \frac{f_s}{V_s} + \frac{f_u}{V_u} \right] FM,$$

Accident Calculations

M

Inhalation Dose

$$D_{INH} = K_{INH} \times C_{INH}$$

$\left(\frac{pCi/}{cm^3}\right)$ (rem/μCi inhaled) — EIS App. G-5

External γ Dose

$$D_{IMM} = K_{IMM} \times C_{imm}$$

$\left(\frac{pCi/}{cm^3}\right)$ $(rem\text{-}cm^3/\mu Ci\text{-}hr)$ — EIS App. G-5

Immersion Dose

$$D_{wimm} = K_{wimm} \frac{R_t}{d} \left(\frac{1 - e^{-\lambda T t}}{\lambda t}\right) C_{wimm}$$

$(rem\ cm^3/\mu Ci\text{-}hr.)$

R_t = surface dep. pCi/cm^2-sec

EIS App. 6-6

D_{wimm} = water immersion dose

d = depth of water

λt = effective λ

t = build up in water

Atmospheric Dispersion

Using Gaussian Plume Dispersion for Ground Level Concentrations, EIS G-1 Equation of Pasquill Reduces to

$$x = \frac{Q}{\Pi \sigma_y \sigma_z \mu} e^{\left[-\frac{1}{2} \left(\frac{H}{T_z}\right)^2\right]}$$

EIS p. G-3

χ = pCi/m^3
T_y = horiz. dispersion coef. (m)
T_z = vert. dispersion coef. (m)
H = effective ht. of plume
Q = emission rate (pCi/sec)

AIRDOS-II
(FORTRAN on CDC 6600)

<u>To Calculate Curies (Release)</u>

NUREG 0170 Vol. 1 G-1

$Q^1 = (n_i)$ (RF) (AER) (RESP) (E) (DF)

(n_i)	(Ci/ shipment)
(RF)	(Fraction Released)
(AER)	(Fraction as Aerosol)
(RESP)	(Fraction Respirable in Aerosol)
(E)	(Particle Size Dust Factor)
(DF)	(Dilution Factor)

Radioactivity Released in Transportation Accidents

Type of Accident	Common Assumptions	Source	Fraction Released From Drum	Fraction Released to Environment	Fraction in Air	Fraction Entrained in Air	Fraction Respirable	Amt of Radioactivity
Rail CH-TRU	Pasquill Stability Factor=F	1 Flat Bed Car 3 Type B Packages 42 Drums/Package 126 Drums	50% in Drums Released to Packages 63	10% 6.3	10% .64 Drum	1.4% .0090	62% .0055 Drum	See Inventory of Radioactivity
Truck CH-TRU	Wind Speed = 1 m/sec	1 truck 42 Drums 42 Drums	50% 21	10% 2.1	25% .5	---------	---1%-------- .0065 Drum	See Inventory of Radioactivity
Rail RH-TRU	Inversion Layer = 1000 m Release Height = 20 m	1 Flat Bed Car 5 Canisters	1% (Only Volatile fission products)	10%				.01 Ci Cs-137
Rail Spent Fuel		1 Cask 10 Canister/cask	30% Kr-85 1% Cs	100% Kr-85 10% Cs				7800 Ci Kr-85 440 Ci volatile f/p

Transportation X/Q Factors

at 0.5 mi, F condition
μ= 1 m/sec, H = 20

p. G-3 $$\frac{X}{Q} = \frac{1}{\pi \sigma_Y \sigma_Z \mu} e\left[-1/2\left(\frac{H}{z}\right)^2\right]$$

$$\sigma_z = .016d(1 + .003d)^{-1} = .016(805)[1 + (3-4)(8+2)] = 10.39$$

$$\sigma_y = .04d(1 + .001d)^{-1/2} = 32.2[1 + .08]^{-1/2} = 31.0$$

$$\frac{X}{Q} = \frac{1}{\pi(10.4)(31.0)(1)} e{-1/2}\left(\frac{20}{10.4}\right)^2 = 9.9-4(.158) = \underline{\underline{1.6\ -4}}$$

As comparison:

Worst annual at 0.5 mi = 9.0 - 5 (Table H-36) 10 x lower
(X/Q)5% for 1 hour, 0.5 mi = 4.3 - 4 (Table 21, App. H)
3 x higher (X/Q) max for 1 hour, 0.5 mi = 1.1 - 3

The X/Q for gound level release is between 5% and max one-hour X/Q so is conservative enough. Justification for using effective height of 20m is not obvious.

Also, can't check whether X max at 1/2 mile is correct.
See additional comments on χ/Q in Chapter 8.

APPENDIX III

EEG-2

HEALTH & ENVIRONMENT department

Review Comments on
Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico
SAND 78-1596, Volumes I and II, December 1978

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

August, 1979

Second Edition
10/79

CONTENTS

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is no environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department - the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and other organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

Robert H. Neill
Director

INTRODUCTION

The purpose of this document is to review and evaluate the scientific information contained in the Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico, SAND 78-1596, Volume I and II, December, 1978, (herein referred to as the GCR), and its supporting references, as it pertains to the environmental, health and safety aspects of the radioactive waste repository proposed near Carlsbad, New Mexico.

These evaluations and interpretations are based on reviews by the Environmental Evaluation Group (EEG) staff and several consultants with expertise on geological aspects of the site. EEG also convened two technical meetings to explore some topics of particular concern.

The review focused on some major concerns regarding areas in which more data or more detailed analysis appeared necessary and did not comment on those areas with which EEG agrees such as Seismology, or on areas which fall outside the scope of EEG's mission such as Resources. In this sense, the review may appear negative in tone and does not acknowledge those areas that have been thoroughly investigated by Sandia, and the U.S. Geological Survey and other contractors of the U.S. Department of Energy. It is recognized that additional data have been obtained since August, 1978, which may answer some of the questions raised.

The review describes in detail the important geotechnical issues on which there are questions or differences in interpretation and comments on the technical basis for certain conclusions presented in the GCR.

ACKNOWLEDGEMENTS

This document reflects the efforts of a number of individuals. The review is a synthesis of comment by the EEG staff consisting of

Robert H. Neill, Director
James K. Channell, Environmental Engineer
Lynn W. Gelhar, Hydrologist*
Carla Wofsy, Mathematician

and the following consultants who have reviewed and commented on portions of the GCR:

Mary Anderson, Assistant Professor of Geology, University of Wisconsin
Roger Anderson, Professor of Geology, University of New Mexico
Lokesh Chaturvedi, Associate Professor of Geological Engineering, New Mexico State University
Stanley Davis, Professor of Hydrology and Water Resources, University of Arizona
George Griswold, President, Tecolote Corporation
Gerardo P. Gross, Professor Geophysics, New Mexico Institute of Mining & Technology
William Hiss, Geologist, U.S. Geological Survey
Gary Landis, Assistant Professor of Geology, University of New Mexico

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*Dr. Lynn Gelhar served as a part-time member of the EEG staff from February 15 to July 1, 1979, during which time he reviewed aspects of the Geological Characterization Report (GCR) and prepared an early draft of the EEG comments on that report. He was not involved in any way in the preparation of the final version of EEG's comments on the GCR.

Donald Langmuir, Professor of Geochemistry, Colorado School of Mines

Allan Sanford, Professor of Geophysics, New Mexico Institute of Mining & Technology.

Each of the consultants had an opportunity to review and comment on an early draft of this document. In the process of the evaluation there were informal contacts and a meeting on March 22 and August 20, 1979 with personnel from Sandia Laboratories and the U.S. Geological Survey who are associated with the WIPP project. Their assistance in clarifying interpretations in the GCR and providing reference materials is acknowledged. They also indicated that a considerable amount of data has been obtained by the Department of Energy since the GCR was prepared over a year ago that will be published shortly.

PRINCIPAL CONCERNS

The following geotechnical questions, each of which bears on the short-term or long-term integrity of the site, are not resolved by the August 1978 information in the GCR and its references. DOE is continuing to gather and analyze data relevant to these features and processes.

1. What is the origin, evolution and occurrence of the high-pressure brine-reservoirs which were encountered in the upper part of the Castile formation in ERDA No. 6 and in at least 6 wells within 9 miles of the site? (See Section 2).

2. What is the origin, evolution and occurrence of the "breccia pipes" which have been encountered in the area? They may be localized deep dissolution features which originate in the lower portion of the evaporites and migrate upward. Such localized dissolution features could now exist or develop later beneath the proposed site (see Section 3).

3. What are the processes and rates of deep dissolution of salt near the site? There may be a preferential removal of the salt horizon which is proposed for the repository (see Section 3).

4. What are the regional and site hydrologic conditions for the aquifers above and below the evaporites? The hydrologic information is necessary to assess any possible long-term release of radioactive material from the repository (see Section 5).

Additional information on geological phenomena will be required by EEG in order to assess their significance in any potential release of radioactive materials to the surface and any effect on the health and safety of people and on the environment.

REVIEW OF GEOTECHNICAL ISSUES

1. Site Selection Procedures and Criteria

The following references suggested endorsement by different agencies in the selection of sites for an underground radioactive waste repository. Were they official recommendations by those agencies or were they made by individual staff members?

a) "...the USGS and ORNL selected the Permian Basin in New Mexico as best satisfying their site selection guidelines." (2-5.1)*?

b) "In the opinion of both ORNL and USGS, the two core holes, AEC 7 and 8, indicated acceptable subsurface geology at the ORNL site." (2-5.4)

c) "On November 14, 1975, the USGS recommended an area about seven miles southwest of the ORNL site for further examination"? (2-7.1)

There are several instances in which criteria appear to have been developed or altered to satisfy the condition of the WIPP site. A failure of the proposed repository to meet a given design criterion does not in itself mean there is a hazard. It does identify or flag those areas that need to be thoroughly analyzed to determine whether or not the consequences of failure could result in radiation exposure to people. The requirement (2-12.3) that the site be located at least one mile from a borehole penetrating the Salado formation was changed from two miles to one mile after the site at the ERDA No. 6 borehole was discovered to be unacceptable.

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*The notation (2-5.1) refers to Chapter 2, page 5, paragraph 1 of the GCR.

a) The GCR states that the studies of Snow and Chang (1975) and Walters (1975) allowed a more quantitative judgment on the question (2-6.2).

   1) What specific results of these studies justify the statement that "This buffer would assure more than a quarter of a million years of isolation using very conservative flow assumptions"?

   2) How are the conditions of those studies pertinent to the WIPP situation?

b) A report by Fader (1973) is also cited (2-12.3) as justification of the one mile criterion. However, this study was based on field observations of surface subsidence near abandoned wells in a Kansas salt bed and indicated that borehole dissolution can develop very rapidly in terms of geologic time. The area of surface subsidence was found to be approximately 1000 feet in diameter after about 31 years and subsidence of over 10 feet was observed. In view of these other studies, are there any analyses to substantiate the "quarter million years of isolation" and justify the one-mile criterion?

c) Griswold (1977, p. 12) is also cited (2-12.3) as providing justification for the one-mile criterion but Griswold's report only had a general statement that "This change, which resulted from studies performed for ORNL on the dissolutioning effects in boreholes, was made desirable by the extensive deep gas-exploration drilling in the Delaware Basin."

The ORNL criterion "no active mining within 5 miles (2-10.3) was also changed to "minimize existing potash lease rights in Zones I and II" (2-22.1).

The criterion that the site should be located one mile from a dissolution front (2-21) appears to be arbitrary in view of the uncertainty of the mechanism and rates of dissolution. According to Fig. 2-9, the dissolution front at the top of the Salado is located slightly inside the western boundary of Zone IV of the site. This would be about 1.8 miles west of the boundary of Zone II, the limits of underground storage in the proposed WIPP repository (4-39.1). How accurately is the location of the dissolution front and the rate of 6-8 miles per million years known?

2. Brine Reservoirs in the Evaporites

As noted on (2-11.2), an artesian brine flow was encountered at the original site at ERDA No. 6. Aspects of this brine occurrence are discussed in several locations in the report (e.g. 1-16.3, 1-31.4, 2-11.2, 4-67.3, 4-69.3, 6-19.4, 7-75.2, 7-90.1, 7-99.3, 7-102.4, 8-5.1). This approach together with some omissions has made it difficult to assess. The ERDA No. 6 brine, accompanied by concentrations of H_2S exceeding OSHA's standards for occupational exposure, was encountered on the flank of an extreme localized upthrusting structure from the middle of the Castile; dips as high as 70° were seen in the core and the middle anhydrite unit (A-11) has been displaced vertically by as much as 950 feet (Anderson and Powers, 1978,p. 79). According to a report to Sandia Laboratories [Tiab, 1977, p. 1]*, the well flowed at 662 barrels/day, but this data is not in the GCR. Tiab [1977, p. 6] also reported that the volume of the reservoir at ERDA No. 6 could be as large as 2 million barrels of water. The GCR reports Griswold's estimate of 100,000 to 1 million barrels in the discussion of lithium resources (8-5.1).

Seven wells have encountered brine reservoirs within a distance of 9 miles from the site. Griswold's (1977, page 42) Table XII (see below) gave data on four nearby oil wells

*References in brackets are listed in the end of this document; all other references are given in the GCR.

which have also encountered artesian brine reservoirs; these flows are typically an order to magnitude larger than that of ERDA No. 6. Griswold (personal communication to Lynn Gelhar, April 6, 1979) confirmed that two additional wells (Masco No. 1 & 2, Sec. 20, T22S, R33E) encountered artesian brine in the Castile. The GCR gives only sketchy information on these additional brine flows. Locations of "artesian brine flows" are shown in Figure 2-5 but the text (2-13.3) that describes the figure simply refers to "..., brine flow anticlines,..." without discussion. A more comprehensive discussion of these brine reservoirs should have been included in Chapter 6 on hydrology.

Griswold (1977)

TABLE XII

Brine Flows From Nearby Wells

Well Name	Location	Flow Rate (bbl/day)	Depth of Flow (ft.)
ERDA No. 6	Sec. 35, T21S, R31E	600	2709
Hudson Federal	Sec. 1, T23S, R30E	12,000	2802
Culbertson-Erwin	Sec. 26, T22S, R32E	Strong	3515
Bootlegger Ridge	Sec. 36, T22S, R32E	20,000	3671
Gulf 1-A	Sec. 25, T22S, R32E	36,000	3600

The Castile brine reservoir encountered about 1/4 mile from the southwest corner of the outer boundary of the site at the Belco Hudson Federal well is discussed briefly (4-68.1). This occurrence, with an estimated flow of 12,000 barrels/day (Griswold, 1977), demonstrated that such brine flows are not always associated with the highly deformed region near the

Capitan reef. Griswold's Figure 6 (see Figure 1) graphically demonstrated the stratigraphic position of these brine flows in relationship to the proposed repository.

Several statements are made in the report implying that Castile brine flows are generally associated with anticlinal structures; these include: use of the term "...brine flow anticline..." (2-13.3), the criterion on anticlinal structures (2-22.1), the discussion of structure of the 124 marker bed on (4-69.3) and discussion of lithium resources (8-5.1). The structure of the top of the Castile (Figure 4.4-6) indicates anticlinal features within the immediate site area (e.g. at the north edge of Zone II) which are as severe as that associated with the Belco Hudson Federal brine flow. In view of the common association of the brine flows and anticlinal structures there appears to be little justification for the statement on (4-73.1); "There is no suggestion here of deformation of the type associated with artesian brine reservoirs."

The GCR makes no attempt to evaluate the possibility that geo-pressurized brine with H_2S may occur within the evaporites in places without anticlinal structures. Anderson (1976, p. 21-22) described such an occurrence at the UNM-Pokorney No. 1 location and noted that dissolution effects were similar to those observed at ERDA No. 6.

Brine reservoirs occur in the Castile formation which is directly below the Salado formation where the repository would be located and the brine reservoir at the ERDA No. 6 location has intruded locally up to the level of the lower part of the Infracowden salt. The origin, occurrence and configuration of these brine reservoirs are not adequately addressed in the GCR. For example, the geochemical analyses of the ERDA No. 6 brine are generally inconclusive with regard to the origin and period of isolation of the brine (see Section 6). It is conceivable that stress changes due to repository construction and/or heat generating wastes in combination with the high pressure in an underlying brine reservoir could induce deformation and fracturing which would release brine into the repository. In view of the large flows and volumes, high pressures, and accompanying H_2S of these reservoirs, they need to be characterized in detail in order to assess their role as a potential threat to health, safety and environment. Finally, future resource exploration could conceivably penetrate an underlying brine reservoir and bring pressurized brine to the surface.

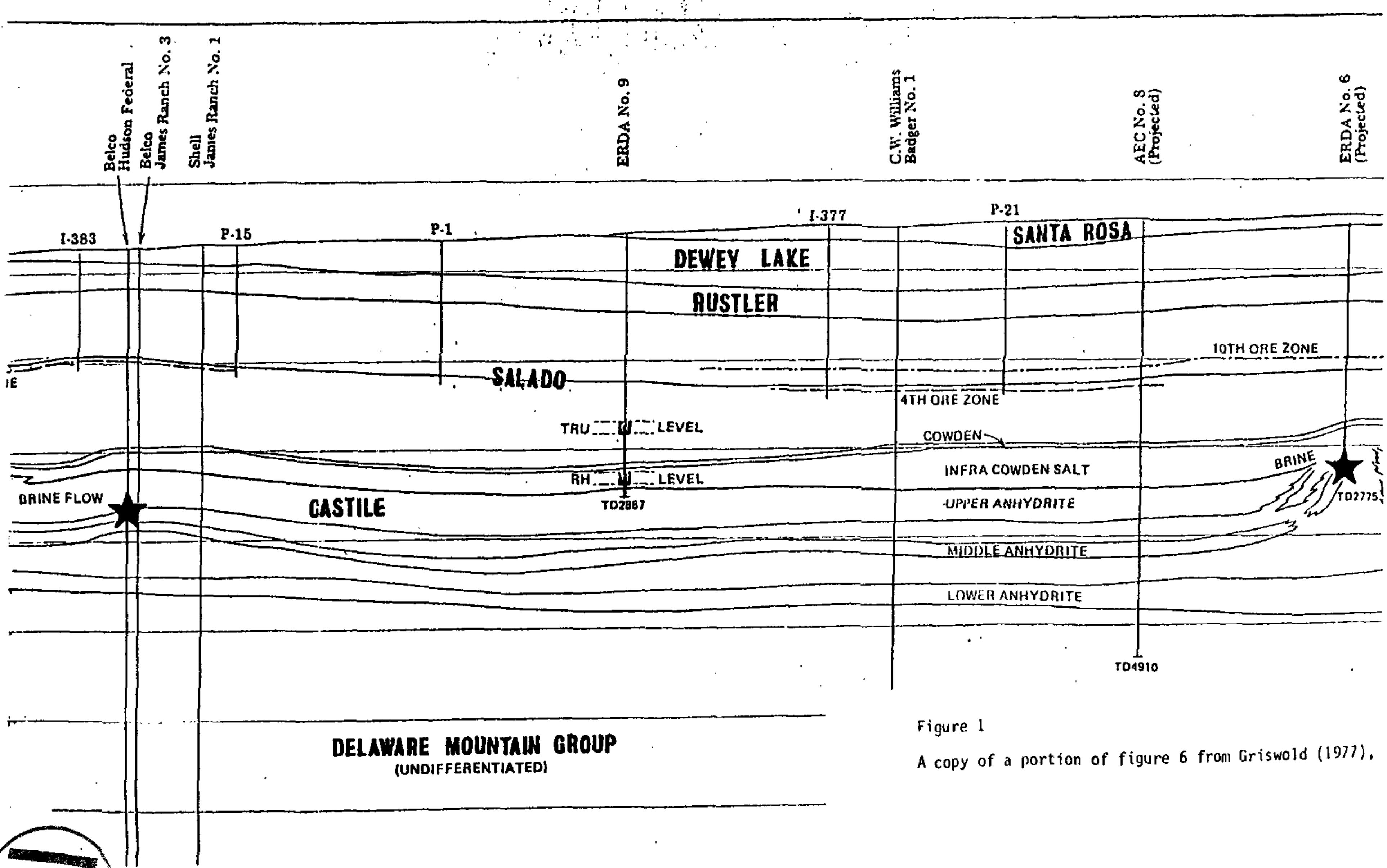

Figure 1

A copy of a portion of figure 6 from Griswold (1977).

3. Dissolution Processes and Rates

Salt dissolution can occur at different depths in the salt beds. The GCR presumes that the dissolution at the top surface of the Salado (shallow dissolution) is the most significant (1-26.2, 6-38). However, the presence of on-going deep dissolution, near the levels of the repository, has been suggested as a possible threat to the site. Both types of dissolution are discussed separately below.

Shallow Dissolution.

The GCR adopts the estimate by Bachman and Johnson (1973) that the lateral shallow dissolution front located 2 miles west of the site is approaching the site at 6 to 8 miles per million years and would take 225,000 years to reach a point 1,500 feet above the repository. However, the dissolution is probably not advancing eastward at a uniform rate. The front is envisioned as a "feather edge" (4-37.2) and certain tongues of the edge may move faster than others. Vertical dissolution is estimated at 0.33 to 0.5 feet per 1,000 years which would require 3 million years to remove the 1,500 feet of evaporites above the repository. Much of the salt in the Rustler formation directly above the repository has already been removed (4-41.3 and Figure 6.3-7) by dissolution along this front. How accurately is the location of the dissolution front and the rate of dissolution known?

Deep Dissolution.

The question arises whether deep dissolution is an on-going process in or near the horizons proposed for the repository and may play a role in helping to bring radioactive waste to the surface. EEG is presenting the following discussion in an attempt to help resolve the issue.

The GCR stated that exploratory holes, including ERDA 10 and ERDA 11 (6-2.1) as well as other data, indicate that deep dissolution is not taking place near the site. Anderson (letter to EEG, 4/24/79) has provided a photograph of a portion of the ERDA 10 core which shows a possible dissolution breccia in the lower anhydrite of the Salado formation. Anderson (letter to EEG, 5/14/79) also provided a photograph of core from WIPP 11 at a depth of 3100 feet showing clear replacement halite indicative of solution activity. The photographs are not included in this review since they do not reproduce clearly. EEG is sending them to the DOE for their interpretation. Why is ERDA 10 considered to be "...the nearest probable location of regional deep dissolution..." (6-42.1)?

According to Anderson (1978) deep dissolution within or below the salt has occurred extensively in the Delaware Basin. The GCR quoted Anderson's (1978) estimate that 50 percent of the original salt of the Delaware Basin evaporites has been removed (6-37.14) and that the salt from that unit will be gone from the basin in about another million years (6-45.3) but does not include his estimate that 73 percent of the lower Salado salt has been removed. Anderson's data indicate that the lower Salado salt beds, in which the disposal horizons are located, have been the most active zone of dissolution in the basin.

The GCR (6-45.2) appears to question Anderson's (1978) conclusion that dissolution is mainly a Cenozoic process and that it could remove the entire lower Salado salt in another million years, hypothesizing that deep dissolution may have been important in the Jurassic period. Anderson (1978) concluded that "The advancing effects of lateral dissolution can be expected to reach the disposal site before removal of the overlying salt beds." Are there any recent data to resolve this difference between Anderson and the GCR?

The GCR stated that "The proposed site is in an area of the Delaware Basin that is free of regional deep dissolution, but localized features are present in the vicinity" (6-41.3). What are these localized features?

The following geological phenomena may be related to deep dissolution.

Feature 5 mi. SE of site. The GCR discussed a map of Anderson on deep-seated dissolution features in the northern Delaware Basin and stated "The nearest of these deep mid-basin features to the proposed WIPP site...occurs about 5 miles southeast of the site..." (4-64.2). The sonic log of the Perry Federal #1-31 well in that area (Sec. 31, T22S, R32E, Fed-1, Figure 4.1-2) indicated that 200 feet of Infracowden salt was missing (R. Anderson, personal communication to Lynn Gelhar, 4/24/79). Furthermore, a major structural depression appeared in the 124 marker bed in that same location (see Figure 4.4-7). A similar depression in the 124 marker bed was found in the northern part of the WIPP site (see Figure 4.4-7, Sec. 9, T22S, R31E). The GCR suggests that this feature "...is not significant to the WIPP site" (4-70.1), citing isopach maps of Anderson (1978), and seismic reflection data. However, none of this information resolves the question of whether this depression is a deep-dissolution feature. The isopach maps (Figs. 4.3-4 through 4.3-7) do not cover the lower portion of the Salado or the Castile where the deep dissolution would be expected.

Anderson's regional isopach maps obviously are not going to resolve this feature because they are based on deep well data which are sparse in the site area. Seismic reflection data for the next horizon below the 124 marker bed (top of the Castile, Fig. 4.4-6) are inclusive in that area which is identified as "highly disturbed area".

Thinning of salt. Anderson's (1978) Figure 16 also showed a possible dissolution feature at the southwest edge of the site. The Infracowden salt (the high level waste horizon) thins rapidly toward the southwest and disappears completely about three miles from ERDA No. 9 in the area of this feature (Anderson 1978, Figure 7). The GCR (4-35.1) presents Jones' and Anderson's different interpretations of this thinning. Griswold (1977, p. 42) has suggested that brine pockets may be left behind a dissolution (suberosion) front. Might some of this thinning of Infracowden salt be associated with dissolution and brine flows in the area of the Belco Hudson Federal well?

The GCR (4-35.1) indicates that the lower member of the Salado is 1,195 feet thick at ERDA No. 9 and "...thins to 430 feet near the northeast corner of the area,..., due to beds missing at corrosion surfaces...". Where was the 430 foot thickness measured? "Corrosion" surfaces in ERDA No. 6 core samples are associated with dissolution (Anderson and Powers 1978). Is this thinning primarily due to faulting or is dissolution also a factor?

Origin of San Simon Sink. In discussing the origin of San Simon Sink, the GCR indicates that "shallow dissolution is a factor in the development of this sink" (6-40.3). In view of the depth of collapse, the scale of the feature, and its location along the reef margin, why is deeper dissolution not considered an equally good possibility?

Breccia pipes. Breccia pipes or "domal karst features" (Vine, 1960) are thought to be a result of localized removal of salt and are discussed on pages 2-17.2, 3-18, 4-7.1, 4-41.2 and 10-12.1. The second paragraph of the section on page 3-17 discussed Anderson's hypothesis that breccia pipes are caused by localized deep dissolution and brine density flow through fractures connected to an underlying aquifer. Anderson (1978) suggested that breccia pipes are formed by dissolution from below followed by collapse of the overlying units. Breccia pipes would then migrate upward and might eventually penetrate the surface. The deep dissolution theory of breccia pipe formation is consistent with conclusions reached in investigating the Michigan Basin [Landes, Ehlers, Stanley 1954] and collapse structures of the Prairie Formation Saskatchewan

[DeMille et al, 1964]. Anderson suggested that these processes are ongoing and that breccia pipes are presently being formed or could be activated in the basin. If Anderson's ideas are correct, and in view of the presence of dissolution features near the site, it is not inconceivable that breccia pipes may exist or may develop beneath the proposed repository.

The GCR indicated that recent drilling (WIPP 13) of a suspected breccia pipe has shown that the resistivity anamoly is not caused by dissolutioning (4-7). What data formed the basis for this interpretation? Also, what additional studies are planned to resolve the origin, occurrence and significance of breccia pipes? Anderson's (1978) concept, as well as others, of the origin of dissolution features in the salt beds in the Delaware Basin should be treated in detail.

The nature and occurrence of deep dissolution has not been resolved by the information in the GCR. Anderson (1978) has presented evidence indicating that deep dissolution can play a significant role in the removal of salt and concluded "Extensive regional and localized dissolution in the Delaware Basin and the random distribution and on-going nature of localized dissolution suggests that this particular basin may have already progressed to a stage of dissolution where geological estimates of site integrity may not be obtained with the required degree of certainty" (page IV). How will the mechanism and rate of deep dissolution be determined?

Future course of the Pecos River. Another aspect of salt dissolution is its possible effect on the future course of the Pecos River. The thickness of the salt section decreases on the order of 1000 feet from the WIPP site to a point at the Pecos River directly west of the site and the corresponding difference in surface elevation is around 400 feet. If dissolution causes subsidence east of the Pecos River, it could cause the river to migrate eastward toward the site. If the course of the Pecos River is so altered, this could lead to accelerated dissolution near the site.

The GCR does note briefly that the course of the Pecos River may be affected by solution features (3-10), but does not consider possible eastward migration of the river or its role in ongoing and future dissolution. What is being done to evaluate this possibility?

4. Site Structure and Geophysical Exploration

Information on structural features within the evaporites in and around the WIPP site is needed to evaluate potential hazards such as brine reservoirs or breccia pipes which may be associated with deformation or dissolution in the evaporites. Potash exploration holes provide some detail on shallow features but the only direct information on the disposal levels in the lower Salado is from a single well, ERDA No. 9. All information in the GCR on the underlying Castile formation in the site area appears to be based on seismic reflection surveys.

The GCR identified several anomalous features which may be of concern including:

a) A resistivity anomaly in the northern portion of Zone II bearing some resemblance to the patterns associated with breccia pipes (4-7.1). The GCR said it is a shallow surficial feature with no disturbance of underlying beds, based on drilling WIPP 13.

b) A 70-foot depression at the top of the Salado formation, two miles NE of the site (4-7.1).

c) A depression in the 124-marker bed in the Salado formation on the northern edge of the site, one mile west of feature b) (Figure 4.4-7). According to Anderson (1978,

p. 78), this feature could be associated with faulting in the Bell Canyon formation. If so, this would suggest that the depression was formed by deep dissolution, possibly caused by movement of water upward from the Bell Canyon formation.

d) A missing section of Infracowden salt (base of the Salado formation) 5 miles southeast of the site which also shows up higher in the Salado formation as a depression in the 124-marker bed.

e) A salt anticline located on the northern boundary of the site originating in the Castile formation. WIPP 11 was drilled through this structure to the lower anhydrite of the Castile and did not encounter brine (4-68.3, 4-69).

f) Seismic reflection data suggested the presence of faults at the top of the Salado formation north of ERDA No. 9 but data from WIPP 18, 19, 21 and 22 showed no apparent faulting (4-72).

Several wells were drilled to evaluate some of these features (WIPP 11, 13, 18, 19, 21, 22) and in each case the interpretation was that the anomaly was not significant. No information is given in the GCR on the type of data that was collected from the wells or the depth of the wells. What data are available for these wells?

The configuration of the top of the Castile (Figure 4.4-6) is important because that horizon may reflect deformation related to brine reservoirs or deep dissolution. Figure 4.4-6 indicated several faults with vertical displacement up to 300 feet, a possible anticline northeast of the site, and a "highly disturbed area" extending to the northeast. The significance of these structures is recognized in the GCR (4-73.1). "Among aspects needing further investigation,

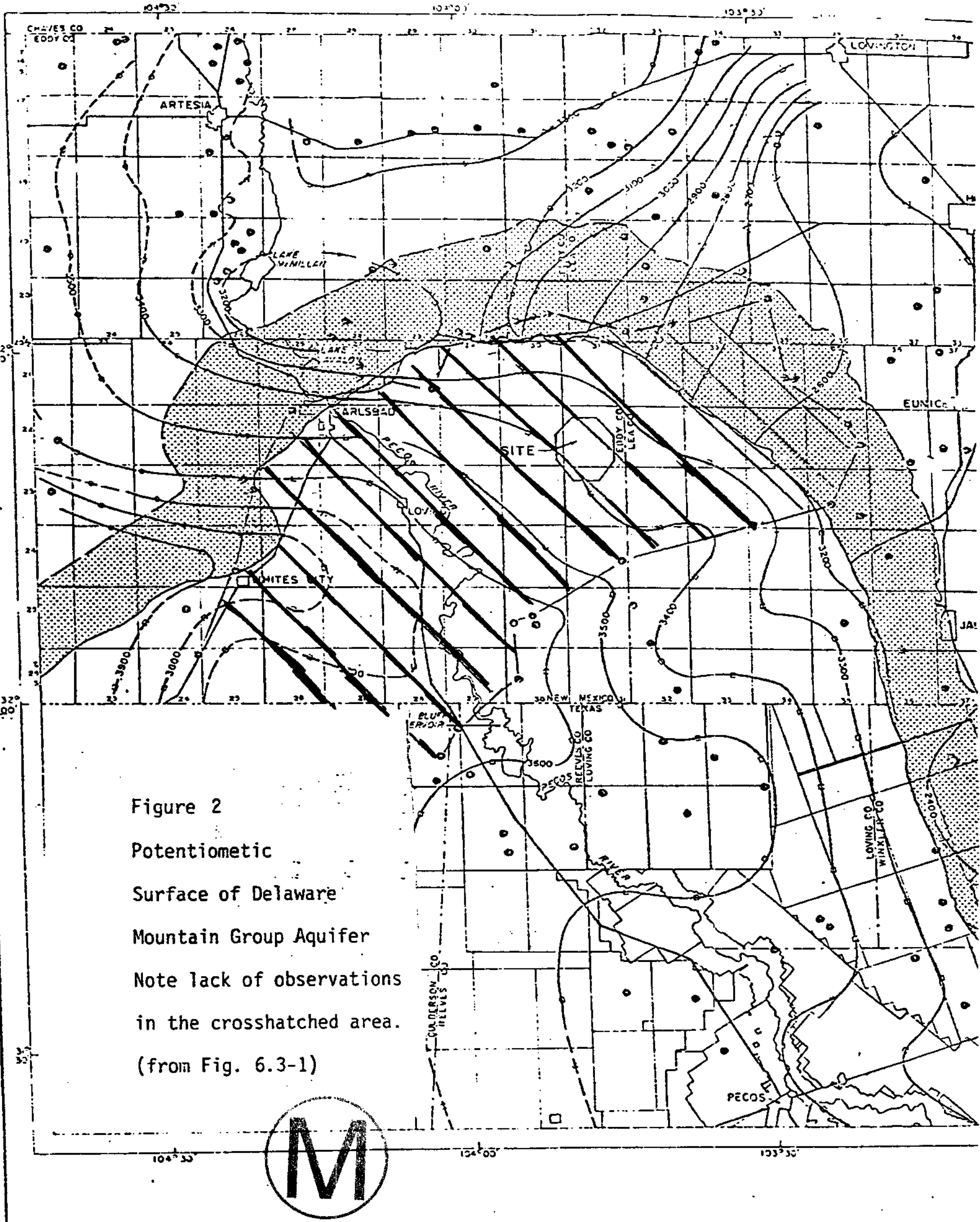

Figure 2
Potentiometic
Surface of Delaware
Mountain Group Aquifer
Note lack of observations
in the crosshatched area.
(from Fig. 6.3-1)

perhaps the most significant is a determination of the extent to which the upper levels of the Castile closest to the repository levels have been deformed by any salt deformation that may have taken place in the lower halite units of the Castile." Because of these uncertainties, the following statements in paragraph (4-73.1), (1) "There is no suggestion here of deformation of the type associated with brine reservoirs..." and (2) "This knowledge will permit a more detailed assessment relative to the location, design and construction of the storage facility but is not believed necessary for a general qualification of the site." do not appear warranted on the basis of information in the GCR or its references. In view of the complex structural feature indicated by Figure 4.4-6, what detailed justification is available?

Because of the possibility of localized deep-dissolution features (breccia pipes) in the site area, there is a need to define the ability of the seismic reflection method to detect such features. What information is available on the ability of the seismic reflection method or other geophysical techniques to detect breccia pipes or brine reservoirs?

5. Hydrology

Aquifers exist above, below and adjacent to the evaporite beds which are proposed for the repository. Therefore, subsurface hydrology at the site and in the region is a major concern because ground water flow controls the process of salt dissolution and is a primary transport mechanism for the release of radioactive material from the repository.

The underlying aquifer (Delaware Mountain Group) is discussed on (6-14); the potentiometric map for this aquifer (Fig. 6.3-1) is based on Hiss (1975). As shown in Figure 3, there is a large area around the site in which no well data were available. Are there additional data which could be included in this map? What about AEC 8? Also, would it be more useful to map the potentiometric surface of Delaware Mountain Group aquifers using a density near that of the aquifer waters?

The GCR (6-16.1) indicates that recharge to the Delaware Mountain Group occurs via precipitation on the outcrops and downward leakage through the younger rocks where the evaporites have been removed. If there is to be any assessment of the effects of climate change on this aquifer, it is necessary to know more specifically the locations and conditions in the recharge area(s) of the Delaware Mountain Group aquifer.

Data on the overlying aquifers are more extensive but the regional potentiometric map for the Rustler aquifers (Figure 6.3-2) contains no data from east of the site. The degree of connection between the brine aquifer and the Rustler aquifers east of the site should be clarified. Do the two aquifers have the same potentiometric surface (Figure 6.3-2)? The GCR contains no specific information on the nature of recharge to the Rustler aquifer; on (6-9.4) it states "...is presumed to be from precipitation in outcrop areas or from overlying formations." How much recharge occurs and what fraction of this enters the aquifer from the outcrop areas, and what fraction from the overlying formations? How will the recharge and flow in the Rustler aquifer be affected by climatic change? The summary of the Mercer and Orr (1978) report in the GCR (6-30.2) noted that head distributions in the Culebra Dolomite indicate fluid movement to the southeast across the site. This observation is not consistent with the regional potentiometric map (Figure 6.3-2) which indicated flow toward the southwest. How are these differences reconciled?

The summary stated "...measurements of the effective porosity...are very difficult to obtain". Have ranges been established of the effective porosity in the site area? This parameter is important in the hydrologic transport modeling of the long-term release of radioactive material from the repository. Aquifers adjacent to the evaporite beds are also of importance especially in relation to possible deep-dissolution in the evaporites. The discussion of the Capitan aquifer (6-17) does not consider the possibility of some lateral connection between the reef aquifer and the salt beds with the resulting development of deep-dissolution wedges and reef-margin dissolution features (Anderson, 1978).

The statement on (6-10) referring to the Castile formation "...as an aquiclude separating the Salado from the underlying sandstones of the Delaware Mountain Group" does not consider the possibility of fracture permeability which may be associated with deformation in the Castile, as suggested by Anderson (1978) in relation to deep dissolution.

The question of the effect of climate change on the hydrologic regime is not addressed.

Generally the hydrologic data for the region and the site is not adequate to characterize the long-term hydrologic transport of radioactive materials or to define the mechanism and rates of salt dissolution.

6. Geochemical Analyses

M

The analyses of waters from ERDA No. 6 (Sections 7.7 and 7.9) are intended to resolve questions about the nature and origin of this brine reservoir; the appropriate questions are stated on (7-90). On (7-102.4) the GCR concludes, on the basis of the uranium disequilibrium model, that the ERDA No. 6 reservoir "...has no connection with any other known ground water, and has been in its present environment for at least 880,000 years." This conclusion is unjustified. A more qualified statement is found on (7-99.1) that assumes an original connection to the Capitan reef and an original activity ratio equal to that of the Capitan reef water at "Carlsbad 7", $\alpha_0 = 5.14$.

One could assume as an initial value the results for the Middleton (α_0 = 1.81) or Hackberry (α_0 = 1.22) waters (Table 7.27) which also come from the Capitan aquifer and are geographically closer to ERDA No. 6 (see Fig. 7.18). From Figure 7.20 these values of α_0 yield much smaller ages; about 300,000 years for Middletone and a "negative" age for Hackberry. The results of the uranium-disequilibrium dating are stongly dependent on an assumed α_0 and do not provide any definitive information about the age or degree of isolation of the ERDA No. 6 reservoir.

On (7-99.1) it is indicated that the solid, liquid and gaseous phases are not in chemical equilibrium in the ERDA No. 6 brine reservoir. A static body of water would be expected to come to chemical equilibrium with surrounding rocks within a relatively short time frame. (Opinions expressed to EEG ranged from weeks to decades). Yet this presumably very old water was not found to be in chemical equilibrium with the host rock. One or more of the following is implied:

a) The laboratory analyses of brine, gas and stable isotopes are in error.

b) The ERDA No. 6 water is not "old", i.e., the interpretation of the uranium-disequilibrium method in the GCR (7-99) is invalid.

c) Water which has been in contact with other types of rocks is mixing with the brine reservoir fluids and preventing equilibrium.

d) Biogenic reactions which prevent equilibrium are occurring.

e) The surrounding rocks are not halite or anhydrite, contrary to core data.

As stated on (7-78) "The isotopic composition of ERDA No. 6 brine is consistent with an approach to isotopic equilibrium between water and clay minerals, not necessarily in the Castile." This observation is an additional indication that the ERDA No. 6 brine may not be indigenous to the Castile; this possibility is further supported by the following:

a) Gas analyses from ERDA No. 6 (7-76) predict a calculated P_{O_2} of 8.8×10^{-83} using CO_2-CH_4 redox equilibria. This value is not compatible with sulfate evaporite mineral assemblages.

b) Results of the synthesis of ERDA No. 6 water chemistry (Sample 14, Table 7.20) using the U.S. Geological Survey computer program WATEQF indicate that the water is undersaturated with halite, anhydrite and gypsum, but is saturated with calcite and dolomite.

c) WATEQF calculates a P_{CO_2} of $10^{-2.09}$; P_{CO_2} calculated from the basis of calcite saturation is $10^{-1.98}$ indicating that ERDA No. 6 water is in equilibrium with calcite.

These points suggest the possibility that ERDA No. 6 water has recently been in contact with dolomite and calcite, e.g. the Capitan limestone and associated dolomites (Figure 3.3-2) or the Bell Canyon formation which "contains considerable limestone interbeds and lime rich intervals" and whose top unit consists of limestone (Figure 4.3-2). Two possible routes for water movement from the Capitan reef were suggested by Anderson (1978, pp. 69, 72): along the contact between the Castile and Salado formation, or moving upward from the Bell Canyon formation through fractures in the Castile formation.

The stable isotope data for ERDA No. 6 water (Figure 7.12) indicated isotopic composition which is distinct from modern meteoric waters. However, these data do not give a positive indication of the origin of the water in the brine reservoir.

Regional water chemistry information is important because it can help to understand salt dissolution conditions and clarify the interpretation of the regional hydrology. However, the data are limited and are not systematically related to the possible flow system. There are two water samples from the Bell Canyon aquifer listed in the GCR (AEC 8 on Table 6-3.3 and Sample No. 9 on Table 7.20) and they have different chemical compositions. The composition diagram of Figure 3 was prepared from concentrations of 3 of the 8 ions listed on Table 7.20. Only one Bell Canyon water sample is included (No. 9). Figure 3 suggests that this Bell Canyon water sample has a composition similar to the three water samples from the Salado. This is consistent with the observation in the GCR that "this brine probably did not originate in the Bell Canyon, but its solutes probably came from nearby evaporites" (7-74.3). A possible interpretation of these observations is that solutes in the Bell Canyon aquifer have originated in the overlying evaporites. While this is not conclusive, it supports the Anderson (1978) hypothesis of deep dissolution through connection with the underlying aquifer.

None of the questions posed on (7-90) concerning the ERDA No. 6 reservoir are resolved with any degree of certainty by the geochemical information in Chapter 7; all that can be said is that the origin and evolution of such brine reservoirs in the evaporites remains a mystery.

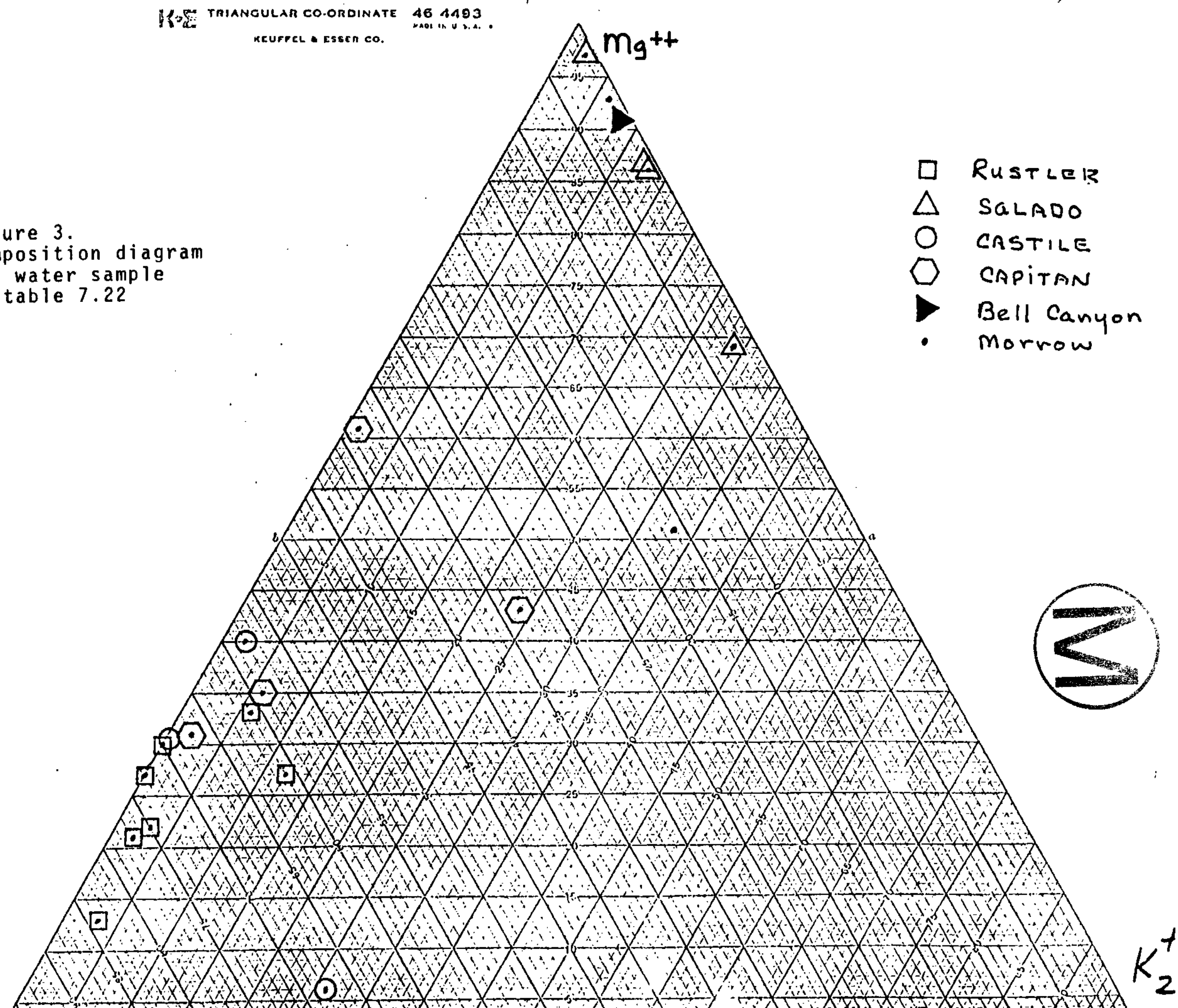

Figure 3.
Composition diagram
for water sample
of table 7.22

7. Rock Properties and Special Studies

The special studies of Chapter 9 are not being reviewed at this time. These studies are very important for the evaluation of the long-term integrity of a proposed repository, but Chapter 9 generally covers ongoing work which has not come to definitive conclusions. The following are some general concerns which will have to be resolved before the long-term integrity of the site can be evaluated.

a) The thermo-mechanical properties of salt and other adjacent rock are very complex especially when one is concerned with the regional-scale deformation induced by a proposed repository. The *in situ* properties of rocks at this scale can be strongly affected by impurities, heterogeneity and fracturing which is not accounted for in laboratory experiments of the kind described in Chapter 9. This problem is recognized on (9-2.3).

b) The radionuclide sorption properties of rocks are important in the hydrologic transport modeling of the long-term radioactive releases from a proposed repository. The static experiments with powdered rock samples (9-26) may not be relevant to the flow in fractured rock that would be involved in the Rustler aquifer (6-30.4).

   Additional laboratory and field work will be required to realistically describe the *in situ* sorptive properties of rocks at the site.

c) Migration of brine inclusions within the salt under the influence of waste induced thermal gradients could lead to undesirable accumulations of water in the repository. On (7-68.2) "Accurate predictions of the behavior of *in situ* inclusions in the thermal gradient around a canister in salt cannot be obtained at this time...". More information is required on this phenomenon.

8. General Comments

"The purpose of the GCR is to provide an account of the known geotechnical information considered relevant to site selection (see Section 2-3) for the proposed WIPP site" (2-2.2). Further discussion on (2-2.2) states "...for the most part, specific judgments regarding the suitability of the site are not made." A conclusion is presented on (2-7.1) that "Sufficient information has now been developed to allow the site to be adequately characterized for site selection purposes," and on (2-23.6) the statement is made that "...much basic information has been gathered indicating no major technical problems with the site as it is now understood."

Based on our review of the GCR and its references, additional data collection and analyses will be required in order for EEG to conduct its assessment of any potential release of radioactive materials to the surface and any subsequent effect on the health and safety of people and on the environment. Critical analyses of the role of localized geological perturbations such as breccia pipes, brine pockets and varying rates of dissolution are required for hydrologic transport modeling.

References

Landes, K.K., et al. "Geology of the Mackinac Straits Region and Sub-Surface Geology of Northern Southern Penisula," The Mackinac Breccia, Michigan Geological Survey Publication 44, Geological Series 37 (1954), pp. 123-254.

De Mille, G., et al. "Collapse Structures Related to Evaporites of the Prairie Formation, Saskatchwan," Geological Society of America, v. 75, (1964), pp. 307-316.

Tiab, D. Perform Reservoir Calculations on Brine Accumulation at ERDA No. 6 and Other Locations in the Vicinity of the Los Medanos Site in S.E. New Mexico, March 2, 1977.

APPENDIX IV

RADON RELEASES FROM WIPP

Summary

The quantities of radon expected to be released from operation of the WIPP site were calculated without any local measurements. The situation is discussed in greater detail below.

WIPP DEIS Radon Emanation Estimates

The DEIS uses a value of 0.9 curies/year of Radon-222 and 0.04 curies/year for Radon-220 obtained from the Nuclear Regulatory Commission's Final Generic Impact Statement on Mixed Oxide Fuels (GESMO). The DEIS also uses a typical concentration of 1×10^{-9} curies/cubic meter in exhaust air. These values are apparently estimates since they are unreferenced in the GESMO document.

There are no data in the DEIS on either uranium levels or radon at the surface or in the Salado formation where extensive mining would occur. In general, the Carlsbad area has a slightly lower than average terrestrial radiation, which suggests low uranium concentrations in the soil. While salt beds are usually low in uranium content, there are significant variations in different areas or geological formations and averages cannot be presumed. It is interesting to note that Carlsbad Caverns has high enough radon levels (up to 0.25 Working Levels) for the National Park Service to be concerned about exposure to their employees. (Ref. 1).

Since concentrations of radon from mines can vary over two to three orders of magnitude, it is necessary to obtain uranium, radium and radon data underground and at the surface. Three areas of environmental concern include:

(1) the amount of radon exhausted from the repository;

(2) the quantity of radon that emanates from the salt stored above ground; and

(3) the radon naturally emanating from the salt storage area (so that it can be estimated whether salt storage increases or reduces net emanation).

The possible doses from radon, while low, could be significant compared to other releases from the repository. See the attached calculations.

Radon Dose Estimates

DEIS Estimates

p. 8-33 $Q = 0.90$ Ci/y ^{222}Rn, 0.04 Ci/y ^{220}Rn

p. H-59 $\frac{X}{Q} = 6.2 \times 10^{-7} \frac{s}{m^3}$ at James Ranch (3 miles SSW of site)

$$\frac{pCi}{m^3} = \frac{9 \times 10^{11}\ pCi/y}{3.15 \times 10^{7}\ \frac{s}{y}} \left(6.2 \times 10^{-7}\ \frac{s}{m^3}\right) = \underline{\underline{0.18\ pCi/m^3}}$$

$$\text{Dose, mrem/y} = 0.18\ \frac{pCi}{m^3}\ \frac{(0.625\ mrem/y)}{\frac{pCi}{m^3}} = \underline{\underline{0.011\ mrem/y}}$$

Bronchial Epithelium

[conversion factor is from G-44 in GEIS Uranium Mills and is the average dose a resident indoors would get from an outside concentration of 1 pCi/m^3 of ^{222}Rn. This dose is to bronchial epithelium. Dose to pulmonary lung is only 4-11% of this (pages 6-39 and 6-67 of GEIS)]

p. 9-39 The DEIS uses a dose of 2.5×10^{-4} mrem/y to lung. This can be checked by the above information and the Dose Committment Factor from NUREG-0172, Table 8.

$$\text{Dose} = \frac{pCi}{m^3} \left(\frac{m^3}{y}\ \text{inhalation}\right) \left(\text{DCF}\ \frac{mrem}{pCi\ \text{inhaled}}\right)$$

$$= 0.18\ (7300)\ (2.05 \times 10^{-6}) = 2.6 \times 10^{-4}\ \frac{mrem}{y}$$

Reasonableness of DEIS Estimate

Assume an emanation rate from the mine equal to the average rate (1 pCi/sec-m^2) and that there may be as much as 5×10^5 m^2 exposed area in the tunnels and storage rooms (this could be high by factor of 2-3, depending on the plan for opening and closing rooms in the repository).

Then:

$$Ci/y = 5 \times 10^5 \; m^2 \left(10^{-12} \frac{Ci}{m^2\text{-}s}\right) 3.15 \times 10^7 \; \frac{s}{y} = \underline{\underline{15.7}} \; Ci/y$$

From Mine

No estimate has been made from possible salt pile radon. If radon emanation is even 1 pCi/m^2 - s above background, then for a 30 acre pile:

$$Ci/y = 30 \; Ac. \left(4.05 \times 10^3 \; \frac{m^2}{AC}\right) 3.15 \times 10^7 \; \frac{s}{y} \left(10^{-12} \frac{Ci}{s\text{-}m^2}\right)$$

$$Ci/y = \underline{\underline{3.8}} \; Ci/y \quad \text{from pile (per 1 pCi/}m^2\text{ - s)}$$

These values may be higher than exist at the site but they are by no means an upper bound, e.g. a variety of metal mines have been observed to have radon concentrations 2-40 times those assumed here. Evaporite deposits are typically an order of magnitude lower, yet in some cases they contain commercial ore deposits. Also, there is poor correlation between radon levels and ore geochemistry.

Possible Radon Doses

Assume 20 Ci/yr. radon release and check doses at two closest privately owned areas (James Ranch, use 3.0 mile SSW; and 2.8 mile NW) where residences are possible. Also check dosage at maximum 0.5 mile sector, because these areas are open to people.

Inhalation Dose

$$\text{millirem/yr.} = \frac{PCi}{s} \left(\frac{\chi}{Q} \frac{s}{m^3}\right) \frac{0.625 \text{ mrem/y}}{PCi/m^3}$$

$$= \frac{20 \times 10^{12} \frac{PCi}{y}}{3.15 \times 10^{7} \frac{s}{y}} (6.2 \times 10^{-7})\ 0.625 = \underline{\underline{0.25}} \text{ mr/yr.} \quad 3.0 \text{ mi}$$

$$= 6.34 \times 10^{5} \ (2.9 \times 10^{-6})\ .625 = 1.1 \text{ mr/yr.} \quad 2.8 \text{ mi}$$

$$= 6.34 \times 10^{5} \ (9 \times 10^{-5})\ .625 = \underline{\underline{35.7}} \text{ mr/yr.} \quad 0.5 \text{ mi}$$

Regional Annual Radon Dose Committment

A crude estimate of the total dose to the regional population from all pathways can be obtained by prorating the doses shown on Table 6-15 (attached) from the Generic Environmental Impact Statement on Uranium Milling (NUREG-0511). Adjustments need to be made for the difference in regional population (94,050 for WIPP versus the 57,300 used in Table 6-15) and for the curies of radon released (7,000 versus 20 curies/year).

$$\text{Adjustment Factor} = \frac{94{,}050}{57{,}300} \frac{20}{7000} = .00469$$

Bronchial Epithehium Dose = 138 man-rem (.0047) = $\underline{\underline{0.65}}$ man-rem

Bone Dose = 53.3 (.33) (.0047) = $\underline{\underline{0.08}}$ man-rem

Whole Body Dose = 6.47 (.35) (.0047) = $\underline{\underline{0.01}}$ man-rem

Lung Dose = 12.8 (.50) (.0047) = $\underline{\underline{0.03}}$ man-rem

Dose Comment

The regional doses from a 20 curie/year radon release are small. They are, however, similar in magnitude to the total doses presented in Table 9-19, not trivial as suggested on page 9-39.

It is also noted that the individual doses calculated in Table 9-18 are for James Ranch. Areas outside the security fence have χ/Q values as large as 9×10^{-5} s/m^3 (WNW at 0.5 mile) which is 145 times as large as used here. This needs further consideration.

Table 6.15 Annual Population and Environmental Dose Commitments Resulting from Operation of the Model Mill

Exposure Pathway	Annual Population Dose Commitments, person-rem/yr[a]							
	Total Dose Commitments				Doses Received by the Regional Population[b]			
	Whole Body	Bone	Lung	Bronchial Epithelium[c]	Whole Body	Bone	Lung	Bronchial Epithelium[c]
External from ground	0.511	0.511	0.511	-	0.511	0.511	0.511	-
External from cloud	2.36	2.36	2.36	-	2.36	2.36	2.36	-
Inhalation	0.170	4.61	6.48	138.	0.170	4.61	6.50	138.
Vegetable Ingestion	3.58	50.0	3.58	-	2.74	38.3	2.74	-
Meat Ingestion	2.94	30.24	2.94	-	0.437	4.49	0.437	-
Milk Ingestion	0.458	5.5	0.458	-	0.253	3.04	0.253	-
TOTALS	10.0	93.2	16.3	138.	6.47	53.3	12.0	138.

Exposure Pathway	Annual Environmental Dose Commitments, person-rem/yr							
	Total Dose Commitments				Doses Received by the Regional Population[b]			
	Whole Body	Bone	Lung	Bronchial Epithelium[c]	Whole Body	Bone	Lung	Bronchial Epithelium[c]
External from ground	1.97	1.97	1.97	-	1.97	1.97	1.97	-
External from cloud	2.36	2.36	2.36	-	2.36	2.36	2.36	-
Inhalation	0.170	4.61	6.50	138.	0.170	4.61	6.50	138.
Vegetable Ingestion	4.52	59.6	4.52	-	3.46	45.6	3.46	-
Meat Ingestion	4.70	40.7	4.70	-	0.710	7.24	0.710	-
Milk Ingestion	0.725	8.45	0.725	-	0.400	4.66	0.400	-
TOTALS[d]	14.6	125.7	20.9	138.	9.07	66.4	15.4	138.

[a] Based on exposure during the final year of mill operation.

[b] Doses received by the regional population are less than total doses for ingestion pathways because the regional population consumes only 76.5%, 14.9% and 55.2% of regionally produced vegetables, meat, and milk, respectively.

[c] Doses presented for the bronchial epithelium are those resulting from inhalation of short-lived Rn-222 daughters.

[d] The following percentages of annual dose commitments received by the region are due to annual radon releases (7.0 kCi): whole body, 35%; bone, 33%; pulmonary lung, 50%; and bronchial epithelium, 100%.

References - Appendix IV

1. U.S. Environmental Protection Agency. Radiation Protection Activities (EPA-520/4-77-005), 1976.

2. U.S. Nuclear Regulatory Commission. Draft Generic Environmental Impact Statement on Uranium Milling (NUREG-0511), April 1979.

3. U.S. Environmental Protection Agency. Radioactivity in Selected Mineral Extraction Industries, A Literature Review (ORP/LVF-79-1), November 1978.

APPENDIX V

ATMOSPHERIC DISPERSION COEFFICIENTS

I Long Term Averages

Procedure Used. Several key χ/Q values were calculated by EEG by a separate hand calculation to determine if the values from Table H-36 in the Draft EIS were reasonable. The procedure used differed in several ways from the MESODIF Code:

(1) It did not account for a plume being blown back over the source to contribute on the "second pass".

(2) It did not include the effect of releases during the 0.7% of the time that winds are below 0.3 meters per second ("calm conditions").

(3) The horizontal and vertical dispersion coefficients (σy, σz) for Category F were used for Category G conditions.

All of these differences would tend to make the calculated values of χ/Q less than those obtained from MESODIF.

The basic expression used was:[1]

$$\frac{\bar{\chi}}{Q}\text{ long-term} = \Sigma_{i} = A,B,C,D,E,F \; \frac{\left(\frac{2}{\pi}\right)^{1/2} fFi}{\sigma z_i \, \mu_i \, \frac{2\pi x}{n}} \; e^{-\frac{h^2}{2\sigma z^2}}$$

where

$\bar{\chi}$ = annual average downwind concentration in the sector of interest at distance x downwind, $\mu Ci/m^3$

Q = annual average discharge rate, $\mu Ci/s$

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[1] From: Fowler, Ted W., "Air Submersion Skin Surface Dose Rate from Noble Gases", EPA Radiological Review Guidelines No. 3, May 1973.

f = frequency of the time that wind blows in a given sector

$\frac{2\pi x}{n}$ = sector width where x is the downwind distance and n is number of sectors

F_i = annual stability persistence frequency for the f_i th meterological conditions (A,B,C,D,E, and F)

σ_{z_i} = vertical stability parameter for the i th meteorological condition at distance x downwind, m

$\bar{\mu}_i$ = wind speed at ground level for the i th meteorological condition, m/s

h = effective stack height, m

if elevated releases are ignored and 16 sectors are used this reduces to:

$$\frac{\bar{\chi}}{Q} = \Sigma_{i = A,B,C,D,E,F} \frac{2.032 f F_i}{\sigma_{z_i} \mu_i x}$$

The normal use of this equation would be where only the frequency of stability categories (in Table H-35 for the WIPP site) and the annual distribution of wind direction (Table 20, Annex 1, of Appendix H) is known. Average values of wind speed ($\bar{\mu}_i$) are used for each stability category (from Fowler). A sample calculation is shown below for the northwest downwind sector at 2.8 miles from the site.

Stability Category	F_i	$\bar{\mu}_i$ $\left(\frac{m}{s}\right)$	σ_z (m)	$\frac{F_i}{\sigma_{z_i} \bar{\mu}_i} \left(\frac{s}{m^2}\right)$
A	.255	2.46	2600	4.00 - 5
B	.033	2.69	570	2.11 - 5
C	.031	3.98	240	3.34 - 5
D	.136	5.86	83	2.77 - 4
E	.105	3.68	53	5.28 - 4
F	.119	2.00	33	5.07 - 3
G	.216			
			=	5.97 - 3

For NW downwind sector (f = 0.182)

$$\frac{\chi}{Q} = \frac{2.032\ (.182)(5.97-3)}{4.5 + 3} = \underline{\underline{(4.9 - 7)}}\ \frac{s}{m^3}$$

DEIS value from H-36, by interpolation = $(3.3 - 6)\frac{s}{m^3}$

A similar calculation at 3.0 miles SSW of the site gives a value of $(7.8 - 8)\frac{s}{m^3}$ compared to the DEIS value of $(6.2 - 7)\frac{s}{m^3}$

The DEIS contains more meteorological data than needed for the above simplified calculation. Use can be made of these data by using actual data for wind speed and stability category frequency in each downwind sector. An example is shown below for 2.8 miles northwest of the site. Wind speed frequency for each stability category is obtained from Tables 13-20 in Annex 1, Appendix H for the southeast wind direction.

Stability Category	μ_i (m/s)	fF_i	σ_z (m)	$\frac{fF_i}{\sigma_z \mu_i}$ $\left(\frac{s}{m^2}\right)$	
G & F	0.85	.033	33	1.28 - 3	
	2.25	.038		0.51 - 3	
	4.05	.002		0.02 -3	1.81 - 3
E	0.85	.003	53	0.67 - 4	
	2.25	.028		2.34 - 4	
	4.05	.022		1.02 - 4	
	6.55	.005		0.14 - 4	0.42 - 3
D	0.85	.001	83	0.14 - 4	
	2.25	.009		0.48 - 4	
	4.05	.005		0.15 - 4	0.08 - 3
C	2.25	.001	240	0.02 - 4	
	4.05	.001		0.01 - 4	0.00 - 3
B & A	Negligible by inspection				
					Σ = 2.31 - 3

$$\left(\frac{X}{Q}\right)_{2.8 \text{ mi NW}} = \frac{2.032\ (2.31 - 3)}{4.5\ +3} = (1.0 - 6)\frac{s}{m^3}$$

DEIS value from H-36, by interpolation $=(3.3 - 6)\frac{s}{m^3}$

A similar calculation at 3.0 mi SSW of the site gives a value of (1.4 - 7) $\frac{s}{m^3}$ compared to the DEIS value of (6.2 - 7) $\frac{s}{m^3}$.

Also, a calculation for 0.5 mi NW downwind sector was (1.6 - 5) $\frac{s}{m^3}$ compared to (6.2 - 5) $\frac{s}{m^3}$ in DEIS.

II Short Term Averages

The $(\frac{\chi}{Q})_{5\%}$ and $(\frac{\chi}{Q})_{50\%}$ one hour frequencies were calculated from inspection of Tables 16-19, in Annex 1, Appendix H. The key factor in determining each value is to find the $\sigma_{z_i} \mu_i$ value that is minimum at a given distance. This is done in the tabulation below at 800 m.

Stability Category	σ_{z_i} (m)	μ_i $(\frac{m}{s})$	$\sigma_{z_i} \mu_i$ m^2/s	Inverse Ranking
G & F	12	0.85	10	1
		2.25	27	4
		4.05	49	7
		6.55	79	
E	18	0.85	15	2
		2.25	41	5
		4.05	73	
		6.55	117	
D	27	0.8	23	3
		2.25	61	8
C	50	0.8	42	6

A SE wind direction (NW downwind sector) occurs 18.2% of the time. Consequently, the 5% frequency is 0.91% of the total time; the 50% frequency is 9.1%.

Percent occurrence: $G_{.85} = 2.6$; $F_{.85} = 0.7$; $D_{.85} = 0.1$; $E_{.85} = 0.3$; $G_{2.25} = 1.8$; $F_{2.25} = 2.0$; $E_{2.25} = 2.8$.

$\therefore (\frac{X}{Q})_{5\%}$ = G stability, 0.85 $\frac{m}{s}$ speed.

$$= \frac{2.032\ (1)}{10(805)} = (2.5 - 4)\frac{s}{m^3}$$

DEIS has $(2.8 - 4)\frac{s}{m^3}$

$(\frac{X}{Q})_{50\%}$ = E stability, 2.25 $\frac{m}{s}$

$$= \frac{2.032\ (1)}{41(805)} = (5.2 - 5)\frac{s}{m^3}$$

DEIS has $(6.3 - 5)\frac{s}{m^3}$

III Summary of Results

ATMOSPHERIC DISPERSION COEFFICIENTS
(Comparison of EEG and DEIS values)

Downwind Sector	Long-Term Values				One-hour Values			
	DEIS s/m^3		EEG s/m^3	RATIO DEIS/EEG		DEIS s/m^3	EEG s/m^3	RATIO DEIS/EE
SSW, 3.0 mi	6.2-7	(a)	7.8-8	7.9	(c)	5.6-5	1.5-5	3.7
		(b)	1.4-7	4.4	(d)	5.8-6	2.1-6	2.8
NW, 2.8 mi	3.3-6	(a)	4.9-7	6.7	(c)	6.5-5	1.6-5	4.1
		(b)	1.0-6	3.3	(d)	8.3-6	3.8-6	2.2
NW, 0.5 mi	6.2-5	(b)	1.6-5	3.9	(c)	2.9-4	2.5-4	1.2
					(d)	6.3-5	6.2-5	1.0

(a) Short method, using average stability category frequencies from H-35 and wind speed.

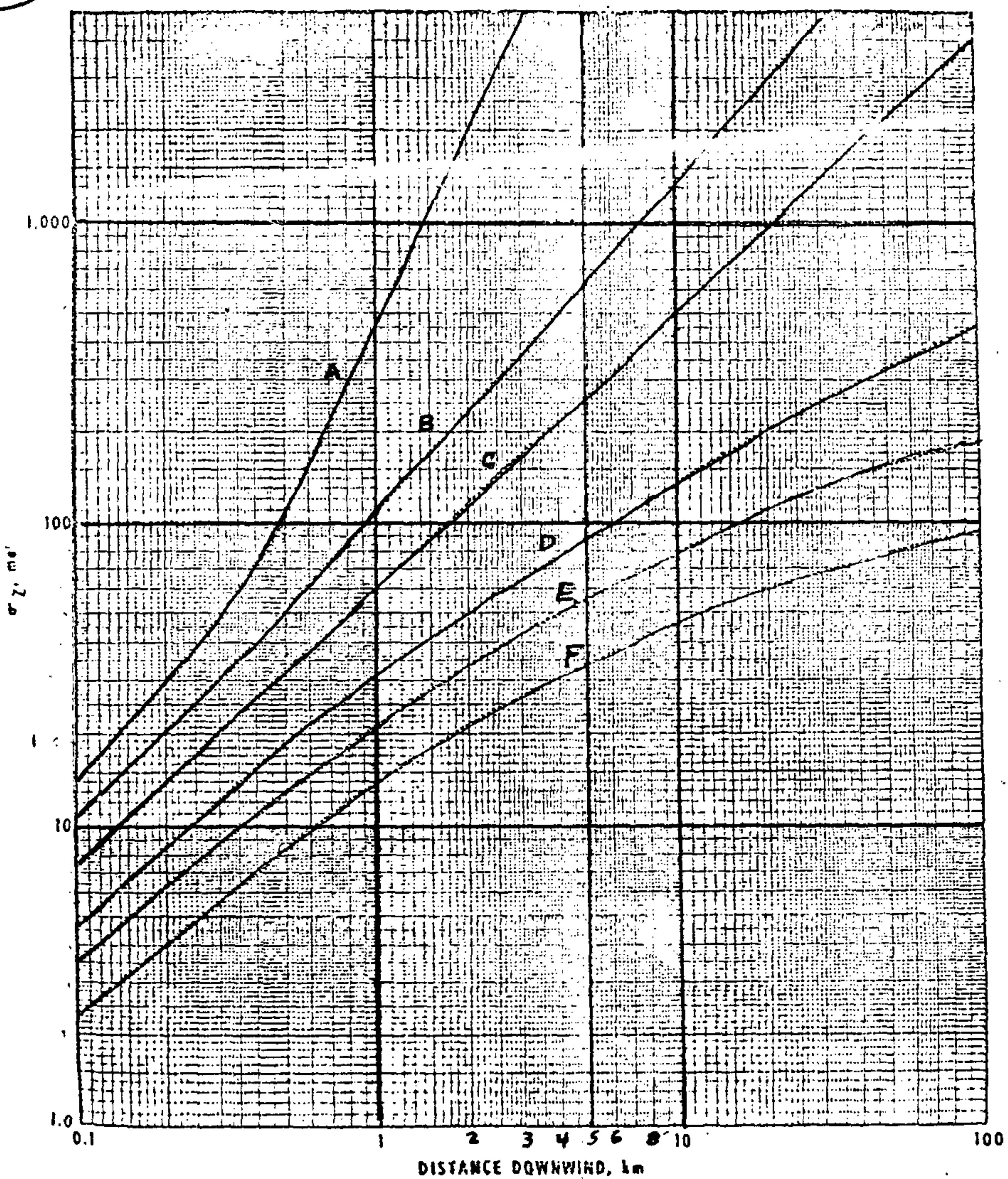
(b) Procedure using specific meteorological data in Annex 1, Appendix H.

(c) 5% occurrence, one hour frequency (Table 21, Annex 1, Appendix H).

(d) 50% occurrence, one hour frequency (Table 21, Annex 1, Appendix H).

The agreement is not too close in most cases with the values in the DEIS being consistently higher. Higher values in the DEIS are to be expected from the differences in models. The use of stability Category G parameters and the incorporating of calm winds into the model might reasonably increase the calculations by more than two-fold. Including the plume being blown back on the source would tend to increase the values some also. This is considered satisfactory agreement and it is concluded that the values used in the DEIS are reasonable.

Figure 1 - Vertical dispersion coefficient as a function of downwind distance from the source (2)



(2) Turner, D. Bruce, "Workbook of Atmospheric Dispersion Estimates", U.S. Department of Health, Education, and Welfare, Public Health Service, 1967.

IV Air Quality χ/Q

For calculation of the 24-hour ground-level concentration of particulates, the DEIS (p. 9-8) used the following equations (from Turner, 1969; PEDCo, 1973):

$$= \frac{0.360}{\pi \mu \sigma_y \sigma_z}$$

and assumed "restrictive dispersion conditions" that gave $(\sigma_y \sigma_z) = 17{,}000\ m^2$ at 2 miles. This is equivalent to category D conditions as computed by the formulas in Table G-1. This gives an "effective χ/Q" of:

$$\frac{\chi}{Q} = \frac{0.36}{\pi \mu (17{,}000)} = \frac{0.36}{\pi (3.14) 17{,}000} = (2.1 - 6) \frac{s}{m^3}$$

This value can be compared to the χ/Q values calculated in Appendix H for long term and one-hour frequency.

$$\left(\frac{\chi}{Q}\right)_{50\%} = (15 - 6) \frac{s}{m^3} \quad \text{(SW downwind sector)}$$

$$\left(\frac{\chi}{Q}\right)_{\text{long term}} = (5.9 - 6) \frac{s}{m^3} \quad \text{(NW downwind sector)}$$

Since the 24-hour χ/Q by this calculation is only about one-third of the annual χ/Q calculated in Appendix H, it is concluded that the two methods are inconsistent.

V Transportation X/Q Factors

From page G-3:

$$\frac{X}{Q} = \frac{1}{\pi \sigma_y \sigma_z u} e\left[-\tfrac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

Assumptions: distance = 0.5 mi, F stability conditions,
μ = 1 m/s, h = 20m

$$\sigma_z = .016d(1 + .0003d)^{-1} = .016(805)[1 + (3-4)(8+2)]^{-1} = 10.39$$

$$\sigma_y = .04d(1 + .0001d)^{-\frac{1}{2}} = 32.2[1+ .08]^{-\frac{1}{2}} = 31.0$$

$$\frac{X}{Q} = \frac{1}{\pi(10.4)(31.0)(1)} e^{-\frac{1}{2}\left(\frac{20}{10.4}\right)} = 9.9\text{-}4(.158) = \underline{\underline{(1.6 - 4)}}\frac{s}{m^3}$$

As comparison:

Worst annual (X/Q) at 0.5 mi = $(9.0 - 5)\frac{s}{m^3}$ (Table H-36).
9% of above.

$\left(\frac{X}{Q}\right)_{5\%}$ for 1 hour, 0.5 mi = $(4.3 - 4)\frac{s}{m^3}$ (Table 21, App. H).
44% of above.

$\left(\frac{X}{Q}\right)_{max}$ for 1 hour, 0.5 mi = $(1.1 - 3)\frac{s}{m^3}$. 111% of above.

The $\left(\frac{X}{Q}\right)$ for ground level release is between 5% and max one-hour $\frac{X}{Q}$ so is conservative compared to values used elsewhere in the DEIS.

Since the assumption of an elevated release significantly reduces the calculated doses, there should be more of a justification for its use, especially in an accident where no fire is assumed. Furthermore, the assumption of stability F conditions is not especially conservative since less stable conditions can result in similar concentrations occurring closer than 0.5 miles from the source. This analysis should consider other distances and stability categories and also the case of a ground level or other elevated release height.

Simple Model for Estimating Maximum Radionuclide Concentrations in the Pecos River, and Associated Ingestion Doses, due to the Release of Radioactivity from the WIPP Repository

by Moses A. Greenfield

A. The Square Wave Model

The model used in the Draft Environmental Impact Statement (DEIS, 1979) is based on a system of "three coupled partial differential equations describing the behavior of a liquid phase injected into an aquifer system" (INTERA, Sept. 1977). The equations are based on conservation of liquid mass, energy and the mass of a contaminant dissolved in the fluid. Additionally there are equations for each radioactive nuclide which conserve mass for each species and take account of radioactive decay.

Solutions for this complex system of coupled non-linear partial differential equations are obtained by developing finite-difference approximations in a three-diminsional grid (INTERA, Sept. 1977). There is also interest in developing relatively simpler solutions based on a one-dimensional approximation. The authors of the INTERA report checked the adequacy of their programmed trace component equations by comparison with known one-dimensional analytical solutions for radioactive chains (Lester et al, 1975). One-dimensional transport models have been developed by a number of writers and used to test parameter dependence and to compare different nuclide behaviors (Holly et al, 1971; Borg et al, 1976; Barr, 1979). It is helpful to give an elementary derivation to gain insight into the importance of the various terms that appear.

In Holly's treatment (loc. cit.) account is taken of nuclide transport due to water flow in a homogeneous, isotropic, porous aquifer with hydrodynamic dispersion, adsorption and desorption, and radioactive decay, with a one-dimensional spatial coordinate.

Figure I depicts a homogeneous, isotropic aquifer with groundwater flow rate $\bar{v}$, porosity Θ, single spatial coordinate x, and L and S representing the liquid and solid phases respectively. C_L, C_S represent the concentrations of a radionuclide in the two phases. An equation representing material balance in the element Δx after a time passage, Δt, may be written as follows:

I. $$\theta \cdot \Delta x \cdot \Delta C_L + (1 - \theta) \cdot \Delta x \cdot \Delta C_S = C_L \cdot \theta \cdot \bar{v} \cdot \Delta t$$

(expresses change in quantity of nuclide after a time passage, Δt, in volume element Δx.)

(flow in)

$$-\left(C_L + \frac{\partial C_L}{\partial x} \Delta x\right) \cdot \theta \cdot \bar{v} \cdot \Delta t$$

$\cdot$(flow out)

$$- \lambda \Delta t \left[\theta \cdot \Delta x \cdot C_L + (1 - \theta) \cdot \Delta x \; C_S\right]$$

(decay Fraction) (inventory in L,S.)

$$-D_L \frac{\partial C_L}{\partial x} \cdot \theta \Delta t + D_L \left[\frac{\partial C_L}{\partial x} + \frac{\partial^2 C_L}{\partial x^2} \Delta x\right] \theta \Delta$$

(flow associated with dispersion at entrance, exit of element; D_L assumed independent of x.)

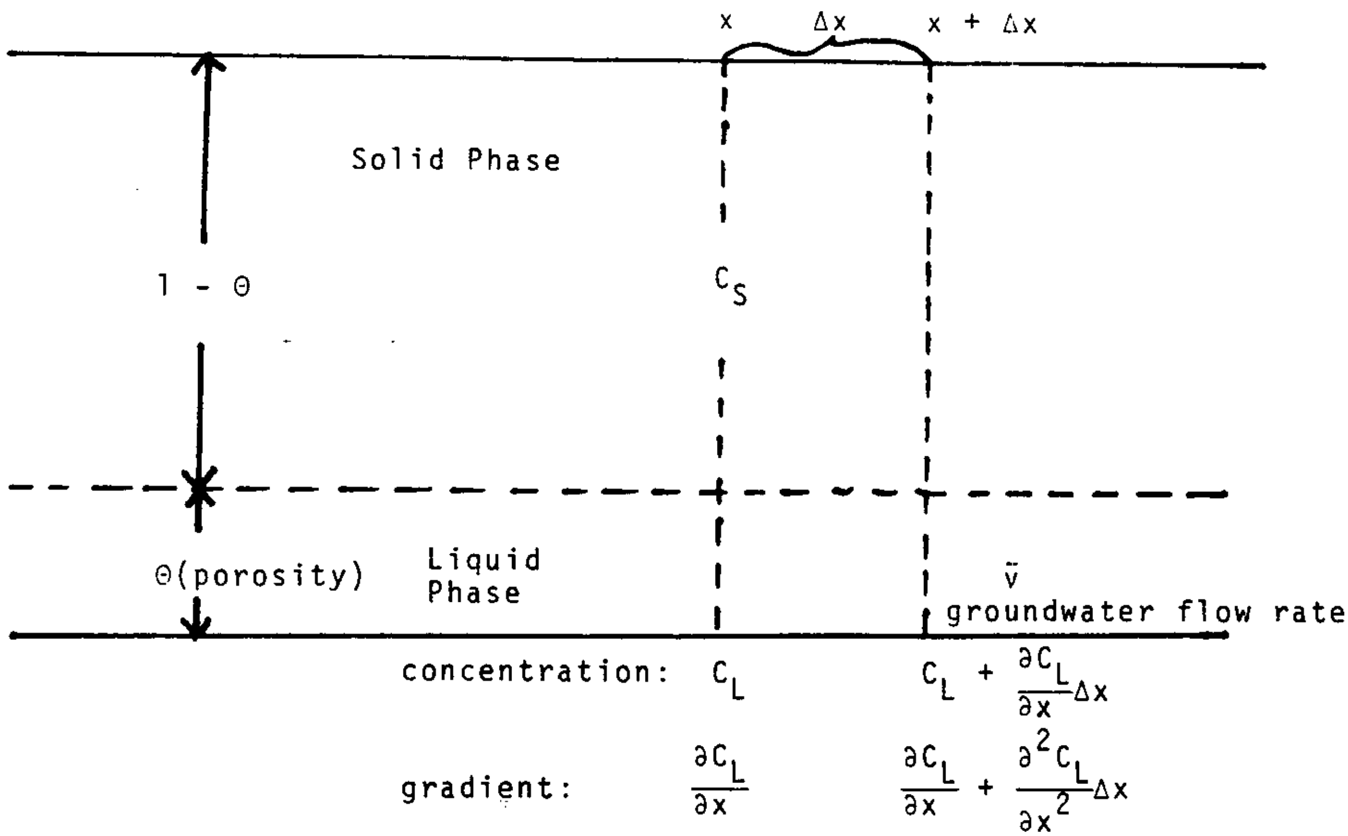
Equation I represents the material balance for any nuclide; λ is the decay constant and D_L is the coefficient of hydrodynamic dispersion.

Combining terms and dividing by $\theta \cdot \Delta x \cdot \Delta t$, gives:

II. $$\frac{\partial C_L}{\partial t} + \frac{1 - \theta}{\theta} \frac{\partial Cs}{\partial t} = - \bar{v} \frac{\partial C_L}{\partial x} + D_L \frac{\partial^2 C_L}{\partial x^2} - \lambda \left[C_L + \frac{1 - \theta}{\theta} Cs\right]$$

Adsorption may be introduced by assuming instantaneous equilibrium and reversibility between liquid and solid phases, with:

$$C_s = K_d' C_L \quad (K_d' \text{ dimensionless})$$



Volume Elements:

Liquid $\Theta\Delta x$

Solid $(1-\Theta)\Delta x$

C_L, C_S in $\frac{\mu Ci}{ml}$ or similar units

Figure 1

Also, let $K_d' = \rho_B K_d$, with ρ_B(g/ml) = bulk density of aquifer.

Then $\frac{C_s}{\rho_B} = K_d C_L$; ($\frac{C_s}{\rho_B}$ in μCi/g, K_d in ml/g).

K_d is called the distribution coefficient, and is a measure of the extent to which the solid adsorbs the nuclide. Values for K_d are listed in the DEIS, Volume II, Table K-3, page K-20, and were used as input parameters for the calculations made in the report.

Replace C_s in II by $\rho_B K_d C_L$. Then

III. $$\left(\frac{\partial C_L}{\partial t} + \lambda C_L\right)\left(1 + \frac{1 - \Theta}{\Theta} \rho_B K_d\right) = - \bar{v} \frac{\partial C_L}{\partial x} + D_L \frac{\partial^2 C_L}{\partial x^2} .$$

IV. Let $B = 1 + \frac{1 - \Theta}{\Theta} \rho_B K_d$; $K_L = e^{\lambda t} C_L$.

Then:

V. $$B \frac{\partial K_L}{\partial t} = - \bar{v} \frac{\partial K_L}{\partial x} + D_L \frac{\partial^2 K_L}{\partial x^2}$$

Let $t' = t/B$.

Then:

VI. $$\frac{\partial K_L}{\partial t'} = - \bar{v} \frac{\partial K_L}{\partial x} + D_L \frac{\partial^2 K_L}{\partial x^2} .$$

Values for D_L = 185 m^2/yr (P. Brannen, personal communication to M. Greenfield, 1979) and $\bar{v}$ = 4.45 m/yr (=0.04 ft/day)

(DEIS, II, K-14; also DEIS, I, 9-112) have been used in the report calculations.

Note that $\frac{D_L}{\bar{v}}$ = 41 m = 136 ft.

If the concentration gradient changes are small in ~40 meters, perhaps $D_L \frac{\partial^2 K_L}{\partial x^2}$ can be neglected in some approximation compared to $\bar{v} \frac{\partial K_L}{\partial x}$.

VII $$\frac{\partial K_L}{\partial t'} + \bar{v}\,\frac{\partial K_L}{\partial x} = 0$$

Any function of the form $f\,(x - \bar{v}t')$ or $f[x - (\frac{\bar{v}}{B})\,t]$ will satisfy this partial differential equation; it represents a traveling wave form, f, moving with the speed $\frac{x}{t} = \frac{\bar{v}}{B}$ from repository site towards the river. Thus if B>>1, then the consequences will be a retarded nuclide movement. The actual concentration C_L is of the form $e^{-\lambda t}f$. For a collection of nuclides, indexed by i, each will move with its own velocity, $\bar{v}/Bi$, and will be modified by its own decay factor, $e^{-\lambda_i t}$, and the appropriate inventory activity, A_i.

If one assumes a common dissolution time, T_d, then $\frac{A_i}{T_d}$ is the time rate of release from the repository, acting as a source term. Figure 2 depicts the "spectral" composition of nuclides traveling from the repository to the Pecos River.

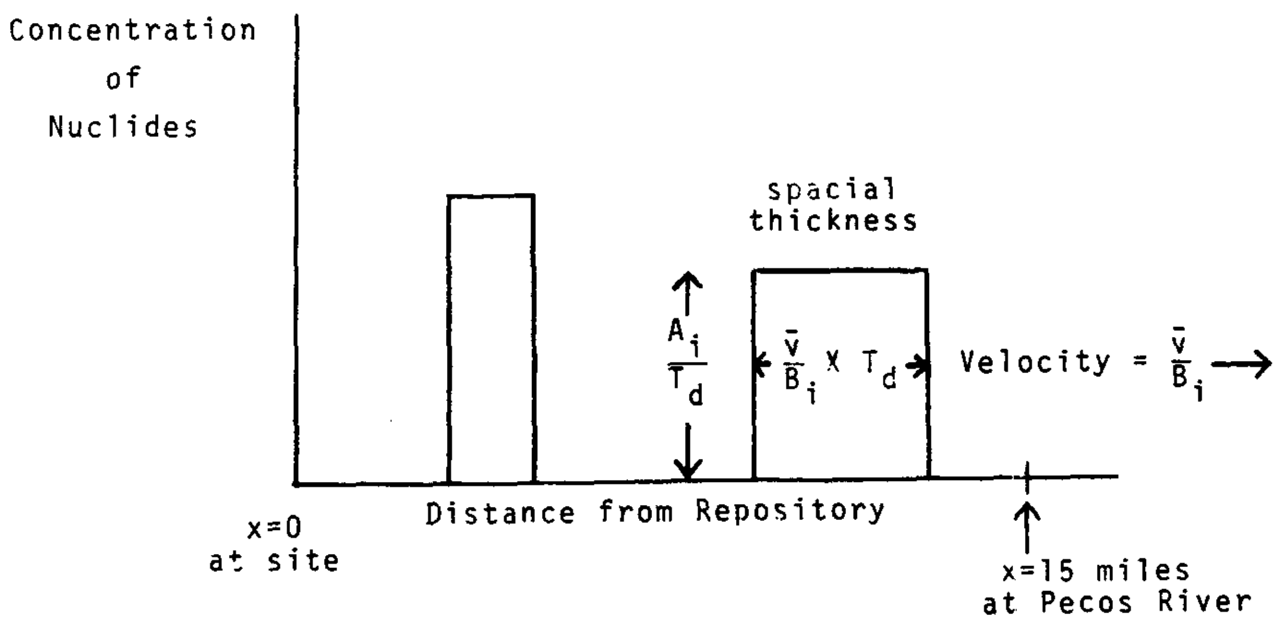


Figure 2.

Arrival time $(AT)_i$ to Pecos River is $\frac{15 \text{ miles}}{\bar{v}/B_i}$.

Release Rate from Repository (RRR) is $\frac{A_i}{T_d}$.

Discharge Rate at Pecos River (DR_{PR}) is $\frac{A_i}{T_d} e^{-\lambda_i (AT)_i}$

If the flow rate of the Pecos River is F, then the concentration of nuclides at the Pecos River, (C_{PR}), is $\frac{A_i}{T_d} \cdot \frac{1}{F} \cdot e^{-\lambda_i (AT)_i}$,

at the arrival time $(AT)_i$.

The purpose of constructing this rather crude and simple "square wave" model is to use a zero order approximation approach for comparison with the calculations in the DEIS reports. Since the model is one-dimensional and dispersivity is neglected, one may reasonably expect concentrations and doses to be greater than those based on a more elaborate 3 dimensional approach. Clearly this comparison is intended only as a rough check on the validity of the methodology used in the DEIS calculations. If there is an approximate agreement, then attention may be turned to the assumed values for the input parameters, notably $\bar{v}$ the groundwater flow velocity and the K_d values.

B. Parent-Daughter Decay Chain

The preceeding analysis assumes that repository inventory accounts for all the nuclides that potentially may travel towards the Pecos River. Actually one must consider daughter decay products as additional sources. In some instances the production of the nuclide via decay may be much greater than the source from the repository. Another reason for the importance of decay products stems from the retardation values, B, for some nuclides. For example, the K_d value for Thorium is given as 2200 ($\frac{ml}{g}$) (DEIS, II, Table K-3, p. K-20). This leads to a B value of the order of 10^4, which precludes the travel of Thorium from the repository (Th-230 and Th-229). However, Th-229 is the daughter decay product of U-233 which is present in the repository inventory. The listed value of K_d for uranium is 1 (ml/g) (DEIS, II, Table K-3, p. K-20) which leads to a B value for uranium of about 19. Thus U-233 travels from the repository to the Pecos River in a time interval of approximately $(AT)_{U-233}$ = 19(15 mi./.04 ft./day) = 10^5 years. The Th-229 in effect gets a "piggy-back" ride and makes the journey in the same time interval. The following analysis develops the relations needed to compute release rates into the Pecos River and consequent concentrations.

Assume a single daughter, D, from a parent, P, with decay constants λ_D, λ_P. The initial parent activity (in the repository) is $A_{P,0} = \lambda_P N_{P,0}$ ($N_{P,0}$ is the number of parent atoms initially in the repository). Assume the daughter activity initially is $A_{D,0} = 0$.

In general.

I.

$$\frac{dN_D}{dt} = \lambda_P N_P - \lambda_D N_D = A_P - A_D$$

$$N_P = N_{P,0} e^{-\lambda_P t}$$

Thus, at t=0:

II.

$$\left.\frac{dN_D}{dt}\right|_0 = \lambda_P N_{P,0} = A_{P,0}$$

Thus, the initial rate of production of daughter activity is:

III.

$$\lambda_D \left.\frac{dN_D}{dt}\right|_0 = \left.\frac{dA_D}{dt}\right|_0 = \lambda_D A_{P,0}.$$

For a very long lived parent, III is a convenient approximation for computing the rate of production of a daughter.

The general solution for I is:

IV.

$$N_D = \frac{A_{P,0}}{\lambda_D - \lambda_P} \left[e^{-\lambda_P t} - e^{-\lambda_D t} \right]$$

The general form for $\frac{dA_D}{dt} = \lambda_D \frac{dN_D}{dt}$ can be stated as:

$$\text{V.} \qquad \frac{dA_D}{dt} = \lambda_D A_{P,0} \left[\frac{\lambda_D e^{-\lambda_D t} - \lambda_P e^{-\lambda_P t}}{\lambda_D - \lambda_P} \right]$$

One may also compute the ratio (A_D/A_P):

$$\text{VI.} \qquad \frac{A_D}{A_P} = \frac{\lambda_D}{\lambda_D - \lambda_P} \left[1 - e^{-(\lambda_D - \lambda_P)t} \right]$$

For sufficiently long times (with $\lambda_D t >> 1$), VI becomes:

$$\text{VII.} \qquad \frac{A_D}{A_P} = \frac{\lambda_D}{\lambda_D - \lambda_P}$$

An approximation for the daughter discharge rate into the Pecos River can be derived. Assume that $B_D >> B_P$. One may picture the "square wave" concentration of the parent making its journey to the Pecos River, dropping or leaving behind the daughter product distributed along the pathway from repository to the Pecos River. Compute the total activity of the daughter at the arrival time, AT_P, of the parent $(AT_P = \frac{15 \text{ miles}}{\bar{v}/B_P})$, distributed spatially along the 15 miles.

From VI:

$$\text{VIII.} \qquad A_D = \frac{\lambda_D}{\lambda_D - \lambda_P} \left[1 - e^{-(\lambda_D - \lambda_P)\,(AT)_P} \right] \times A_{P,0} e^{-\lambda_P (AT)_P}$$

If one makes the approximation that this activity of the daughter is uniformly spread over the 15 miles (actually there is a small gradient which is computed later in this report for an actual case), then the spatial distribution at the time AT_P is:

$$\frac{\Delta A_D}{\Delta x} = \left. \frac{A_D}{15} \right|_{t = AT_P}$$

Now one may compute the linear velocity of this distributed activity as:

$$V_D = \frac{\bar{v}}{B_D}$$

Combining the spatial distribution with the velocity yields the discharge rate into the Pecos River (DR_{PR}):

IX. $$DR_{PR} = \frac{A_D}{15} \times \frac{\bar{v}}{B_D} \Bigg|_{t=AT_p}$$

C. <u>Computation of Discharge Rates into the Pecos River and of Concentrations; Comparison of Peak Values (and Times) With Intera Calculations</u>

Scenario 4 mandates the full flow of Rustler aquifer through the repository, and assumes the complete dissolution of the spent fuel assemblies along with the bedded salt. The DEIS states that this proposed event is a bounding case, and for this reason it was chosen for calculation using the linear, square-wave model.

Column 1 of Table 1 lists the nuclide and Column 2 lists the inventory activity, A, in curies contained in the 1000 spent fuel assemblies in the repository. These numbers are based on the tabulated values of Ci/liter for each nuclide, 10 years after discharge from the reactor, (DEIS, I, Table 9-44, p. 9-104), and the computed volume per assembly (or canister) of 485 liters. This number is based on the stated dimensions of the assembly as 14 inch diameter by 16 foot length.

$$Vol_{can} = \frac{\pi D^2 H}{4} = \frac{\pi}{4}\left(\frac{14}{12}\right)^2 16 \text{ ft.}^3$$

$$= 17.1 \text{ ft.}^3 = 485 \text{ l.}$$

Thus the inventory listing for Tc-99 is obtained as:

$$1.4 \times 10^{-2} \text{ Ci/l} \times 485 \text{ l/can} \times 10^3 \text{ can}$$

$$= 6.8 \times 10^3 \text{ Ci.}$$

Th-232 is omitted in column I because the inventory is very small, a factor of 10^4 less than the next larger amount (Th-229).

Column 3 lists the release rate from the repository (RRR) in (μCi/sec), obtained by dividing the activity in column 2 by the dissolution time T_d = 4650 yrs. = 1.47×10^{11} sec.

This value for T_d is based on a dissolution rate of 21.4 ft.^{3}/day (salt plus radioactive material), and a repository volume of (930 x 930 x 42)ft.^{3} = 3.63×10^7 ft.^{3}. Thus $T_d = \frac{3.63 \times 10^7}{21.4}$ days = 1.70×10^6 days = 4,650 yrs. = 1.47×10^{22} sec.

(DEIS, I, p. 9-112; II, p. K-14.)

Column 4 lists the values for the retardation factor, $B = 1 + \frac{1-\theta}{\theta} p_B K_d$ (equation IV, section A). The porosity, Θ, for the Rustler aquifer is taken as 0.1 (DEIS, II, K-18): ρ_B is assumed to be 2g/m^3. Values for K_d are taken from DEIS, II, Table K-3, p. K-20.

Column 5 lists arrival times, AT, at the Pecos River computed as:

$$(AT)_i = B_i \ (5280) \text{ years.}$$

Since $(AT)_i = 15 \text{ mi.}/(\bar{v}/B_i)$ and $\bar{v}$ = .04 ft./day or 15 ft./yr.

Column 6 lists half- lives (DEIS, I, Table 9-44, 9-104).

Column 7 lists computed discharge rates into the Pecos River (DR_{PR}) in units of (μCi/sec), based on the release rate from repository with an appropriate decay factor: $(DR_{PR}) = (RRR)e^{-\lambda(AT)}$.

Column 8 lists the concentration in the Pecos River computed by dividing the discharge rate by the volume flow rate of the river, 515 l/s (DEIS I, 9-116).

Column 9 lists peak values for concentrations in the Pecos River as computed by INTERA and listed in BDM/TAC 79-156-TR, Appendix B, P. B-4 through B-27.

D. <u>Discharge Rates into Pecos River, Concentrations for Daughter Products</u>

Discharge rates for a number of nuclides were not computed (column 7) either because of relatively short half-lives, or rather large B (K_d) values or both (Ra-226, Th-229, Th-230, Np-237, Pu-239, Pu-240, Pu-242, Am-243). However a number of these are produced as daughter products of "traveling" parents and computations are then made on that basis. For example:

U-234 (P) →→→ Th-230 (D);
Th-239 (P) →→→ Ra-226 (D);

Thus both Ra-226 and Th-230 will piggy-back on the U-234.

In the case of U-233, the repository is a source. Np-237 in the repository doesn't travel because of a large B(K_d) value. However Np-237 does produce U-233, which constitutes a second (and larger) source for that nuclide. Additionally:

U-233 (P) →→→ Th-229(D).

In this case the Th-229 will piggy-back on a traveling parent, U-233.

D.1. Consider this series:

U-238 (4.8×10^9 yrs.)
↓
U-234 (2.4×10^5 yrs.)
↓
Th-230 (0.77×10^5 yrs.)
↓
Ra-226 (1.6×10^3 yrs.)

For the first pair (U-238, U-234):

A_{U-238} (repository) = 146Ci
RRR U-234 = 5.9×10^{-3} (μCi/sec)

(from Table 1, column 2 and 3). From section B, equation III,

$$\lambda_{U-234} \frac{dN_U}{dt} = \frac{0.693}{2.4 \times 10^5 \text{ yr.}} \times 146 \text{ Ci} \times 10^6 \text{ µCi/Ci}$$

$$\times \frac{\text{yr.}}{0.315 \times 10^8 \text{ sec.}}$$

$$= 1.3 \times 10^{-5} \text{ µCi/sec.}$$

This is <1/4% of RRR U-234, and is unimportant as a source term.

D.2. Now consider U-234→ Th-230; A_{U-234} = 870 Ci.

Compare the initial rate of growth of Th-230 activity with the repository source, RRR_{Th-230}. From section B, equation III,

$$\lambda_{Th-230} \frac{dN_{Th-230}}{dt} = \frac{0.693}{0.77 \times 10^5 \text{ yr.}} \times 8.7 \times 10^2 \text{ Ci}$$

$$\times 10^6 \text{ µCi/Ci} \times \frac{\text{yr.}}{0.315 \times 10^8 \text{ sec}}$$

$$= 2.5 \times 10^{-4} \text{ µCi/sec.}$$

This is about 5 x RRR_{Th-230} (= 4.6×10^{-5} µCi/sec).

Thus not only is the radioactive decay of U-234 a larger source term to produce Th-230 (compared to repository), but the uranium also acts as a carrier.

The method outlined in section B is now used to compute the discharge rate into the Pecos River.

First compute the total activity of the Th-230, distributed along the 15 miles. The time of interest is the arrival time, AT, for the parent of U-234, which is 1.0×10^5 yrs. (Table 1, column 5). At t = 10^5 yrs., the activity of U-234 is:

$$A_{U-234(t=o)}\; e^{-\lambda_{U-234}(AT)}$$

$$= 870 \text{ Ci} \times \exp\left\{\frac{-0.693 \times 10^5}{2.4 \times 10^5}\right\}$$

$$= 870 \times 0.75$$

$$= 652 \text{ Ci}.$$

The activity of daughter Th-230 is given by (section B, equation VIII):

$$\frac{A_{Th-230}}{A_{U-234}} = \frac{0.693/0.77}{(0.693/0.77) - (0.693/2.4)} \times \left[1 - e^{-\left(\frac{0.693}{0.77} - \frac{0.693}{2.4}\right)}\right]$$

$$= 0.67.$$

Thus, $A_{Th-230} = 652 \times 0.67 = 437$ Ci at $5=10^5$ yrs.

The distribution of this activity spatially over the 15 miles is not uniform, but the gradient is not large. It can be estimated by computing the rate of formation in (Ci/Kyr) at the Pecos River ($t=10^5$ yrs.) vs. the rate of formation at the repository with an allowance for a time interval of 10^5 hrs. to elapse.

Using section B, equation III, at the repository, at t=0:

$$\frac{dA_{Th-230}}{dt} = \frac{0.693}{0.77 \times 10^2 \text{ Kyr}} (870\text{Ci}) = 7.8 \text{ Ci/Kyr}$$

Thus at the repository, at $t=10^5$ yrs., this would in effect be diminished by the decay factor:

$$\exp\left\{\frac{-.693 \times 10^5}{0.77 \times 10^5}\right\} = 0.407$$

or $\frac{dA_{Th-230}}{dt} = 7.8(.407) = 3.2$ Ci/Kyr at the repository at $t=10^5$ yrs.

However at the Pecos River, at $t=10^5$ yrs, from section B, equation V:

$$\frac{dA_{Th-230}}{dt} = \left(7.8 \frac{Ci}{yr}\right) \left[\frac{\frac{0.407}{0.77} - \frac{0.749}{2.4}}{\frac{1}{0.77} - \frac{1}{2.4}}\right] = 1.9 \text{ Ci/Kyr}$$

Thus an inventory of 437 Ci of Th-230 is distributed along the path from the repository to the Pecos River, with a spatial gradient such that the relative concentration (Ci/mile) at the repository is just $\frac{3.2}{1.9} = 1.7$ x the value at the Pecos River. If the variation is assumed to be linear with distance it can be shown that the spatial gradient varies from 36.7 $\frac{Ci}{mile}$ at the repository to 21.7 Ci/mile at the Pecos River. (If uniformity had been assumed, the value would be $\frac{437 \text{ Ci}}{15 \text{ miles}} = 29.1 \frac{Ci}{mile}$). The linear speed of this activity is computed as:

$$V_{Th-230} = \frac{\bar{v}}{B_{Th-230}} = \frac{0.04 \text{ ft/day}}{0.396 \times 10^5} \left[\frac{1}{0.528 \times 10^4 \text{ ft./mile}}\right]$$

$$\times \left[\frac{1}{0.864 \times 10^5 \text{ sec/day}}\right]$$

$$= 0.221 \times 10^{-14} \text{ miles/sec.}$$

Combining the speed with spatial gradient one computes the discharge rate:

$$DR_{Th-230} = 21.7 \frac{Ci}{mile} \left(10^6 \frac{\mu Ci}{Ci}\right) 0.221 \times 10^{-14} \frac{miles}{sec}$$

$$= 4.80 \times 10^{-8} \frac{\mu Ci}{sec.}$$

Dividing by the flow rate of the Pecos River, $F = 515 \frac{\ell}{sec}$:

$$C_{PR,\ Th\text{-}230} = \frac{4.80 \times 10^{-8} \ \frac{\mu Ci}{sec}}{5.15 \times 10^{2} \ \frac{\ell}{sec}}$$

$$= 0.93 \times 10^{-10} \ \mu Ci/\ell.$$

The comparison value (Intera) listed in BDM-TAC 79-156-TR, Appendix B, B-12 is:

$$1.01 \times 10^{-10} \ \frac{\mu Ci}{\ell} \quad \text{at} \quad t = 10^{5} \text{ years.}$$

D.3. The calculation for radium-226, the last daughter of interest in the U-238 chain can only be approximated with the crude model being used, in part because of its relatively short half-life. However an upper limit can be estimated.

Since Ra-226 is so short-lived, it may be assumed to be in secular equilibrium with its parent, Th-230. At or close to the time $t = 10^{5}$ years, the parent activity is $A_{Th\text{-}230} = 437$ Ci (see D.2.). In this case, use section B equation VII, to compute the daughter activity:

$$A_{Ra\text{-}226} = 437\ (1.02) = 446 \text{ Ci.}$$

The spatial distribution will be the same, virtually, as for the Th-230. Thus at or near the Pecos River the spatial gradient will be $21.7 \times 1.02 = 22.1 \frac{Ci}{mile}$. If one assumes that the Th-230 distribution has advanced to or near the Pecos River, then the Ra-226 would move with greater speed, since its B value is much lower (~ 450) than that for Th-230 (39,600). The potential discharge rate into the Pecos River would be the product of the spatial gradient and the speed of advance. Thus:

$$DR_{Ra\text{-}226} = 22.1 \times 10^{+6} \ \frac{\mu Ci}{mile} \times \frac{0.04 \ \frac{ft.}{day}}{450} \times \frac{1}{5.28 \times 10^{3} \ ft./mile}$$

$$\times \frac{1}{8.64 \times 10^{4} \ sec./day} = 4.31 \times 10^{-6} \ \mu Ci/sec.$$

This must be considered an upper limit, since it is clear that prior to the arrival of Th-230 to the Pecos River, the production of the Ra-226 from the leading edge of the Th-230 would "race" ahead of the thorium column, but would also undergo relatively rapid decay (radium has a short half-life in this context of 1600 yrs.). Thus there would actually be some build-up of Ra-226 at or near the Pecos River over some period of time.

The discharge rate computed above must be compared with the total production rate of Ra-226 from Th-230, to ascertain whether that would constitute a rate-limiting process. Using section B, equation III:

$$\frac{dA_{Ra-226}}{dt} = \frac{0.693}{1600\ \text{yrs.}}\ (437\ \text{Ci})\ \left(10^{+6}\ \frac{\mu\text{Ci}}{\text{Ci}}\right)\ \frac{1}{0.315 \times 10^{8}\ \frac{\text{sec}}{\text{yr.}}}$$

$$= 0.60 \times 10^{-2}\ \mu\text{Ci/sec.}$$

Thus Th-230 is producing Ra-226 at a rate which is orders of magnitude greater than the rate at which Ra-226 is leaving Th-230 as a discharge into the Pecos River.

An upper limit value for the concentration in the Pecos River is computed by dividing the discharge rate by the river's flow rate, F:

$$C_{PR,\ Ra-226} = \frac{0.431 \times 10^{-5}\ (\mu\text{Ci/sec})}{0.515 \times 10^{3}\ (\text{l/s})}$$

$$= 0.84 \times 10^{-8}\ (\mu\text{Ci/l})$$

$$= 8.4 \times 10^{-9}\ (\mu\text{Ci/l}).$$

The listed concentrations in BDM/TAC 79-156-TR, Appendix B, B-13, show increasing values up to the last tabulation for $t=10^{5}$ yrs. of 7.5×10^{-10} (μCi/l).

D.4. Consider Np-237 $\rightarrow\rightarrow\rightarrow$ U-233 as a source term for the U-233. The repository produces a release rate for U-233 of 0.99×10^{-5} µCi/sec, and continues this for a dissolution time DT = 4650 yrs. For this same time interval one may compute the activity of U-233 produced by decay from the Np-237 inventory of 440 Ci.

From Section B, equation VI:

$$\frac{A_D}{A_P} = \frac{\lambda_D}{\lambda_D - \lambda_P} \quad [1 - e^{-(\lambda_D - \lambda_P)t}].$$

In this case t (=4650 yrs.) is sufficiently small that $(\lambda_D - \lambda_P)t << 1$. Thus one may rewrite the above as:

$$\frac{A_D}{A_P} = \lambda_D \cdot t,$$

(by expanding the exponential).

Thus: $$A_{U\text{-}233} = A_{Np\text{-}237} \times \frac{0.693 \times 4560}{1.6 \times 10^5}$$

$$= 440 \text{ Ci} \times 0.020$$

$$= 8.86 \text{ Ci at } t = 4650 \text{ yrs.}$$

This is in effect to be added to the repository inventory of 1.46 Ci for U-233. Thus the correction to the previously computed concentration in the Pecos River of 1.2×10^{-8} µCi/l is:

$$1.2 \times 10^{-8} \times \frac{8.86 + 1.46}{1.46} = 8.5 \times 10^{-8} \left(\frac{\mu Ci}{l}\right).$$

See the entry in column 8, Table 1 for U-233. Compare with the BDM, Appendix B, B-25 value of 6.2×10^{-8} $\left(\frac{\mu Ci}{l}\right)$.

D.5. Consider Th-229 as the daughter of U-233. As the U-233 moves to the Pecos River, it produces Th-229 which is then distributed over the 15 miles from the repository to the river (because of the large B value for Thorium). To obtain the total activity of Th-229 produced by decay, it is first necessary to compute the total activity of U-233 produced in $t = 10^5$ years by decay from Np-237. From section B, equation VI:

$$\frac{A_{U-233}}{A_{Np-237}} = \frac{\lambda_{U-233}}{\lambda_{U-233} - \lambda_{Np-237}} \times \left[1 - e^{-(\lambda_{U-233} - \lambda_{Np-237})t}\right]$$

at $t = 10^5$ yrs., with appropriate values for the λ's:

$$\frac{A_{U-233}}{A_{Np-237}} = 0.356;$$

at $t = 10^5$ yrs., $A_{Np-237} = 440 \times \exp\left\{\frac{-0.693}{21}\right\}$

$$= 426 \text{ Ci.}$$

Thus $A_{U-233} = 151$ Ci at $t = 10^5$ yrs. Since Th-229 is a short lived daughter, it will be in transient equilibrium with U-233 and have virtually the same activity of 151 Ci.

Thus the spatial distribution of the Th-229 is $\frac{151}{15} \frac{\text{Ci}}{\text{mile}} = 10.0 \frac{\text{Ci}}{\text{mile}}$

$$= 10 \times 10^6 \frac{\mu\text{Ci}}{\text{mile}} .$$

The linear speed of the Th-229 is $0.221 \times 10^{-14} \frac{\text{miles}}{\text{sec}}$ (see similar calculations for Th-230).

Therefore: $DR_{PR} = 10.0 \times 0.221 \times 10^{-14} \times 10^{+6}$

$$= 2.21 \times 10^{-8} \ \mu Ci/sec$$

and $C_{PR, \ Th\text{-}229} = \dfrac{2.21 \times 10^{-8}}{0.515 \times 10^{+3}} \quad \dfrac{\mu Ci}{l}$

$$= 4.3 \times 10^{-11} \ \frac{\mu Ci}{l} .$$

Compare with BDM, Appendix B, B-26 value of 1.5×10^{-11} (μCi/l).

E. <u>Comparison of I-129 and TC-99 with DEIS, I, for Discharge Rate and Maximum Concentrations</u>

The computed value for the discharge rate into the Pecos River for I-129 is $1.0 \times 10^{-4} \ \frac{\mu Ci}{sec} \times 0.864 \times 10^{5} \ \frac{sec}{day}$ = (μCi/day).

The value given as a maximum in DEIS, I, Fig. 9-14(b), 9-113 is 12.2 (μCi/day).

One may picture the time sequence for the square-wave calculation and for the DEIS computation as follows:

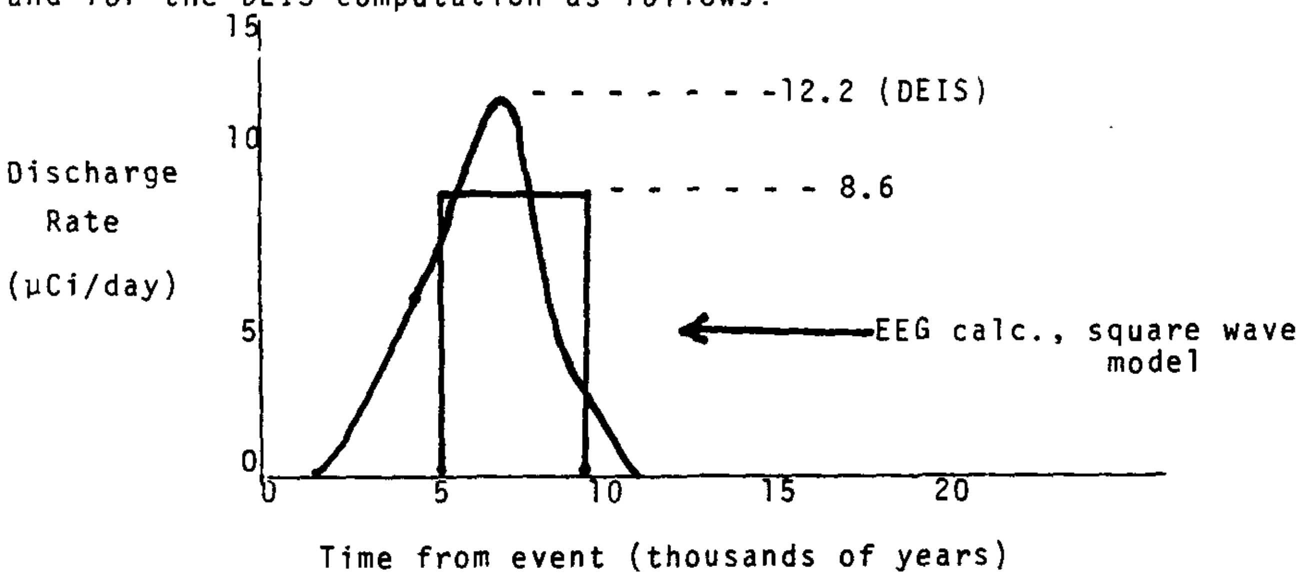


Figure 3

For the concentration at the Pecos River, one may picture the time sequence as follows:

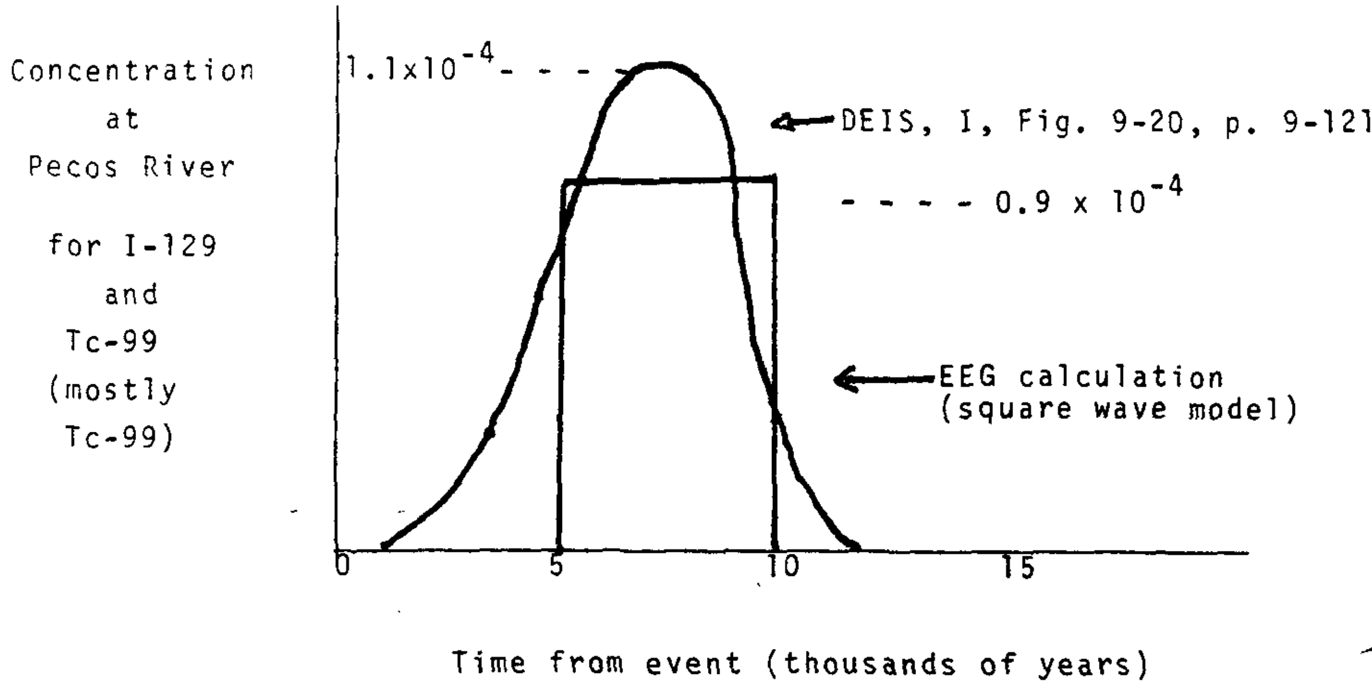


Figure 4

F. Use of "Square Wave" Model to Calculate Dosages to Whole Body and Organs

Scenario 4, Spent Fuel Assemblies at Malaga Bend

One may test the square wave model by combining Pecos River concentrations (µCi/l) with the assumed ingestion rate of 730 (l/yr.) to obtain µCi ingested. The mrem dose will be spread over a time interval depending on the t_{eff} (effective half-life) for the nuclide in the whole body (or organ of interest). Conventionally a 50 year commitment period is utilized. For nuclides like Tc-99 with rapid elimination (t_{eff} ~ 5 to 30 days), the dosage interval virtually coincides with the ingestion time. For radium and thorium with very slow elimination, the body (organ) content diminishes slowly, and the dosage is spread over the 50 years. Thus, the final computed dose is equivalent to mrem/yr. only for rapidly equilibrated nuclides (Tc-99). For others, the designation is the unavoidably awkward: mrem/per 50 yr. per µCi ingested. If the ingestion is assumed to re-occur a second year, a third year, etc., then the mrem/50 yr. will increase approximately linearly with the <u>total</u> ingested number of µCi's, for radium and thorium but <u>not</u> for Tc-99 (see Figure 5).

Note the temporal relation between uptake rate I (µCi/yr.) and body or organ content q (µCi) for various nuclides.

Note that the DEIS, pages 9-122 and 9-123, uses the notation "Dose rate (rem/yr.)" which is inappropriate. To be consistent with its own source material it should read: "Dose Commitment/one year intake" or equivalent.

Nuclide	T_{eff}	I (uptake rate, μCi/yr.)	q(body or organ content, μCi
Tc-99	5-30 d.		
I-129	7-100d (thyroid)		
U	15-300d (bone)		
Th	55 yrs. (kidney) 190 yrs. (bone)		
Ra-226	44 yrs. (bone)		

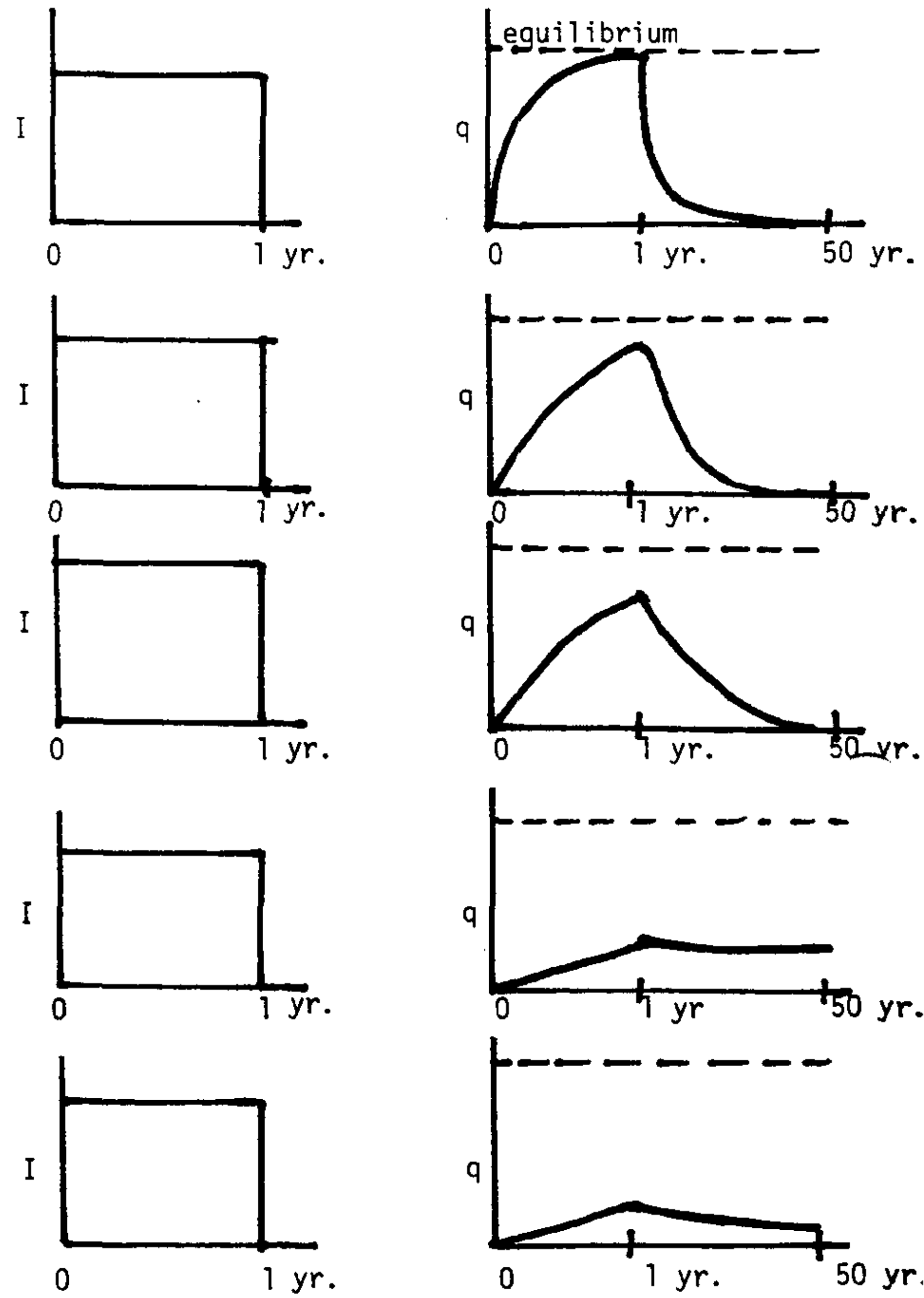


Figure 5

Tables 2-8 include the following, column by column:

column 1: nuclide

column 2: concentration at the Pecos River in (μCi/l), as computed by square wave model

column 3: mrem/μCi ingested, as tabulated in NUREG 0172 for whole body (or organ); based on ICRP Reports 2 (1959), 6 (1962) and 10 (1967).

column 4: col. (2) x col. (3) x 730 ℓ/yr = mrem/one year intake

column 5: compare with BDM/TAC 79-156-TR, Appendix B listings, pages designated

bottom of page : compare with EIS-I; 9-122, 123, maximum dose, upper transmissivity assumption.

The tables give comparisons for 10 nuclides and for 8 organ systems, where appropriate (e.g. of the 10 nuclides only I-129 contributes to thyroid dose). The nature of the concordance between columns (4) and (5) follows that obtained previously between Pecos River concentrations, "square wave" model vs. computer listings in BDM, Appendix B print-outs. The ratios of "square wave" to computer listings for doses vary from a minimum of 1.2 to a maximum of 5.0 with a mean value of 4.0.

Comparisons (for internal consistency) between DEIS maximum values and BDM sums are generally good, with one exception: for Lower Large Intestine [LLI], the sum of BDM listings is $0.124 \frac{\text{mrem}}{\text{1 yr. intake}}$ vs. 0.158 for the DEIS maximum value, a difference of 24%.

G. Comments

The square wave model yields results which differ from INTERA - BDM listings (e.g. for maximum concentrations in Pecos River) by factors ranging from 1.1 to 11.2 (for Radium-226) with a mean value of 4.2 (see Table 1). Considering the crudity of the one-dimensional square wave model, this may be considered fair agreement. The same degree of variation is present in the comparisons of total body and organ doses (see Tables 2-8). Usually the square wave model leads to a higher estimate, as expected.

Perhaps the most useful outcome of the calculations made is that it permits one to put as a lower priority the question of the validity of the methodology employed in the DEIS calculations of nuclide concentrations and doses by ingestion. Instead one may consider the key parameters that lead to the final results. This would include the K_d values which are responsible for holding-back such nuclides as Pu, N_p, and Thorium. Also, one would include the basic driving parameter, $\bar{v}$, the assumed ground water flow velocity. A thorough review appears to be appropriate to permit an assessment to be made of the validity of the values actually employed in the DEIS. Additionally, it is probably useful to examine the scenarios used in the DEIS to consider whether indeed 'bounding cases' have been included, as stated in the report.

TABLE 1

MOVEMENT OF NUCLIDES FROM REPOSITORY TO PECOS RIVER (15 mi.)

Comparison of Peak Values with Intera (BDM** listings)

NUCLIDES	ACTIVITY Ci	RELEASE RATE FROM REPOSITORY RRR (μci/s)	RETARDATION FACTOR B	ARRIVAL TIME AT PECOS RIVER AT (YRS.)	HALF-LIFE (YRS.)	DISCHARGE RATE INTO PECOS RIVER DR_{pr} (μci/s)	CONCENTRATION IN PECOS RIVER C_{pr} (μci/l)	BDM PEAK VALUE (time, yrs)
Tc-99	6.8×10^{3}	4.6×10^{-2}	1	5.4×10^{3}	2.1×10^{5}	4.5×10^{-2}	0.87×10^{-4}	1.2×10^{-4} (7000)
I-129	15	1.02×10^{-4}	1	5.4×10^{3}	1.6×10^{7}	1.0×10^{-4}	1.9×10^{-7}	2.7×10^{-7} (7000)
Cs-135	1.5×10^{2}	1.02×10^{-3}	270	1.5×10^{6}	2.3×10^{-6}	0.65×10^{-3}	1.3×10^{-6}	
Ra-226	1.26	0.86×10^{-5}	450	2.4×10^{6}	1.6×10^{3}			
Ra-226*				1×10^{5}		4.3×10^{-6}	8.4×10^{-9}	0.75×10^{-9} (10^{5})
Th-229	0.06	0.4×10^{-6}	39,600	2.1×10^{8}	7.2×10^{3}			
Th-229*				1×10^{5}		2.2×10^{-8}	4.3×10^{-11}	1.5×10^{-11} (10^{5})
U-233	1.46	0.99×10^{-5}	19	1.0×10^{5}	1.6×10^{5}	0.64×10^{-5}	1.2×10^{-8}	
U-233*'			19	1×10^{5}			8.5×10^{-8}	6.2×10^{-8} (10^{5})
U-234	8.7×10^{2}	5.9×10^{-3}	19	1×10^{5}	2.4×10^{5}	4.4×10^{-3}	8.5×10^{-6}	1.8×10^{-6} (10^{5})
U-235	7.8	5.3×10^{-5}	19	1×10^{5}	7×10^{8}	5.3×10^{-5}	1.0×10^{-7}	0.24×10^{-7} (10^{5})
U-236	1.4×10^{2}	0.95×10^{-3}	19	1×10^{5}	2.3×10^{7}	0.95×10^{-3}	1.8×10^{-6}	0.47×10^{-6} (10^{5})
U-238	1.46×10^{2}	0.99×10^{-3}	19	1.0×10^{5}	4.8×10^{9}	0.99×10^{-3}	1.9×10^{-6}	0.37×10^{-6} (10^{5})
Th-230*			39,600	1.0×10^{5}	0.77×10^{5}	4.8×10^{-8}	0.93×10^{-10}	1.01×10^{-10} (10^{5})

*as a daughter product   'repository plus parent   **BDM-TAC-79-156-TR, Appendix B, B-4 to B-27

TABLE 2

Whole Body - Adult - Drinking 730 l/yr

NUCLIDE	C_{pr} (μci/l)	NUREG 1072 m rem/50y per μci/yr	p.	(1)(2)x730(l/yr) m rem/1 yr intake	BDM 79-156-TR App. B m rem/1 yr intake	p.	
I-129	1.9×10^{-7}	9.21	21	1.28×10^{-3}	2.5×10^{-3}	B-100	t=6,000 to 8,000 yrs.
Tc-99	0.87×10^{-4}	5.02×10^{-2}	21	3.19×10^{-3}	5.5×10^{-3}	B-108	
Cs-135	1.3×10^{-6}	7.99	22	7.58×10^{-3} 1.5×10^{6} yrs			
U-238	1.9×10^{-6}	4.54x10 +D*	23	6.30×10^{-2}	1.27×10^{-2}	B-124	t($.0^{5}$ yrs.
U-234	8.5×10^{-6}	5.17x10	23	$32.\times10^{-2}$	7.0×10^{-2}	B-132	
Th-230	0.89×10^{-10}	5.70x10	23	3.7×10^{-6}	7.9×10^{-6}	B-140	
Ra-226	0.84×10^{-08}	2.2×10^{5}	23	1.35	0.29	B-148	
U-236	1.8×10^{-6}	4.96x10	23	6.52×10^{-2}	1.8×10^{-2}	B-172	
U-235	1.0×10^{-7}	4.86x10 +D	23	3.55×10^{-3}	0.98×10^{-3}	B-204	
U-233	8.5×10^{-8}	5.28x10	23	3.28×10^{-3}	2.65×10^{-3}	B-228	
Th-229	0.88×10^{-10}	3.91×10^{2}	23	2.51×10^{-5}	0.81×10^{-5}	B-236	
				COMPARE			
Sum				1.80 m rem / 1 yr int	0.394 m rem / 1 yr int		

Also compare EIS, 9-122(a): 0.399 m rem / 1 yr int

Note: Ra-226 accounts for 75% of total!!

*Includes effect of daughters

TABLE 3

Bone - Adult - Drinking 730 l/yr.

NUCLIDE	C_{pr} (μci/l)	NUREG 0172 m rem/μci intake	p.	(1)(2)x730(l/yr) m rem/1 yr intake	BDM 79-156-TR App. B.	p.	
I-129	$1.9x10^{-7}$	3.27	21	$4.54x10^{-4}$	$9.45x10^{-4}$	B-98	t=6,000 to 8,000 yrs.
Tc-99	$0.87x10^{-4}$	$1.25x10^{-1}$	21	$0.79x10^{-2}$	$1.38x10^{-2}$	B-106	
U-233	$8.5x10^{-8}$	$8.71x10^{2}$	23	$5.40x10^{-2}$	$4.16x10^{-1}$	B-226	t = 10[illegible] yrs.
U-234	$8.5x10^{-6}$	$8.36x10^{2}$	23	5.19	1.13	B-130	
U-235	$1.0x10^{-7}$	$8.01x10^{2}$	23	$5.85x10^{-2}$	$1.50x10^{-2}$	B-202	
U-236	$1.8x10^{-6}$	$8.01x10^{2}$	23	1.05	0.289	B-170	
U-238	$1.9x10^{-6}$	$7.67x10^{2}$	23	1.06	0.214	B-122	
Th-229	$0.88x10^{-10}$	$7.98x10^{3}$	23	$5.13x10^{-4}$	$1.66x10^{-4}$	B-234	
Th-230	$0.89x10^{-10}$	$2.06x10^{3}$	23	$1.83x10^{-4}$	$2.84x10^{-4}$	B-138	
$Ra-226_D$	$0.84x10^{-8}$	$3.02x10^{5}$	23	1.85	0.403	B-146	
				COMPARE			
Sum				9.26 m rem / 1 yr int	2.09 m rem / 1 yr int		
DEIS-I, 9-122(d):					2.09 m rem / 1 yr int		

U-234 accounts for 55% of total.

TABLE 4

Thyroid - Adult - Drinking 730 l/yr.

NUCLIDE	C_{pr} (μci/l)	NUREG 0172 m rem/μci intake	(1)(2)x730(l/yr) m rem/1 yr intake	BDM 79-156-TR App. B
I-129	1.9×10^{-7}	7.23×10^{3} p. 21	1.00	1.86 p. B-101
			COMPARE	
EIS-I, 9-122(b):				1.88 m rem/yr

t=6,000 to 8,000 yrs.

TABLE 5

Liver - Adult - Drinking 730 l/yr.

NUCLIDE	C_{pr} (μci/l)	NUREG 0172 m rem/μci intake	(1)(2)x730(l/yr) m rem/l yr intake	BDM 79-156-TR App. B m rem / 1 yr intake	p.	
I-129	1.9×10^{-7}	2.81	3.90×10^{-4}	8.26×10^{-4}	B-99	t=6,000 to 8,000 yrs.
Tc-99	0.87×10^{-4}	1.86×10^{-1}	1.18×10^{-2}	2.05×10^{-2}	B-107	
Th-229	0.88×10^{-10}	1.19×10^{2}	0.76×10^{-5}	0.25×10^{-5}	B-235	t = 10^5 yrs.
Th-230	0.89×10^{-10}	1.17×10^{2}	0.76×10^{-5}	1.61×10^{-5}	B-139	
Ra-226	0.84×10^{-8}	5.74	3.52×10^{-5}	1.66×10^{-5}	B-147	
U-238*	1.9×10^{-6}			3.68×10^{-5}		
U-234*	8.5×10^{-6}			1.19×10^{-6}		
U-236*	1.8×10^{-6}			9.0×10^{-9}		
U-235*	1.0×10^{-7}			7.08×10^{-5}		
U-233*	1.2×10^{-8}			1.31×10^{-4}		
			COMPARE			
Sum				2.58×10^{-4}	at $t=10^5$ yrs.	
EIS-I, 9-123(a):				2.72×10^{-4}		

*No values for liver for U are listed in NUREG 0172.

TABLE 6

Kidney - Adult - Drinking 730 l/yr.

NUCLIDE	C_{pr} (μci/l)	NUREG 0172 m rem/μci intake	p.	(1)(2)x730(l/yr) m rem/ 1 yr intake	BDM 79-156-TR App. B m rem/1 yr intake	p.	
I-129	1.9×10^{-7}	6.04	21	8.4×10^{-4}	16.5×10^{-4}	B-102	t=6,000 to 8,000 yrs.
Tc-99	0.87×10^{-4}	2.34	21	1.49×10^{-1}	2.58×10^{-1}	B-110	
U-233	8.5×10^{-8}	2.03×10^{2}	23	1.26×10^{-2}	0.98×10^{-2}	B-230	t = 10^5 yrs.
U-234	8.5×10^{-6}	1.99×10^{2}	23	1.23	0.27	B-134	
U-235	1.0×10^{-7}	1.87×10^{2}	23	1.36×10^{-2}	0.36×10^{-2}	B-206	
U-236	1.8×10^{-6}	1.91×10^{2}	23	2.51×10^{-1}	0.69×10^{-1}	B-174	
U-238	1.9×10^{-6}	1.75×10^{2}	23	2.43×10^{-1}	0.49×10^{-1}	B-126	
Th-229	0.88×10^{-10}	5.75×10^{2}	23	3.69×10^{-5}	1.20×10^{-5}	B-238	
Th-230	0.89×10^{-10}	5.65×10^{2}	23	3.67×10^{-5}	7.78×10^{-5}	B-142	
Ra-226	0.84×10^{-8}	1.63×10^{2}	23	1.00×10^{-3}	0.23×10^{-3}	B-150	
				COMPARE			
Sum				1.75 ⟷	0.402		
					↕		
					0.408		

EIS-I, 9-123(b):

U-234 accounts for 67 to 70% of total.

TABLE 7

Lung - Adult - Drinking 730 l/yr

NUCLIDE	C_{pr} (µci/l)	NUREG 0172 m rem/µci intake	p.	(1)(2)x730(l/yr) m rem/l yr intake	BDM 79-156-TR App. B 1 yr intake	p.
I-129	1.9×10^{-7}	*		*	1.01×10^{-4}	B-103
Tc-99	0.87×10^{-4}	1.58×10^{-2}	21	1.00×10^{-3}	1.74×10^{-3}	B-111
				COMPARE		

t=6000 to 8000 yrs.

*No value listed for I-129/Lung in NUREG 0172.

EIS-I, 9-123(c) 2.45×10^{-4} at $t=10^5$ yrs.

NUCLIDE	C_{pr} (µci/l)	BDM 79-156-TR App. B 1 yr intake	p.
U-238	1.9×10^{-6}	3.68×10^{-5}	B-127
U-234	8.5×10^{-6}	1.19×10^{-6}	B-135
Th-230	0.89×10^{-10}	7.3×10^{-10}	B-143
Ra-226	0.84×10^{-8}	8.99×10^{-6}	B-151
U-235	1.0×10^{-7}	7.08×10^{-5}	B-207
U-233	8.5×10^{-8}	1.31×10^{-4}	B-231
Th-229	0.88×10^{-10}	3.11×10^{-8}	B-239
U-236	1.8×10^{-6}	9.0×10^{-9}	B-176
Sum		2.49×10^{-4}	

No values of m rem/µci intake for Lung are listed for U in NUREG 0172.

TABLE 8

Lower Large Intestine (LLI) - Adult - Drinking 730 l/yr.

NUCLIDE	C_{pr} (μci/l)	NUREG 0172 m rem/μci intake	(1)(2)x730(l/yr) m rem/l yr intake	BDM 79-156-TR m rem/l yr intake	p.	
I-129	1.9×10^{-7}	4.44×10^{-1}	6.16×10^{-5}	21.5×10^{-5}	B-104	t=6000 to 8000 yrs.
Tc-99	0.87×10^{-4}	6.08	3.86×10^{-1}	6.71×10^{-1}	B-112	
U-233	8.5×10^{-8}	6.27×10^{1}	3.89×10^{-3}	3.12×10^{-3}	B-232	t=10^5 yrs.
U-234	8.5×10^{-6}	6.14×10^{1}	3.81×10^{-1}	0.83×10^{-1}	B-136	
U-235	1.0×10^{-7}	7.81×10^{1}	5.70×10^{-3}	1.53×10^{-3}	B-208	
U-236	1.8×10^{-6}	5.76×10^{1}	7.57×10^{-2}	2.08×10^{-2}	B-175	
U-238	1.9×10^{-6}	5.50×10^{1}	7.63×10^{-2}	1.54×10^{-2}	B-128	
Th-229	0.88×10^{-10}	5.12×10^{2}	3.29×10^{-5}	1.06×10^{-5}	B-240	
Th-230	0.89×10^{-10}	6.02×10^{1}	3.91×10^{-6}	8.30×10^{-6}	B-144	
Ra-226	0.84×10^{-8}	3.32×10^{2}	2.04×10^{-3}	0.452×10^{-3}	B-152	
			COMPARE			
Sum			0.545	0.124		
EIS-I, 9-123(d):				0.158 m rem/yr		

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APPENDIX VII

OPERATIONAL AND LONG TERM RELEASE CALCULATIONS

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APPENDIX VII

OPERATIONAL AND LONG TERM RELEASE CALCULATIONS

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Item VII-A

Annual Dose Commitment at James Ranch from Routine Operation Releases

The Draft EIS uses the Releases to the Environment tabulated in Table 8-6 to calculate doses at James Ranch (3.0 miles south-southwest of the center of the site) in Table 9-18. The following calculation is based on Table 8-6 and the extrapolated χ/Q value from Table H-36.

$$\text{Dose} = \left(\frac{\chi}{Q}\right) Q \text{ (inhalation per year) (Dose Commitment Factor)}$$

adjusting for units

$$\text{Dose} = \left(\frac{\chi}{Q}\,\frac{s}{m^3}\right)\left(\frac{m^3}{y}\text{ intake}\right)\frac{pCi}{Ci}\,\frac{1}{\frac{s}{y}}\left[Q\,\frac{Ci}{y}\left(\frac{mrem}{pCi\text{ intake}}\right)\right]$$

$$\text{Dose} = \frac{(6.2-7)(7.3+3)(1+12)}{(3.14+7)}\;\frac{pCi}{Ci}\;\left[(Q \times DCF)\;\frac{Ci\;mrem}{pCi\;y}\right]$$

$$\text{Dose} = (1.44\;+2)\,(Q \times DCF)\;\frac{mrem}{y}$$

Dose commitment factors are from NUREG-0172, Table 8.

Values of Q x DCF are tabulated on the following page for significant radionuclides from Table 8-6.

TABLE VII-A

Organ Dose Commitments at James Ranch from Routine Releases

Nuclide	Q (Ci/y)	Bone DCF mrem/pCi	Bone Q(DCF) Ci/pCi mrem/y	Lungs DCF mrem/pCi	Lungs Q(DCF) Ci/pCi mrem/y	Whole Body DCF Ci/pCi	Whole Body Q(DCF) Ci/pCi mrem/y
^{3}H	0.45	-	-	1.58-7	7.1-8	1.58-7	7.1-8
^{85}Kr	7.8	-	-	2.41-9	1.9-8	-	-
^{238}Pu	2.3-5	2.74	6.3-5	.182	4.3-6	6.92-2	1.6-6
^{239}Pu	2.6-4	3.19	8.3-4	.172	4.5-5	7.75-2	2.0-5
^{240}Pu	6.4-5	3.18	2.0-4	.172	1.1-6	7.73-2	4.9-6
^{241}Pu	3.5-3	6.41-2	2.2-4	1.52-4	5.2-7	1.29-3	4.5-6
^{241}Am	4.3-6	1.01	4.3-6	6.06-2	2.6-7	6.71-2	2.9-7
^{244}Cm	9.5-7	5.90-1	5.6-7	6.06-2	5.8-8	3.51-2	3.4-8
Σ(DCF)Q			1.31-3		5.12-5		3.13-5
50 year dose commitment = (1.44+2)(QxDCF) =			0.19 mrem		7.4-3 mrem		4.5-3 mrem
=			1.9-4 rem		7.4-6 rem		4.5-6 rem
DEIS values (Table 9-18) =			1.5-4 rem		7.1-6 rem		3.8-6 rem
Ratio DEIS value / EEG value			0.8		0.96		0.84

Item VII-B

Operation Accidents - CH-TRU Waste
Scenario C-7

The activity released and the resulting doses due to operational accident Scenario C-7, Surface Fire (1 hr.), have been evaluated.

The basic assumptions or model of the scenario are given on page 9-50, DEIS and summarized below.

Assumptions

1) It takes one hour to put out the fire.

2) 25% of a typical drum is combustible.

3) 1% of the activity in the combustible waste is released in respirable form per hour.

4) One drum burns, the two adjacent drums burst exposing contents which do not burn, only 10% of spilled contents is powder.

5) A total of 0.0014% of each of the two adjacent drums is respirable and released.

6) The double HEPA filter bank has a decontamination factor of 10^6.

Based on the CH-TRU inventory given on page E-2, DEIS, the following analysis may be made:

Table VII-B

Amount of Radioactivity Released in C-7 Surface Fire

Isotope	Ci/drum (Pg. E-2)	Respirable Release Fraction [0.25% +	Adjacent 2 Drums 2(0.0014%)] x	Decon Factor 10^{-6} =	Ci Released
Pu-238	4.1×10^{-2}	1×10^{-4}	1.148×10^{-6}	10^{-6}	1×10^{-10}
Pu-239	4.8×10^{-1}	1.2×10^{-3}	1.34×10^{-5}	10^{-6}	1.2×10^{-9}
Pu-240	1.2×10^{-1}	3.0×10^{-4}	3.36×10^{-6}	10^{-6}	3.0×10^{-10}
Pu-241	2.9	7.25×10^{-3}	8.12×10^{-5}	10^{-6}	7.3×10^{-9}
Am-241	7.8×10^{-3}	1.95×10^{-5}	2.18×10^{-7}	10^{-6}	1.97×10^{-11}
Total	3.5				8.9×10^{-9}
			DEIS (Table 9-23, Page 9-51)		8.8×10^{-9}

The curies released due to the accident scenario C-7, Surface Fire calculated above is the product of the curies per drum times the sum of the fraction released from the burned drum and two adjacent damaged drums times the decontamination factor.

The curies released to the environment are then dispersed and diluted by using AIRDOS-II in the DOE analysis (page 9-54, DEIS). In order to evaluate the doses due to the releases given in Table 9-25, page 9-56, DEIS, an independent calculation was made using the same procedure as in Item VII-1, with dose commitment factors from NUREG-0172. For a $(\chi/Q)_{50\%}$ of $(5.8\text{-}6)\frac{s}{m^3}$ the dose is:

$$\text{Dose: } \frac{(5.8\text{-}6)(0.83)(1+12)}{(3.6+3)}\,[Q(DCF)] = (1.34 + 3)\,[Q(DCF)]$$

Doses are calculated on Table VII - 3 for the James Ranch. The maximum dose at 0.5 miles is also calculated $(\frac{\chi}{Q})_{max}$ because the public could be at this location.

Table VII-C

Dose Received at James Ranch From
Radioactivity Releases in C-7 Surface Fire

Nuclide	Q Ci	Bone Dose		Lung		Whole Body	
		DCF	Q(DCF)	DCF	Q(DCF)	DCF	Q(DCF)
^{238}Pu	1.0-10	2.74	2.74-10	.182	1.82-11	6.92-2	6.92-12
^{239}Pu	1.2-9	3.19	3.83-9	.172	2.06-10	7.75-2	9.30-11
^{240}Pu	3.0-10	3.18	9.54-10	.172	5.16-11	7.73-2	2.32-11
^{241}Pu	7.3-9	0.064	4.68-10	1.52-4	1.11-12	1.29-3	9.42-12
^{241}Am	1.9-11	1.01	1.92-11	6.06-2	1.15-12	6.71-2	1.27-12
		$\Sigma_{Q(DCF)}$ =	5.54-9		2.78-10		1.34-10
50 year dose commitment		=	7.4-6 mrem		3.7-7 mrem		1.8-7 mrem
		=	7.4-9 rem		3.7-10 rem		1.8-10 rem
DEIS value (Table 9-25)		=	5.5-9 rem		2.7-10 rem		1.3-10 rem
Ratio $\frac{\text{DEIS value}}{\text{EEG value}}$		=	0.74		0.73		0.72
Dose at 0.5 mile		=	1.4-6 rem		7.1-8 rem		3.4-8 rem

Item VII-C

Operational Accidents

Underground Container Failure (hoist drop - R15)

One of the potentially more serious operational accidents with WIPP is described in the DOE DEIS is the hoist drop accident involving a spent fuel canister. The assumptions made are:

1) 0.1% of contents crushed into particles 10 microns or less;

2) Duration of accident - 6 hours;

3) Multiplying 0.84% (6 x 0.14%/h) by the powder inventory will give the airborne and respirable release of all isotopes except H-3, Kr-85, I-129;

4) 30% of H-3, Kr-85, I-129 released during first hour.

5) Gases not retained by filters; and

6) Double HEPA filter bank gives a decontamination factor of 10^6.

Table VII-D, entitled "Hoist Drop Accident", details the calculations going from the spent fuel isotopic inventory to curies released. The results agree with those presented in the DEIS (Table 9-24) for the hoist-drop - spent fuel accident.

The dose that would be received by an individual at the James Ranch was then calculated using the assumptions in the DEIS. The equations used in this calculation are given below. The resulting doses are shown in Table 11 of the main report.

Intake and Dose Equivalent or Dose Commitment Equations for R-15 Accident

Intake

Io = intake in uCi

$$Io = Q\left(\frac{Ci}{s}\right)\ \chi/Q\ \left(\frac{s}{m^3}\right)\ B\ \left(\frac{20\ m^3}{d} \times \frac{6}{24}\right) \times 10^6\left(\frac{uCi}{Ci}\right)\ fa$$

Where Q = quantity in curies released divided by the sec of release.

X/Q = 0.58×10^{-5} s/m^3 given in Table 21, page 26 of Appendix H, Annex 1 DEIS.

B = air intake, breathing rate 20 m^3/d release of 6 hours = (6/24). 20 = $5m^3$

fa = fraction inhaled which reaches critical organ.

Dose Commitment

DE = 50 year dose commitment from short term intake.

$$DE = \frac{74\ Io\ T\ \Sigma E(RBE)n}{m}\ \left(1 - e^{\frac{-0.693\ t}{T}}\right)$$

Where DE = rem (50 year)

$$74 = \left(\frac{51}{0.693}\ \frac{rem.dis.g}{MeV.d.uCi}\right)$$

T = effective half life, days.

$\Sigma E(RBE)n$ = effective energy

t = time of exposure 50 years, (50 x 365 days)

m = mass of critical organ.

Table VII-D

Hoist Drop Accident R-15

Isotope	Table E-5 Ci/Canister	Respirable Dust 0.001 (Ci)	Respirable air-borne Dust 0.0084 (Ci)	gas fraction 0.3	10^{-6} decon*	Ci released
H-3	150	-	-	-		45
Kr-85	2600	-	-	-		780
Sr-90/Y-90	3×10^{4}	3×10^{1}	2.52×10^{-1}		-	2.5×10^{-7}
Ru-106/Rh-106	2.3×10^{2}	2.3×10^{-1}	1.93×10^{-3}		-	1.9×10^{-9}
I-129	1.5×10^{-2}	-	-	-	-	4.5×10^{-3}
Cs-134	4.3×10^{3}	4.3×10^{0}	3.6×10^{-2}		-	3.6×10^{-8}
Cs-137/Ba-137m	4.0×10^{4}	4.0×10^{1}	3.36×10^{-1}		-	3.36×10^{-7}
Pm-147	3.6×10^{3}	3.6×10^{0}	3.02×10^{-2}		-	3.0×10^{-8}
Eu-154	2.4×10^{3}	2.4×10^{0}	2×10^{-2}		-	2.0×10^{-8}
Np-237	1.6×10^{-1}	1.6×10^{-4}	1.34×10^{-6}		-	1.3×10^{-12}
Pu-238	1.3×10^{3}	1.3×10^{0}	1.09×10^{-2}		-	1.1×10^{-8}
Pu-239	1.5×10^{2}	1.5×10^{-1}	1.26×10^{-3}		-	1.26×10^{-9}
Pu-240	2.2×10^{2}	2.2×10^{-1}	1.84×10^{-3}		-	1.8×10^{-9}
Pu-241	3.1×10^{4}	3.1×10^{1}	2.6×10^{-1}		-	2.6×10^{-7}
Pu-242	6.7×10^{-1}	6.7×10^{-4}	5.6×10^{-6}		-	5.6×10^{-12}
Am-241	6.7×10^{2}	6.7×10^{-1}	5.6×10^{-3}		-	5.6×10^{-9}
Am-242m	4.0	4.0×10^{-3}	3.36×10^{-5}		-	3.36×10^{-11}
Am-243	9.1	9.1×10^{-3}	7.6×10^{-5}		-	7.6×10^{-11}
Cm-243	1.5	1.5×10^{-3}	1.3×10^{-5}		-	1.3×10^{-11}
Cm-244	8.8×10^{2}	8.8×10^{-1}	7.39×10^{-3}		-	7.4×10^{-9}

Compares to table 9-24 Spent Fuel Hoist drop.

*Particulate Decontamination (10^{-6})

Scenario 5 - Indirect Pathways Calculation

The DEIS calculated the doses from inhalation and ingestion pathways to an individual living 500 meters downwind from a drilling mud pit that was contaminated with CH-TRU or spent fuel. A procedure is presented on page K-22, K-23 for this calculation. However, the following calculation will attempt to check this result by an alternate procedure, using χ/Q values from H-36.

For the CH-TRU waste case with a 10-inch drill hole, the following assumptions are used:

ρ, do, K, A: same as on K-23

μ : 2.25 m/s

χ/Q : $(2.3\text{-}4)\,s/m^3$ extrapolation from 800m to 500m assuming $\left(\frac{d_2}{d_1}\right)^2$ relationship

Ci/g sample: average concentration from Table E-1 times a sample size of 142ℓ (9.12 inch diameter hole drilling through 11 feet of drums).

Quantity of mud: 100 tons (p. 9-124).

$$\text{Curies/gram of Pu-239:}\quad \frac{\frac{0.48\,Ci}{208\ell}(142\ell)}{100\ \text{tons}\ \ (2000\ \frac{lb}{ton})454\frac{g}{lb}}$$

$$\text{Ci Pu-239 in top cm of mud:}\quad 66.9m^2\ (10^4\ \frac{cm^2}{m^2})(1\ \text{cm depth})^2\ \frac{g}{cm^3}(3.61\text{-}9\frac{Ci}{g})$$

$$= (4.83\text{-}3)Ci$$

$$\text{Source Term, Pu-239}\ \frac{Ci}{s} = (4.83\text{-}3)Ci\ \ (10^{-13})\frac{1}{s}\ \left(\frac{2.25}{1.0}\right)^3 = (5.51\text{-}15)\frac{Ci}{s}$$

$$\text{Dose} = \frac{\chi}{Q}(Q)(\text{inhalation})\text{DCF}$$

$$= (2.3\text{-}4\frac{s}{m^3})(5.51\text{-}3\frac{pCi}{s})(7.3\text{+}3\frac{m^3}{y})(3.19\frac{mrem}{pCi}) = (2.95\text{-}2)\frac{mrem}{y}$$

$$\underline{\underline{(3.05\text{-}5)}}\frac{rem}{y}$$

Dose from other actinides, besides Pu-239, are tabulated below:

Table VII-E

Indirect Pathways Doses - Scenario 5

Nuclide	Ci/drum t = 0	Ci/drum t = +100y	Ci/142ℓ	(DCF)	Q(DCF)
Pu-238	.041	.018	.012	2.74	3.29-2
Pu-240	.12	.12	.082	3.18	2.61-1
Pu-241	2.9	.015	.010	.064	6.4-4
Am-241	.0078	.078	.053	1.01	5.3-2
				ΣQ(DCF) =	3.47-1
Pu-239	.48	.48	.327	3.19	1.04

Total Bone Dose: $(2.95\text{-}5)\frac{rem}{y}\left(\frac{1.39}{1.04}\right) = (3.93\text{-}5) = (3.9\text{-}5)\frac{rem}{y}$ Bone Dose.

This value is close to the value of (3.6-5) rem/y used in Table 9-48 of the DEIS.

It is noted that the χ_1 factors listed on the bottom of page K-23 cannot be obtained from the equation and assumptions at the top of the page without choosing a value for μ, the mean wind speed. The value of 2.25 m/s used in the above calculation is reasonable based on the data in Appendix H (although perhaps lower than the site average) and gives agreement within 10-15%.

Item VII-E

Scenario 5 - Drill Back Accident
Occupational Dose Evaluation

The accident scenario described on pages 9-124 to 9-126 was evaluated to check the reasonableness of the calculations. Data, and source inventories from the DEIS are used and referenced.

Mineral Exploration Case - Spent Fuel

1) The volume of waste in a geological core with a 14 foot fuel rod is:

$$V = \frac{\pi}{4}\left(\frac{2.12}{12}\right)^2 \text{ ft}^2 \text{ [14 ft] } 28.3 \frac{\ell}{\text{ft}^3} = 9.84 \text{ liters}$$

which agrees with the 10 liters used in 9-124.

2) The drill recovers only a fraction of the fuel in an assembly. If the dimensions of an assembly are 8.5 inches square (NUREG-0116, p. 3-8) then

$$F = \frac{\frac{\pi}{4}(2.12)^2}{(8.5)^2} = 0.049 \text{ of contents in one assembly.}$$

3) The dose rate was established by using the inventory in Table E-5, page E-6 of the DEIS and calculating the amount present at 100 years after emplacement (i.e. t + 110 years after removal from reactor). Exposures at 1 meter per curie per hour were obtained from the Radiological Health Handbook, 1979 edition, page 130 or the relationship:

(1) R_{hr} at 1 foot ≈ 6 Ci (mev/γ)(No. of γ/disintegration)

4) Bremsstrahlung was also calculated for Sr-90, Y-90 and Cs-137 and considered for other Beta emitters. The expression:

(2) $f = 3.5 \times 10^{-4}\ ZE$ where f = fraction energy to photons
Z = atomic number absorber
E = maximum Beta energy

gives the amount of γ energy from the beta decay. This value is used in expression (1) to calculate the dose rate at 1 meter. Uranium Oxide, with a Z = 82.2 was used for Z.

5) Ingrowth of 241_{Am} from decay of 241_{Pu} was also calculated using the expression:

$$(3)\quad A_2 = \frac{\lambda_{2}A_{i}}{\lambda_2-\lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right) + A_2^{\circ}\, e^{-\lambda_2 t}$$

for 241_{Pu}, $A_1^{\circ} = 3.1 \times 10^4$ Ci; for 241_{Am}, $A_2^{\circ} = 6.7 \times 10^2$ Ci

at + 100 years:

$$A_2 = \frac{0.00151}{-.0510}\,(3.1 \times 10^4)[.005-.860] + 6.7 \times 10^2(.86) =$$

<u>1350</u> Ci of 241_{Am}

6) Most radionuclides in Table E-5 were eliminated by inspection, because of short half-lives and concentrations that appeared to make the contribution to the does rate negligible.

The above procedure gives an external radiation dose of about 71 rem to the maximum exposed individual with the assumption given in Scenario 5. This is about 20% below the value given in Table 9-47 as an approximation. The reason for being this far below is not known; there appear to be no other nuclides in the inventory that would make much difference.

It is noted that if the time were taken as 100 years after removal from the reactor (rather than 110 years as used here) then the total would be 90 rem.

Conclusion. Agreement on the maximum dose to a drilling crew member is sufficiently close so that the conclusions drawn about the seriousness of such an accident remain valid.

Table VII-F

External Dose Rate From Fuel Assembly Radionuclides

Nuclide	$Ci_{(R+10)}$	$T_{1/2}(y)$	$Ci_{(R+110y)}$	Exp. Factor R/h-Ci	Dose Rates - R/h Assembly	Sample
^{135}Cs	-	-	1.5 - 4	-	-	-
^{137}Cs	4.0 + 4	30.1	4.0 + 3	0.33	1320.	64.6
^{154}Eu	2.4 + 3	16	3.1 + 1	0.62	19.2	0.9
^{85}Kr	2.6 + 3	10.8	4.2 + 0	0.013	.05	-
^{241}Am	6.7 + 2	458	1.35 + 3	0.012	16.3	0.8
^{244}Cm	8.8 + 2	17.6	1.7 + 1	0.00001	-	-
^{234}U	3.9 - 1	2.5 + 5	3.9 - 1	0.010	.004	-
Bremsstrahlung Radiation						
^{90}Sr	3.0 + 4	28.1	2.55 + 3	0.0016	4.2	0.2
^{90}Y	3.0 + 4	(28.1)	2.55 + 3	0.034	85.8	4.2
^{137}Cs	4.0 + 4	30.1	4.0 + 3	0.0034	7.0	0.4
					Dose =	71.1 rem

1) Check volumes used on 9-124 (8 liters in sample.
Assume drill through either 4 levels of drums or 3 of boxes.

$$V_{drum} = [\frac{\Pi}{4}(\frac{2.12}{12})^2 \text{ ft}^2 \text{ core}][2.75 \frac{\text{ft}}{\text{drum}} (4 \text{ drums})]28.3\frac{\ell}{\text{ft}^3} = 7.64\ell$$

$$V_{box} = 7.64\ell[\frac{3.8 \text{ ft of box (3 boxes)}}{11.0 \text{ ft drums}}] = 7.94\ell$$

So the use of an 8 liter sample is reasonable.

2) Since the average drum (p. E-2) has a higher concentration of plutonium than the average box, the drum case will be used. From p. E-6 the only external dose would come from the Am-241 that is present or which ingrows from Pu-241.

$$A_{241_{Am}} = \frac{0.00151}{-.0510} (Ci_{241_{Pu}})[.005 - .860] + (7.8 - 3)\ .86\ Ci_{241_{Am}}$$

$$Ci\ 241_{Pu} \text{ in waste} = \frac{2.9Ci}{208\ell} (8\ell) = 0.112$$

$$Ci\ 241_{Am} \text{ in waste} = \frac{0.0078}{209} (8) = 0.0003$$

at t+100 yrs $A_{241_{Am}} = .00284 + .00026 = \underline{.0030}$ Ci

Dose: $\frac{(3.0 - 3)}{(1.35 + 3)} (16.3) = (35.6 -6) = (0.036 - 3)$ Rem from 241_{Am}

(Table 9-47 uses 1.0 - 3).
Note (from SAND 78-1850 pp. 21-23) a drum could have ≤200 gm Pu or 25 times the average. If one of those were struck +3 average drums the dose would be:

$(3.6\text{-}5)(\frac{224}{32}) = (2.5 - 4)$ Rem from 241_{Am}.

An inspection of nuclides distribution on pages E-36 and E-37 indicates that the only non TRU gamma emitter of possible significance is ^{137}Cs. 6.08 Ci of ^{137}Cs are distributed in 467,323 cubic feet.

$$^{137}Cs \text{ per } 8\ell = \frac{6.08 \text{ Ci } (8\ell)}{(4.67 + 5 \text{ ft}^3)(2.83+1\frac{\ell}{\text{ft}^3})} = (3.68\text{-}6)\text{Ci } ^{137}Cs \text{ in sample}$$

at +100 years =(3.7-7)Ci in sample.

Dose = (3.7-7)0.33 =(1.2-7)Rem from ^{137}Cs

If concentration is $(\frac{224}{32})$ average; ^{137}Cs = $(8.6\text{-}7)\frac{s}{m^3}$

So ^{137}Cs dose is negligible compared to 241Am.

Conclusion. The calculated dose in Table 9-47 for CH waste appears to be accurate and perhaps slightly conservative.

Item VII-F

Scenarios 1-4 (Hydrologic Breach)

Scenarios 1-4 (section 9.5.1) are similar in that all involve the formation of a hydrologic connection between the repository and the Rustler aquifer, after the repository is sealed. In each case, the breach results in dissolution of the waste, passage of the waste into the Rustler aquifer, and passage through the Rustler into the Pecos River.

The three-dimensional model used in the DEIS analysis of nuclide transport in the Rustler was developed by Intera Environmental Consultants. EEG used a simple "square wave" model, described in Appendix VI, to gain a better understanding of the key features of the Intera model and to check some of the DEIS results. Appendix VI includes an application of the square wave model to scenario 4. In this section, the square wave model is outlined briefly and its application to scenarios 1-4 is discussed.

The model assumes that the waste dissolves at a constant rate and enters the Rustler at this rate. Each nuclide then moves toward the Pecos River at a rate equal to the Rustler velocity $\bar{v}$, divided by a retardation factor:

$$B = \frac{1 - \theta}{\theta} \rho K_d$$

where θ is the porosity of the Rustler aquifer, ρ is the bulk density of the Rustler aquifer and K_d is the distribution coefficient associated with adsorption of the given nuclide onto Rustler rocks. The values used for θ and ρ are $\theta = 0.1$ and $\rho = 2$ (g/ml).

Distribution coefficients used in the DEIS are listed in Table K-3, p. K-20. (The large uncertainties associated with these parameters are discussed briefly in Item VII-I of this Appendix.)

Thus each radionuclide has an arrival time (AT) at the Pecos River, 15 miles from the repository:

$$AT = 15\ mi/(\tilde{v}/B).$$

(Earlier arrival times for nuclides produced by radioactive decay of other nuclides are discussed in Appendix VI.)

Each radionuclide has a release rate from the repository (RRR):

$$RRR = \frac{\text{repository inventory activity (Ci)}}{\text{Total dissolution time (sec)}}$$

where the dissolution time (DT) is given by:

$$DT = \frac{\text{repository volume}}{\text{dissolution rate}} .$$

The repository volumes from the CH and RH levels are:

CH volume = 9,000 x 1,200 x 16.5 ft (K-22)
RH volume = 930 x 930 x 42 ft (K-21).

Radionuclide concentrations in the Pecos River (C_{PR}) at the nuclide's arrival time (AT) are found from:

$$C_{PR} = \frac{RRR \times e^{-\lambda(AT)}}{515 \text{ liters/second}}$$

where λ is the nuclide's decay constant and 515 l/sec is the flow rate of the Pecos River (9-116).

Table VII-G summarizes the Rustler velocities and dissolution rates characteristic of the different scenarios. Table VII-H lists dissolution times and selected arrival times for scenarios 1 and 4.

Table VII-G

Rustler Velocities and Dissolution Rates

Scenario	Fluid Velocity $\bar{v}$ in Rustler (ft/yr)*	Dissolution Rates (ft^3/day)** CH	RH
1	17.5	.33	.84
2	15	.15	.39
3	15	.057	.012
4	15	81.	21.4

*"Fluid velocity through the Rustler aquifer for the upper-transmissivity bound is roughly 0.04 ft./day" (p. 9-112); that is 15 ft./year. "In scenario 1, some fluid from the Bell Canyon aquifer is added to the Rustler aquifer; after this addition the fluid velocity in the Rustler aquifer increases slightly -- roughly by a factor of 1/6 (p.9-109). Thus the Rustler fluid velocity in scenario 1 becomes (15 ft/yr) x (7/6) = 17.5 ft/yr.

**In scenario 1, a borehole through the repository connects the Rustler (upper) and Delaware Mountain Group (lower) aquifers. Water flows from the lower to the upper aquifer, dissolving 54 ft^3/day of the salt and waste bordering the borehole (9-111). The fraction of dissolved material which is from the CH repository level is the ratio of the CH level height (16.5 ft.) to the borehole length (2,700 ft.); i.e. 54 x (16.5/2700) ft^3/day or 0.33 ft^3/day of material from the CH level is dissolved. Similarly, 54 x (42/2700) ft^3/day or .84 ft^3/day of material from the RH level is dissolved. For scenario 2, the DEIS states that "The waste-dissolution rate for Scenario 2 was calculated to be less than that for Scenario 1 by a factor of 2.17" (9-109). This was used to calculate the scenario 2 dissolution rates given in Table VII-G. However, these rates add up to 0.54 rather than the total 0.64 ft^3/day given in (9-112; 2). In scenario 3, the rates at which diffusion brings waste and salt into the Rustler are given as 0.057 ft^3/day for the CH repository level and .012 ft^3/day for the RH level (9-112). Scenario 4 is discussed in Appendix V

Table VII - H

Migration and Dissolution Times

Scenario	Arrival time (AT) at Pecos River, (yrs.) if: $K_d=0$	$K_d=1$	$K_d=10$	Dissolution time (yrs.) CH	RH
1	4.5×10^3	8.6×10^4	8.2×10^5	1.5×10^6	1.2×10^5
4	5.3×10^3	1.0×10^5	9.6×10^5	6.0×10^3	4.7×10^3

Item VII- G

Hydraulic Conductivity, Interstitial Velocity in the Rustler Aquifer

<u>Notation</u>:

$\bar{v}$ = interstitial velocity [ft/day]
K = hydraulic conductivity [ft/day]
θ = porosity
Δh = change in head (difference between heights of potential lines) [ft]
$\Delta \ell$ = distance over which Δh is calculated. [ft]

<u>Formula for interstitial velocity</u>:

$$\bar{v} = \frac{K}{\theta} \cdot \frac{\Delta h}{\Delta \ell}$$

(see, for example, Mercer and Orr, 1977, p. 17).

<u>Calculation of $\bar{v}$, from DEIS information</u>:

Let K = 1 ft/day (Fig. K-7, vicinity of WIPP)
θ = 0.1 (Table K-2)
Δh = 3200-2900ft
= 300 ft
$\Delta \ell$ = 15 mi
= 79,200ft.
(Fig. K-3, Fig. K-5)

$$\text{Then } \bar{v} = \frac{1}{0.1} \times \frac{300}{79{,}200} \text{ ft/day}$$
$$= 0.038 \text{ ft/day.}$$

Compare with the DEIS value of 0.04 ft/day (9-112).

This calculation suggests that the interstitial Rustler aquifer velocity of .04 ft/day, taken as an upper bound in the DEIS, is not conservative.

1) Figure K-7 gives hydraulic conductivity values in the Rustler which are lowest (1 ft/day) at the WIPP site and increase after that.

2) A 1977 Mercer and Orr report used in the DEIS transport modeling, gives the average hydraulic conductivity in the rustler as 16 ft/day and the average interstitial velocity as 0.5 ft/day.

3) Transmissivities reported in a later Mercer and Orr report (1979) range from 10^{-4} to 140 ft^2/day and translate to a hydraulic conductivity range of 5×10^{-6} to 7 ft/day. The highest conductivity value measured in a well near WIPP is 2 ft/day (for hydrologic hole H-3 in WIPP Zone II).

Item VII-I

Variability in K_d Values;
Effect on Radiation Exposure

The low radiation doses calculated for the hydrologic breach scenarios result in part from the fact that the K_d value assumed for plutonium retards the rate at which plutonium travels in groundwater by a factor of 37,800.* Thus, by the time it reaches the Pecos River, the large initial inventory of plutonium (in spent fuel or transuranic waste) has decayed to an insignificant quantity. In fact, the only significant nuclides that are not retarded by adsorption are iodine and technetium, and the smallest retardation factor for other nuclides is B = 19 (when K_d = 1) for uranium.

However, much smaller K_d values than those used in the DEIS have been measured using rocks from the Rustler formation (ref. 1, 2). More importantly, laboratory measurements of K_d values probably do not reflect field conditions. For example, small amounts of plutonium or other elements with the capacity of the rocks to adsorb more plutonium; thus a "loading effect" can reduce K_d values. Chelating agents like EDTA can also reduce K_d values, as can temperature, pH and other physical and chemical factors. Finally the equilibrium model in which K_d's make sense may be inappropriate for flow in a fractured medium.

Table VII-I summarizes K_d information for different nuclides and Table VII-J indicates the maximum nuclide concentrations in the Pecos River in scenarios 1 and 4 when low K_d values (K_d = 0 or 1) are assumed.

---

*The retardation factor B is: 1 + 18 K_d (see Appendix VI).

Note that essentially the same effect on nuclide speed can be obtained by lowering the K_d value by a given factor or raising the hydraulic conductivity or interstitial velocity by the same factor. (See Item VII-H for a discussion of variations in hydraulic conductivity and interstitial velocity.)

Table VII-I

K_d Information

Nuclide	K_d used in DEIS	K_d range in refs. 1, 2
Tc-99	0	0.15-6.7
I-129	0	1
Cs-135	15	1 to 6,540
Ra-226	25	-
Thorium	2200	-
Uranium	1	-0.9 to 6.7
Np-237	700	8-23
Plutonium	2100	17.6 to 5400

Table VII-J

Effect of K_d's on Plutonium Concentration in Pecos River, Scenarios 1 and 4, Spent Fuel

Nuclide	Inventory (Ci) at 1000 yrs.	Half-Life Years	Scenario	Release Rate[1] from Repository (μCi/sec)	Decay factor[2] at arrival time, if			Maximum concentration[3] in Pecos River (μCi/l), if		
					K_d=0	K_d=1	K_d=18	K_d=0	K_d=1	K_d=18
Pu-239	1.5×10^5	2.4×10^4	1	3.8×10^2	.88	.08	0	6.5×10^{-5}	1.2×10^{-6}	0
			4	9.7×10^{-1}	.86	.06	0	1.6×10^{-3}	1.1×10^{-4}	0
Pu-240	2.0×10^5	6.5×10^3	1	5.3×10^{-2}	.62	1.0×10^{-9}	0	6.2×10^{-5}	1.0×10^{-8}	0
			4	1.3	.57	2.3×10^{-5}	0	1.4×10^{-3}	5.8×10^{-8}	0

1 $\dfrac{\text{Inventory (Ci)} \times 10^6\ \mu\text{Ci/Ci}}{\text{Dissolution time (sec)}}$ (see Item VII-F, Table VII-H , for dissolution times)

2 $e^{-(\ln 2/\text{half-life}) \times (\text{arrival time})}$ (see Item VII-F, Table VII-H , for arrival times).

3 $\dfrac{\text{Release rate from repository } (\mu\text{Ci/sec}) \times \text{decay factor}}{515\ \text{l/sec flow of Pecos River}}$

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ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-8

EEG-8

NEW MEXICO
HEALTH AND ENVIRONMENT
DEPARTMENT

THE SIGNIFICANCE OF CERTAIN RUSTLER AQUIFER PARAMETERS FOR PREDICTING LONG-TERM RADIATION DOSES FROM WIPP

Carla Wofsy

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Environmental Improvement Division
Health and Environment Department
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September 1980

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NOTICE TO THE READER

The Environmental Evaluation Group (EEG) was assigned to the New Mexico Institute of Mining and Technology in October 1988 by the National Defense Authorization Act, Fiscal Year 1989, Public Law 100-456, Section 1433, and is no longer a part of the New Mexico Health and Environment Department, Environmental Improvement Division. Continued funding is being provided by the Department of Energy through Contract DE-AC04-79AL10752.

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The Significance of Certain Rustler Aquifer

Parameters for Predicting Long-Term

Radiation Doses From WIPP

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FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the Waste Isolation Pilot Plant (WIPP), a Federal radioactive waste repository proposed for construction underground in an area near Carlsbad, New Mexico. The objective of the EEG evaluation is to protect the public health and safety and ensure that there is no environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP. Analyses are conducted by EEG of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies, and other organizations as they relate to the potential health, safety, and environmental impacts of WIPP. These analyses may involve public meetings, site visits, and consultations with agencies, professional associations, and scientific experts.

The project is funded entirely by the U.S. Department of Energy through Contract #DE-AC-04-79AL10752 with the New Mexico Health and Environment Department.

Robert H. Neill
Director

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SUMMARY

This report considers some aspects of the radionuclide transport modeling presented in documents published by the U. S. Department of Energy (DOE) regarding the Waste Isolation Pilot Plant (WIPP) nuclear waste repository proposed for development in Southeastern New Mexico. The radionuclide transport modeling is used to predict worst possible consequences of a WIPP repository breach event in which waste enters groundwater. The aim of this report is to determine whether plausible changes in the parameters used by DOE to describe the flow of groundwater near the WIPP site could result in: a) significantly faster radionuclide movement in groundwater; and b) significantly higher concentrations of radionuclides in Pecos River water and correspondingly higher radiation doses than predicted by DOE. The conclusion reached is that while plausible changes in hydrologic conditions and waste-rock interactions might result in a significant reduction in the time it takes for radionuclides to reach the Pecos River, the shorter travel times do not result in significant increases in the estimated concentrations of radionuclides in the Pecos River nor in the radiation doses associated with the use of such water. Other ways in which parameter changes might affect these concentrations and doses are mentioned in the Conclusions section of the report, but are not the subject of this analysis.

The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Exposures from WIPP

I. Introduction

To estimate worst possible radiation doses which might result from a hydrologic breach of the proposed WIPP repository, the U. S. Department of Energy (DOE) has considered situations in which:

1. groundwater passes through the repository, dissolves some waste and brings the dissolved radionuclides into the Rustler aquifer;
2. the radionuclides are carried by the Rustler water to the Pecos River at Malaga Bend, fifteen miles from the WIPP site.

(See, for example, the WIPP Safety Analysis Report, Ref. 1 and the Draft Environmental Impact Statement for WIPP, Ref. 2). Figure 1 illustrates two of the breach events which have been analyzed.

The aim of this report is to assess the assumptions made in modeling step 2, nuclide transport in the Rustler. The question is: has a worst (plausible) case really been considered?

In its report of a January, 1980 meeting of geologists and hydrologists to discuss conditions in the vicinity of the WIPP site, the Environmental Evaluation Group has summarized information presented concerning the status of hydrologic testing and questions raised concerning the adequacy of the available data for predicting consequences of a repository breach(Ref. 3). It is clear that there are uncertainties in the hydrologic parameters used for modeling flow in the Rustler aquifer, and that there are even greater uncertainties involved in predicting changes in hydrologic conditions that might occur over thousands or millions of years. However, it is not clear that these uncertainties introduce equivalent uncertainties into the projected consequences of a worst case WIPP repository breach. This report will address the question of whether or not a worst plausible case has been considered in the WIPP Safety Analysis Report (SAR) nuclide transport modeling by asking:

Can plausible changes in the nuclide transport modeling assumptions and Rustler aquifer parameters result in significantly higher estimates of peak radionuclide concentrations in Pecos River water? (By "peak concentration" is meant the radionuclide concentration in Pecos River water at Malaga Bend, measured in picocuries per liter, at the time when that concentration is highest.)

In order to limit attention to step 2 of the breach event modeling, nuclide transport in the Rustler aquifer, it is assumed that radionuclides enter the Rustler at a given rate and move along a flow path to Malaga Bend. Then the calculated radionuclide concentrations in Pecos River water and the resulting radiation doses depend primarily on the transit times of the radionuclides in the Rustler, between the WIPP site and the Pecos River. For radionuclides in the initial repository inventory, the longer it takes the nuclide to reach the Pecos River, the smaller its concentration will be in the river, because of radioactive decay of the nuclide. For radioactive decay products, the situation is more complex, because ingrowth causes an increase in activity over a period of time, followed by a decrease.

This paper is organized as follows:

Section II outlines the models used in the WIPP SAR (Ref. 1) and in this report to describe radionuclide transport in the Rustler aquifer. The next two sections explore the relation between peak radionuclide concentrations in the Pecos River and key hydrologic parameters. First, Section III considers the relation between the hydrologic parameters and the radionuclide travel times. Then, Section IV considers the relation between radionuclide travel times and peak radionuclide concentrations in the Pecos River. Sections V and VI examine the plausibility of various changes in parameter values and modeling assumptions used to assess consequences of a WIPP repository breach. In Section VII, radiation dose commitments which could result from drinking Pecos River water are calculated, under a variety of assumptions. Conclusions are summarized in Section VIII.

Although this analysis investigates only a portion of the breach consequence assessment which has to do with nuclide transport in the aquifer, it is necessary to have some source term to use for radionuclide concentration and dose calculations. That is, one must start with a rate at which radionuclides are introduced into the aquifer. For illustrative purposes, this analysis will focus on a single radionuclide, Plutonium-239 (Pu-239). This choice is made for the following reasons: The waste proposed for permanent disposal at WIPP is transuranic waste, primarily that classified as contact handled.* The radionuclide content includes plutonium and americium isotopes. Pu-239 is the dominant radionuclide in contact handled transuranic waste, in the sense that it has a long half-life (2.4×10^4 years) and a higher initial inventory than any of

* Transuranic waste (i.e., waste contaminated with plutonium, americium and other radionuclides with atomic number greater than that of uranium) is classified as contact handled if its container has a surface dose rate of 200 mrem/hr or less.

the other alpha-emitting radionuclides present. However, under the hydrologic modeling assumptions used in the WIPP SAR, Pu-239 travels so slowly in the Rustler aquifer that it decays before it reaches the Pecos River. While its decay product Uranium-235 does contribute significantly to dose estimates, Plutonium-239 itself does not. This analysis will explore the possibility that plausible changes in the hydrologic modeling assumptions can result in a substantial portion of the Pu-239 inventory reaching the Pecos River.

In the WIPP SAR, the hydrologic breach event which would result in the largest amount of waste entering the Rustler aquifer is Communication Event 1, in which water flows from the Bell Canyon aquifer below the repository, through the repository and up into the Rustler aquifer (see Figure 1). Thus, peak radionuclide concentrations and dose commitments will be calculated based on the rate at which Plutonium-239 would be released into the Rustler aquifer under the SAR assumptions for Communication Event 1.

III. Nuclide Transport Model

The Sandia Waste Isolation Flow and Transport model (SWIFT), developed by Intera Environmental Consultants, Inc., has been used by the Department of Energy for calculations involving nuclide transport in the Rustler aquifer (Ref. 4). For the purposes of calculating the nuclide concentrations in Rustler brine entering the Pecos River, a simplified version of the model is used by DOE (Ref. 1, Section 8.2.1.3.3). The basic assumptions made for this application can be outlined as follows:

Assumption 1. Water Flow in the Rustler Aquifer

Water moves along a one-dimensional flow path with average velocity $\bar{v}$ given by Darcy's Law:

$$\bar{v} = \frac{K}{\theta} \cdot \frac{\Delta h}{\Delta \ell} \quad \text{ft/yr} \qquad (1)$$

where:

θ = aquifer porosity

K = hydraulic conductivity or permeability (ft/yr)

$\frac{\Delta h}{\Delta \ell}$ = hydraulic gradient (change in hydraulic head per unit distance).

To account for the fact that at any time and position, some water particles are moving more rapidly than the average while some are moving more slowly, the differential equation describing flow includes a term which reflects this "longitudinal dispersivity."

Assumption 2. Equilibrium Adsorption of Nuclides

At any point in the aquifer and at any time, the activity concentration of a given radionuclide is distributed between the aquifer rock and the aquifer water as follows:

$$C_s = K_d \, C_L \qquad (2)$$

where:

C_s = activity concentration in/on rock (pCi/g)

C_L = activity concentration in water (pCi/mℓ)

K_d = distribution coefficient for the nuclide in question (mℓ/g).

Assumption 3. Radioactive Decay and Ingrowth

Nuclide concentrations change with time because of radioactive decay. These changes are built into the SWIFT model.

In order to study the effects of parameter changes on nuclide concentration and dose estimates, it is useful to simplify Assumption 1 still further and neglect longitudinal dispersivity. This can be justified only if the simplification does not change the model predictions significantly, for the nuclides under consideration. In Appendix VI of Ref. 5, Greenfield has shown that for long-lived radionuclides and their decay products this is indeed the case; that is, the peak concentration and dose estimates obtained using the SWIFT model, including longitudinal dispersivity, are close to those obtained using the analogous model with zero dispersivity. Results of the two models differ by less than a factor of 2 in the case of long-lived initial inventory radionuclides. When additional approximations are made in connection with the simple model to accommodate a decay chain in which different members move with different velocities, the concentration and dose estimates obtained from the two models still differ by less than a factor of 5. Peak concentration and dose estimates obtained using the simpler model tend to be larger than those obtained taking dispersivity into account.

Thus, for the remainder of this analysis, the following assumption will be made.

Assumption 4. Zero Dispersivity

Longitudinal dispersivity is zero. All water particles move with the average velocity $\bar{v}$ given by equation (1).

Under these assumptions, it can be shown (Ref. 5, Appendix VI) that a nuclide with a distribution coefficient K_d (mℓ/g) will move in the aquifer with velocity:

$$r = \frac{\bar{v}}{B} \quad \text{ft/yr} \qquad (3)$$

where B, the retardation factor, is given by:

$$B = 1 + \frac{\rho}{\theta} K_d \qquad (4)$$

ρ = aquifer density (g/mℓ).

III. Hydrologic Parameters and Nuclide Travel Times

Suppose the aquifer parameters defined in Section II are constant over a portion of the flow path which is d feet long. Then the time T that it takes for a nuclide to travel through that part of the flow path is given by:

$$T = \frac{d}{r} = \quad \text{yr} \qquad (5)$$

where r is the nuclide velocity, given in ft/yr.

Combining equations (1), (3), (4) and (5) gives:

$$T = \frac{d(\theta + \rho K_d)}{K\ (\Delta h/\Delta \ell)} \quad \text{yr} \qquad (6)$$

for the time T that it takes for a radionuclide with distribution coefficient K_d to traverse a segment of the aquifer having length d, porosity θ, density ρ, hydraulic conductivity K and hydraulic gradiant $\Delta h/\Delta \ell$.

To illustrate the effects of the various parameters on T, consider Plutonium-239 traversing the first 5 miles of the flow path from the repository to the Pecos River. The parameter values for this interval, based on information in the SAR*, are:

$$d = (5\ \text{mi})\ (5280\ \text{ft/mi}) = 2.6 \times 10^4\ \text{ft}$$

$$\theta = 0.1$$

$$\rho = 2\ \text{g/m}\ell$$

$$K_d = 2.4 \times 10^3\ \text{m}\ell/\text{g}$$

$$K = 1\ \text{ft/day or } 365\ \text{ft/yr}$$

$$\frac{\Delta h}{\Delta \ell} = \frac{100\ \text{ft}}{(5\ \text{mi})\ (5280\ \text{ft/mi})} = 3.8 \times 10^{-3}.$$

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* Table 3.3-1 gives $\theta = 0.1$; Table 2.5-12 gives 2.4×10^3 mℓ/g as the lowest K_d value measured with plutonium, groundwater and Rustler formation rock; Figure 8A-4 gives K=1 ft/day at the WIPP site (Ref. 1).

The hydraulic gradient $\Delta h/\Delta \ell$ is computed on the basis of the potential lines shown in Figure 2. Over the first 5 miles of the flow path from the repository, the calculated hydraulic potentials in the Rustler aquifer drop 100 feet, from about 3150 to 3050 feet.

Substituting these parameter values into equation (6) one finds that the time T that it would take for Pu-239 to migrate over this 5 mile stretch is:

$$T = 9.0 \times 10^7 \text{ yr.}$$

The question is: What changes in parameter values could reduce the travel time T significantly? To make the example more specific, what changes in parameter values could result in an order of magnitude decrease in T?

If the distribution coefficient K_d decreases by an order of magnitude, the travel time T decreases by an order of magnitude. The same decrease in T would result from an order of magnitude increase in hydraulic conductivity K or hydraulic gradient $\Delta h/\Delta \ell$. Changes in the aquifer porosity θ have virtually no effect on the travel time T, provided that the distribution coefficient K_d remains high (say, above 10).

IV. Plutonium-239 Travel Time and Its Peak Concentration in the Pecos River

If Pu-239 enters the Rustler aquifer at a rate of q pCi/sec at the WIPP site, moves in the Rustler according to the assumptions in Section II, and begins to enter the Pecos River at an arrival time T_A years after waste emplacement, then the peak concentration C of Pu-239 in Pecos River water is given by:

$$C = \frac{q\ e^{-(\ell n\ 2)(T_A)/(2.4 \times 10^4)}}{F} \quad p\ Ci/\ell \qquad (7)$$

where 2.4×10^4 years is the half-life of Pu-239 and F ℓ/sec is the Pecos River flow at Malaga Bend. The minimum value for F is given in the SAR as 18 ft^3/sec (Ref. 1, 8.2-9). That is:

$$F = 5.1 \times 10^2\ \ell/sec.$$

As discussed in Section I, the breach event under consideration in this analysis involved a hydrologic connection between aquifers above and below the repository. The SAR describes such a breach event: Communication Event 1. Under the SAR assumptions* for Communication Event 1, the rate q at which Pu-239 in contact handled transuranic waste enters the Rustler is:

$$q = 2.1 \times 10^4\ \ pCi/sec.$$

Thus, from equation (7), the peak concentration C of Pu-239 in Pecos River water is:

$$C = 41 \times e^{-(\ell n2)T_A/2.4 \times 10^4} \quad pCi/\ell \qquad (8)$$

* The steady state repository dissolution rate is given as 0.25 ft^3/day (p. 8.3-5); the fraction of the repository volume which is waste is 0.115 (p. 8.3-3); and the specific activity of Pu-239 in the waste is 2.21×10^{-3} Ci/ℓ (Table 3.1-2). Then q = (0.25 ft^3/day) x (0.115) x (28.32 ℓ/ft^3) x (2.21×10^{-3} Ci/ℓ) x 10^{12} pCi/Ci) ÷ (8.64×10^4 sec/day), (Ref.1).

where the arrival time T_A is the sum of the breach time (i.e. the number of years between waste emplacement and the repository breach event) and the Pu-239 travel time (i.e. the time it takes for Pu-239 to travel in the Rustler aquifer from the WIPP site to the Pecos River).

Using the information in the SAR concerning Rustler aquifer hydrology and distribution coefficients*, the time between a breach event and the arrival time of Pu-239 at the Pecos River would be about 1.4×10^8 years.**

The Pu-239 in the repository inventory would decay in this time, since Pu-239 has a half-life of 2.4×10^4 years. However, this analysis considers whether plausible changes in parameters can lead to significantly shorter travel times and significantly higher radiation doses than those derived from the parameters used in the SAR analysis. For the moment, equation (8) will be used to study the dependence of the peak Pu-239 concentration C on the arrival time T_A, without regard to the plausibility of different T_A values. The plausibility of different arrival time values will be discussed in Section V.

Figure 3 illustrates the relation between the peak Pu-239 concentration C in Pecos River water and the Pu-239 arrival time T_A. Using equation (8), C is plotted against the logarithm of T_A. This semi-log plot makes it easy to see how order-of-magnitude changes in T_A affect C. Table 1 summarized key values of C.

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* Table 2.5-12, Table 8.3-1, Figure 8A-2 and Figure 8A-4, (Ref. 1).

** The sum of the travel times for the first 5 miles, where K=1 ft/day and the last 10 miles, where K=4 ft/day (Ref. 1, Figure 8A-4). The other parameters are as given in Section III.

It can be seen from Figure 3 and Table 1, that arrival times between 0 and 10,000 years all result in roughly the same peak Pu-239 concentrations in the Pecos River. If the Pu-239 starts to enter the Pecos River 100,000 years after waste emplacement, then the peak concentration is less than a tenth of what it would be if the arrival time were 10,000 years. An arrival time of 500,000 years results in a further reduction of the peak Pu-239 concentration by a factor of 10^{-5}.

This suggests a way of making the basic question more precise:

1. Can plausible changes in the modeling assumptions or hydrologic parameters used in the WIPP SAR analysis result in a Pu-239 Pecos River arrival time of less than 100,000 years?
2. Can the Pu-239 arrival time be less than 10,000 years?

V. The Validity of Using Average Parameter Values

As discussed in Section III, an order of magnitude decrease in distribution coefficient (K_d) or increase in hydraulic conductivity (K) or hydraulic gradient ($\Delta h/\Delta \ell$) would result in an order of magnitude decrease in the travel time (T). Parameter changes amounting to more than three or four orders of magnitude would be necessary to reduce the travel time from 14,000,000 years to 100,000 or 10,000 years. The next step, then, in this analysis, is to evaluate the potential for large changes in the three key parameters.

The hydraulic gradient $\Delta h/\Delta \ell$ appears to be the least variable of these parameters. In order for the average hydraulic gradient to increase by a factor of 10, the difference between potentiometric levels of the Rustler at the WIPP site and at the Pecos River would have to go from 300 to 3000 feet. Such a change does not appear credible.

The hydraulic conductivities K for different portions of the flow path are more likely to deviate from the assumed values, either because of difficulties in measurement, non-uniformity of the aquifer or future changes (e.g. fracturing of the aquifer rock or dissolution of salt in the Rustler at the WIPP site). The SAR calculations of hydraulic conductivities in the Rustler show an increase from 1 ft/day near the WIPP site to 64 ft/day at the Pecos River. It does not appear likely that hydrologic conditions in the vicinity of the site would change so drastically in 10,000 or even 100,000 years that they would match present conditions in the Rustler near the Pecos River. Perhaps an increase by one order of magnitude in hydraulic conductivity values can be taken as a worst plausible case.

The most unpredictable of the parameters is the distribution coefficient (K_d). Laboratory K_d measurements using apparently identical rocks, solutions and precedures can differ by an order of magnitude. Changing the rock or solution slightly can result in greater discrepancies. Different laboratories report widely different results (e.g. plutonium K_d values between 16 and 20 mℓ/g for Culebra dolomite and "prepared water" in Ref. 6 and values of 2,100 mℓ/g for Culebra dolomite and brine and 7,300 mℓ/g for Culebra dolomite and groundwater in Ref. 7). In addition to the problems just discussed involving reproducibility of laboratory measurements, there are problems involved with predicting and studying in-situ conditions. Many factors influence the relative amounts of a nuclide in the solid and liquid phases of an aquifer. For example, the concentration of the nuclide in question or of other elements, can affect the capacity of the rock to absorb more of the radionuclide; thus a "loading effect" can reduce K values. Chelating agents like EDTA can also reduce K_d values, as can temperature, pH and other physical and chemical properties of the rock, the water and the nuclide. Table 21 in Ref. 7 shows a reduction of one to two orders of magnitude in K_d (for Gd-153, Eu-152 and Ce-144) when a plywood extract is added to the solution.

Therefore, it is conceivable that average K_d values for nuclides in a waste and brine mixture, moving through fifteen miles of the Rustler aquifer, would turn out to be two or even three orders of magnitude smaller (or larger) than the value used in the WIPP SAR nuclide transport modeling. However, statements in the SAR indicate that the K_d values chosen already reflect a worst case (i.e. lowest plausible average values).

The plutonium K_d value used in the SAR modeling is the lower of two K_d values reported in WIPP site-specific tests using simulated groundwater and Rustler formation rock from just outside the WIPP boundary (Ref. 1, Table 2.5-12). Further, the measurements are made using a highly oxidized species of plutonium, which is thought to be more mobile than species with lower oxidation states but less likely to be present following a repository breach (Ref. 1, p.2.5-43).

VI. Heterogeneity of Aquifer and Nuclide Properties

The preceding section considered the extent to which the average values of key parameters could differ, now or in the future, from those used in the WIPP safety assessment. This section will discuss the extent to which it is appropriate to look at average behavior. The answer proposed is in two parts.

1. In this application, it is appropriate to use average hydrologic parameters to describe water movement in the aquifer.
2. The use of a single average distribution coefficient for each nuclide may mask significant effects resulting from the migration of a subpopulation of the nuclide particles.

Point 1, regarding water movement in the aquifer, requires some qualification. The claim is that it is appropriate to use average parameter values over intervals where there are no large scale changes in hydrologic conditions. For example, one should not lump mile-long stretches where the hydraulic conductivity is measured as 1 ft/yr with mile-long stretches where the hydraulic conductivity is measured as 50 ft/yr. However, small scale variations should not add up to gross effects on water movement over a 15 mile flow path. In its travel from the WIPP site to the Pecos River, each water drop will pass through 1 inch or 10 foot fractures where it moves relatively quickly and through small portions of the aquifer which are less permeable than the average. The hydraulic gradient may be steep over a small interval, but will be less steep than the average somewhere else. This type of variation over short intervals would not result in significant changes in the nuclide concentrations and doses calculated on the basis of average values of hydrologic parameters over several mile intervals.

What is the difference, then, between the use of average aquifer parameters and the use of average distribution coefficients? The difference, as suggested in point 2, is that there may be subpopulations of nuclide particles which migrate through the whole 15 mile flow path in a way that differs significantly from the predicted norm.

Consider the case of plutonium. Under the equilibrium adsorption assumption stated in Section II, using a K_d value of 2400 mℓ/g, each plutonium particle spends a large amount of time associated with the aquifer rock and not moving with the water. This is what slows the plutonium down in its migration through the aquifer. Since there is a single K_d value governing the behavior of all of the particles, all are slowed down equally.

It is more likely, especially given the heterogeneity of the contact handled transuranic waste to be stored in the WIPP repository, that plutonium and other radionuclides will be in various physical and chemical states and complexes and will be heterogeneous in their affinity for aquifer rock and their solubility in water.

Two lines of experimental evidence suggest that if a repository breach occurred, a fraction of the plutonium particles entering the Rustler would move with an effective distribution coefficient of zero. In the plywood extract experiment discussed in Section V, there is an apparently lowering of K_d when the organic material is added to the brine-rock-nuclide mixture used to measure K_d. One interpretation suggested in Ref. 7 is that some of the nuclide particles are in organic complexes. The reason this would lower the apparent K_d is that the particles in organic complexes would remain in solution (i.e. behave as if their K_d were zero) while the other particles would not change their behavior.

In these batch experiments, movement is not observed and the chemical forms of nuclides and nuclide complexes are not determined, so any heterogeneity in form or behavior of the nuclide in question would not be observed directly.

Column infiltration experiments reported in Ref. 6 provide direct evidence of transuranic nuclide fractions which move in water through porous rock columns at the speed of water (i.e. with $K_d = 0$).* Additional amounts of the nuclide are observed to travel more slowly than water in the columns but much more rapidly than would be predicted on the basis of average K_d values measured in either batch or column experiments.**

It is not clear how to apply the results of these column infiltration experiments to nuclide migration modeling in the case of a repository breach event. The experiments discussed in Ref. 6 were not done with Rustler formation rocks. In addition, the nuclides were not in solution with organic material or minerals which would be present in the event of a WIPP repository breach. Finally, nuclide migration behavior over a distance of several centimeters in a column may not mimic nuclide behavior over a fifteen mile path. However, until WIPP-specific experiments or theoretical analyses are performed which rule out the presence of a mobile plutonium (or transuranic) fraction under WIPP conditions, this possibility should be included in the

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* The fractions listed are 7×10^{-5} for Pu^{4+} in limestone; 3×10^{-4} for Np^{5+} in limestone; and 1.3×10^{-2} for Np^{5+} in sandstone (Ref. 6, p. 15).

** For example, in one experiment, 1/1000th of the plutonium used was observed to pass through limestone at a velocity at least equal to ½ the water velocity. A neptunium fraction of 0.12 was observed to move through sandstone at a velocity at least equal to 0.1 times the water velocity (Ref. 6, p. 15).

breach consequence assessment for WIPP. Based on the evidence available so far, it is possible that a portion of the transuranic inventory injected into the Rustler aquifer in the event of a WIPP repository breach would be in a chemical form which would allow it to move through the aquifer unretarded.

The fraction chosen to represent a plausible worst case for the remainder of this analysis is 0.01. That is, this analysis will investigate the consequences of assuming that one percent of the Pu-239 entering the Rustler aquifer in the case of a repository breach moves throughout the fifteen mile flow path at the velocity of the aquifer water. The one percent value is much higher than that observed in the Ref. 6 plutonium/limestone experiment and slightly lower than that observed in the neptunium/sandstone experiment. It is considered to be a plausible worst case value because of the conflicting influences of the presence of organic material (which might create a mobile subpopulation) and the length of the flow path (which allows time for the alteration of chemical form, breaking down subpopulations).

VII. Potential Doses from Drinking Pecos River Water

The WIPP SAR includes calculations of radiation doses which people could receive if Pecos River water were to be contaminated following a repository breach event. The doses calculated are from the ingestion of fish and water and from external exposure during swimming, boating and other activities (Ref. 1, p. 8.2-9). The largest doses are from the ingestion of water, except in the case of Radium-226 where the ingestion of fish leads to slightly greater doses than the ingestion of water. Thus dose projections based on drinking Pecos River water can give a good idea of the overall radiation dose which might be received from the various water uses.

The doses calculated in this section will be whole body fifty year dose commitments received by maximally exposed adults from one year's ingestion of Pu-239 in Pecos River water. These are the doses most easily compared with doses listed in the SAR. The dose commitment D (mrem) resulting from one year's ingestion of water with a Pu-239 concentration of C (pCi/ℓ) is given by:

$$D = (C \text{ pCi}/\ell)(730\ell)(1.9 \times 10^{-5} \text{ mrem/pCi}) \quad (9)$$

where 730 liters is the value recommended in NUREG 1.109 (Ref. 8, Table E-5) as the annual water uptake value to assume for maximally exposed adults and 1.9×10^{-5} mrem is given in NUREG 0172 (Ref. 9, Table 4) as the fifty year total body dose commitment an adult receives from ingesting 1 pCi of Pu-239 in the first year.

Table 2 lists peak Pu-239 concentrations C in Pecos River water and corresponding fifty year total body dose commitments D received by adults drinking 730 liters of the water in a year, for a variety of modifications of the SAR hydrologic modeling assumptions. Figure 4 shows how the dose commitment depends on the average K_d value used, if other parameters and assumptions are as in the SAR. The breach event is assumed to occur 1000 years after waste emplacement.

VIII. Conclusions

Based on the discussion of average parameter values in Section V, it is possible but unlikely that in the event of a hydrologic breach of the WIPP repository, the average values of the key hydrologic transport parameters would differ by more than three orders of magnitude from those used in the SAR modeling, all in a direction which would reduce the Pu-239 travel time to 100,000 years and raise the peak Pu-239 concentration in Pecos River water to 2.3 pCi/ℓ. It is very unlikely that the average Pu-239 travel time would actually be as low as 10,000 years, raising the peak Pecos River concentration to 31 pCi/ℓ.

It is possible, as discussed in Section VI, that a portion of the transuranic nuclide inventory, including Pu-239, will be in a chemical form which allows it to stay in solution and move at the velocity of the aquifer water. If one percent of the Pu-239 entering the Rustler aquifer under the conditions discussed in this analysis were to move throughout the fifteen mile flow path unretarded, this would result in a peak Pu-239 concentration in Pecos River water of 0.37 pCi/ℓ.

The fifty year total body dose commitments which adults drinking 730 liters of Pecos River water in a year would receive from the Pu-239 in the water are:

1. 3.2×10^{-2} mrem, if the Pu-239 travel time in the Rustler aquifer is 100,000 years;
2. 5.1×10^{-3} mrem, if 1% of the Pu-239 in the aquifer has a distribution coefficient (K_d) of zero.

These doses are comparable to the Radium-226 drinking water dose of 3.8×10^{-3} mrem from one year's intake, reported in

SAR Table 8.3-2. Thus, plausible variations in the SAR assumptions governing nuclide transport in the Rustler aquifer do not result in Pu-239 doses which are significantly greater than the Ra-226 doses already projected on the basis of the SAR assumptions. It can also be shown, using the methods of Greenfield in Appendix VI of Ref. 5 that the peak Ra-226 concentrations and doses do not change significantly* under plausible variations in the SAR assumptions.

This analysis addressed a limited question, and the conclusions are limited accordingly. Only part of the breach consequence analysis was considered: the modeling of nuclide transport in the Rustler aquifer. The question asked was essentially: if radionuclides were to enter the Rustler aquifer as described in the SAR breach event modeling, could plausible changes in the SAR nuclide transport modeling lead to predictions of shorter nuclide travel times and greater concentrations of radionuclides in Pecos River water than would be calculated on the basis of the SAR assumptions? The answer is that while plausible changes in hydrologic conditions and waste-rock interactions might result in significantly shortened nuclide travel time in the Rustler aquifer, the shorter times do not result in significant increases in the estimated concentrations of radionuclides in the Pecos River or in the radiation doses received by people drinking the water.

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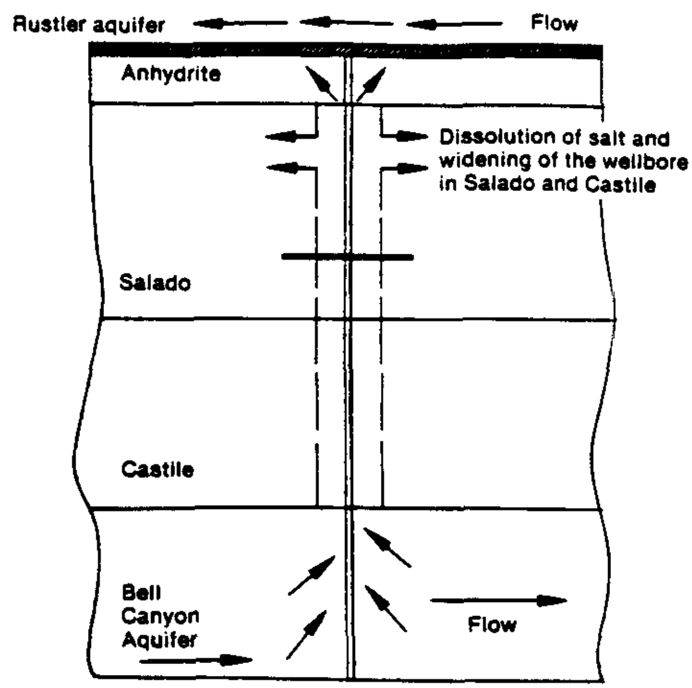
* Doses based on faster water flow in the aquifer, lower K_d's or a portion of the Ra-226 and its parent nuclides traveling with a $K_d = 0$, within limits judged in this paper as plausible, are at most 20 percent higher than those doses calculated based on SAR assumptions. If all of the Ra-226 and its parent nuclides move with a $K_d = 0$, a situation considered unlikely, then the peak Ra-226 concentration in Pecos River water would be about 7×10^{-4} pCi/ℓ and the resulting drinking water dose would be 0.1 mrem (50 year whole body commitment to a maximally exposed adult).

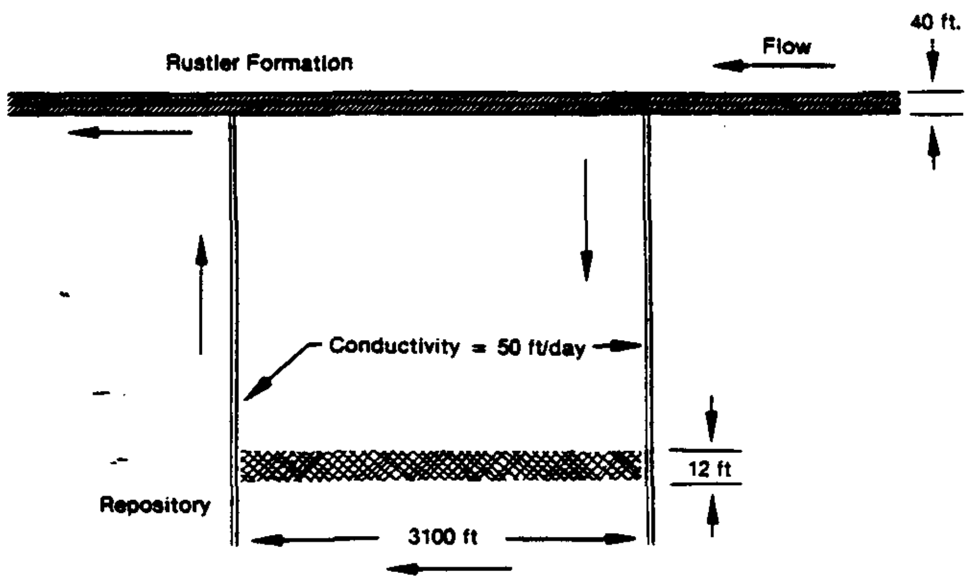
However, aquifer parameters also affect the initial stage of breach consequence analysis, which was not a part of this evaluation. For the breach event considered, in which water flows from the Bell Canyon aquifer below the repository, through the repository and into the Rustler aquifer above the repository the aquifer parameters determine the amount of water flowing through the repository and hence determine the amount of waste dissolved. If the Rustler flow increases, so will the amount of waste entering the Rustler. The relation between the hydrologic parameters and the waste dissolution rate is a subject for further study.

The radiation doses calculated in this study are a function, of course, of the repository inventory. They are low in part because the waste proposed for permanent disposal at WIPP is primarily contact handled transuranic waste. If the repository inventory is changed to include high-level waste, new dose calculations will obviously have to be performed. The methods in this paper can be used to estimate doses from any long-lived radionuclide but because of the zero dispersivity assumption, these methods might be inappropriate for estimating doses from short-lived nuclides.

For short-lived radionuclides, doses would be received primarily from the portion of the inventory moving faster than the average in groundwater.

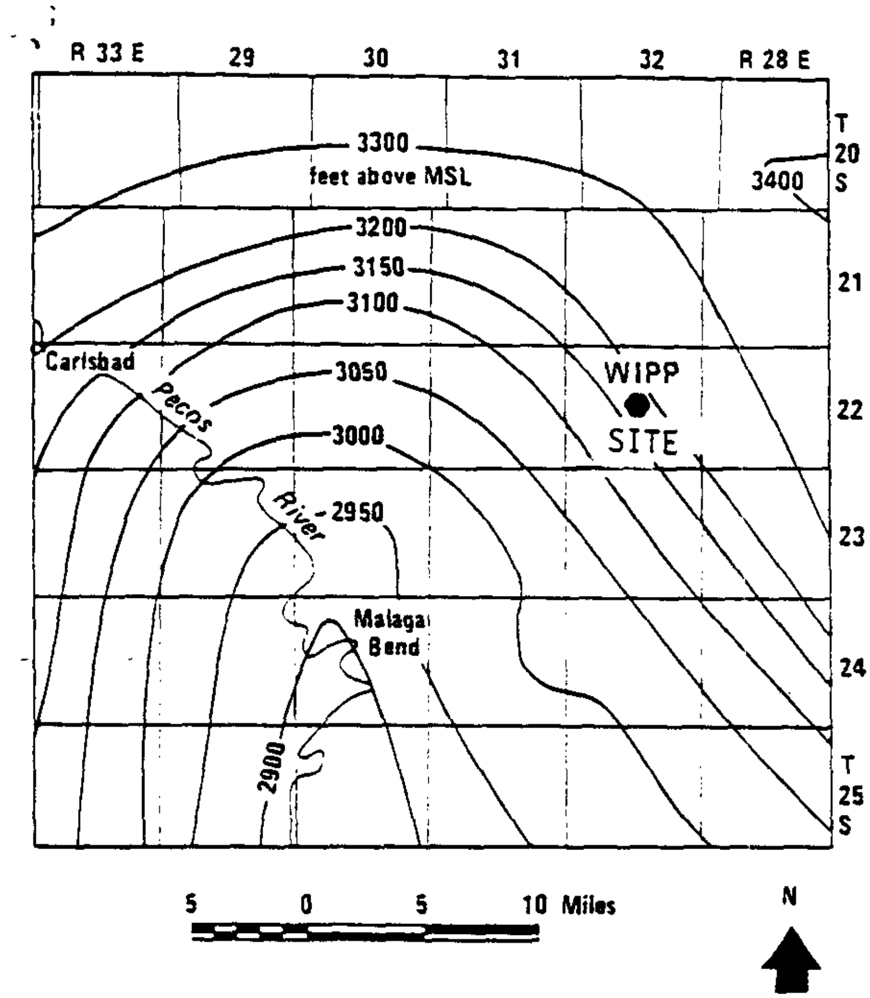


Communication Event 1



Communication Event 2

Figure 1. Schematic Diagram of Two Breach Events, Modified From WIPP DEIS Figures 9-10 and 9-11 (Ref. 2).



NOTES:

1. DATUM IS MEAN SEA LEVEL: VALUES GIVEN IN FEET — FRESH WATER (EQUIVALENT).
2. "RUSTLER AQUIFER" REFERS TO COMBINED CULEBRA AND MAGENTA AQUIFERS.

Figure 2. Reproduced from Figure 8A-2, SAR: Calculated Hydrologic Potentials in the Rustler Aquifer (Ref. 1).

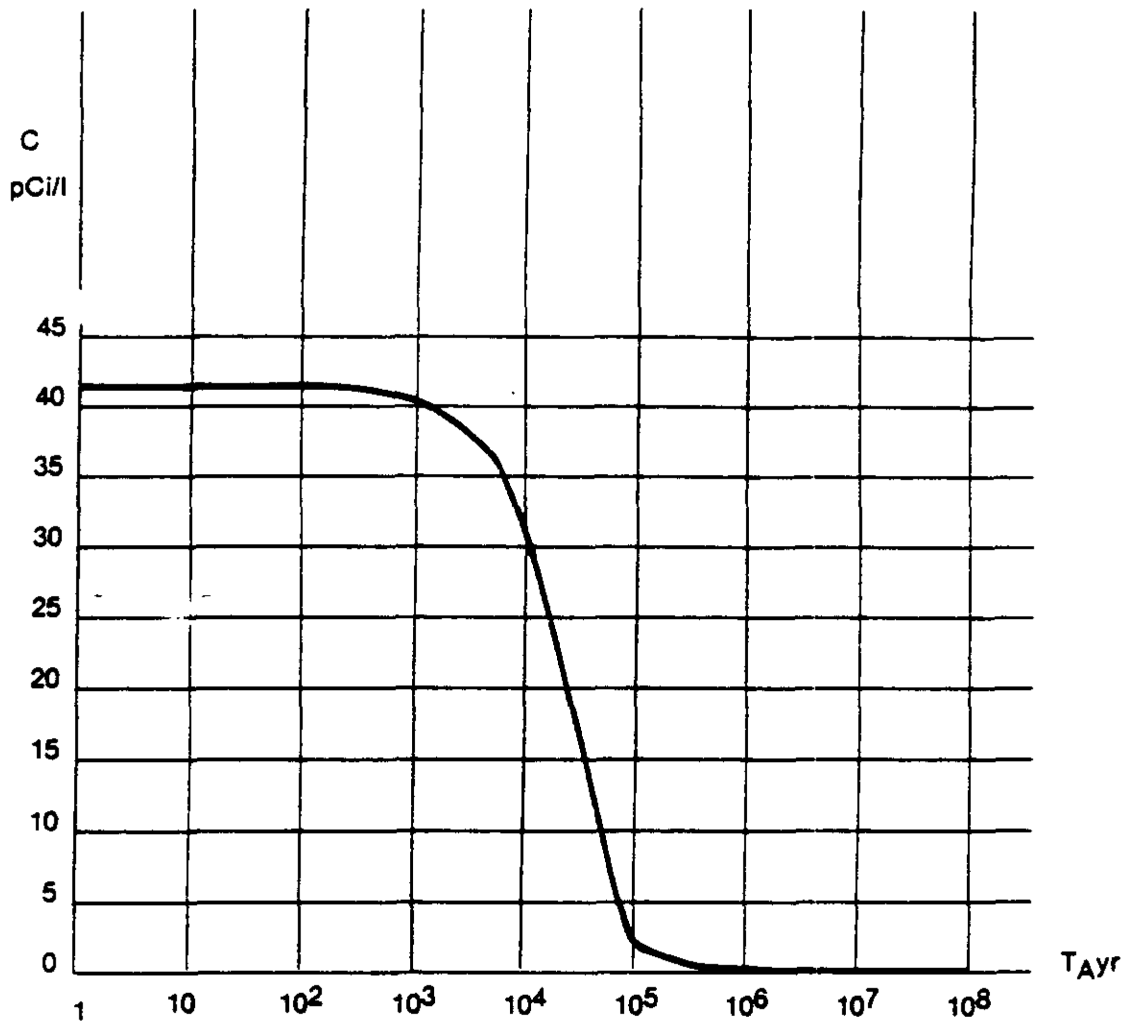


Figure 3. Peak Concentration of Pu-239 in the Pecos River as a Function of Arrival Time T_A.

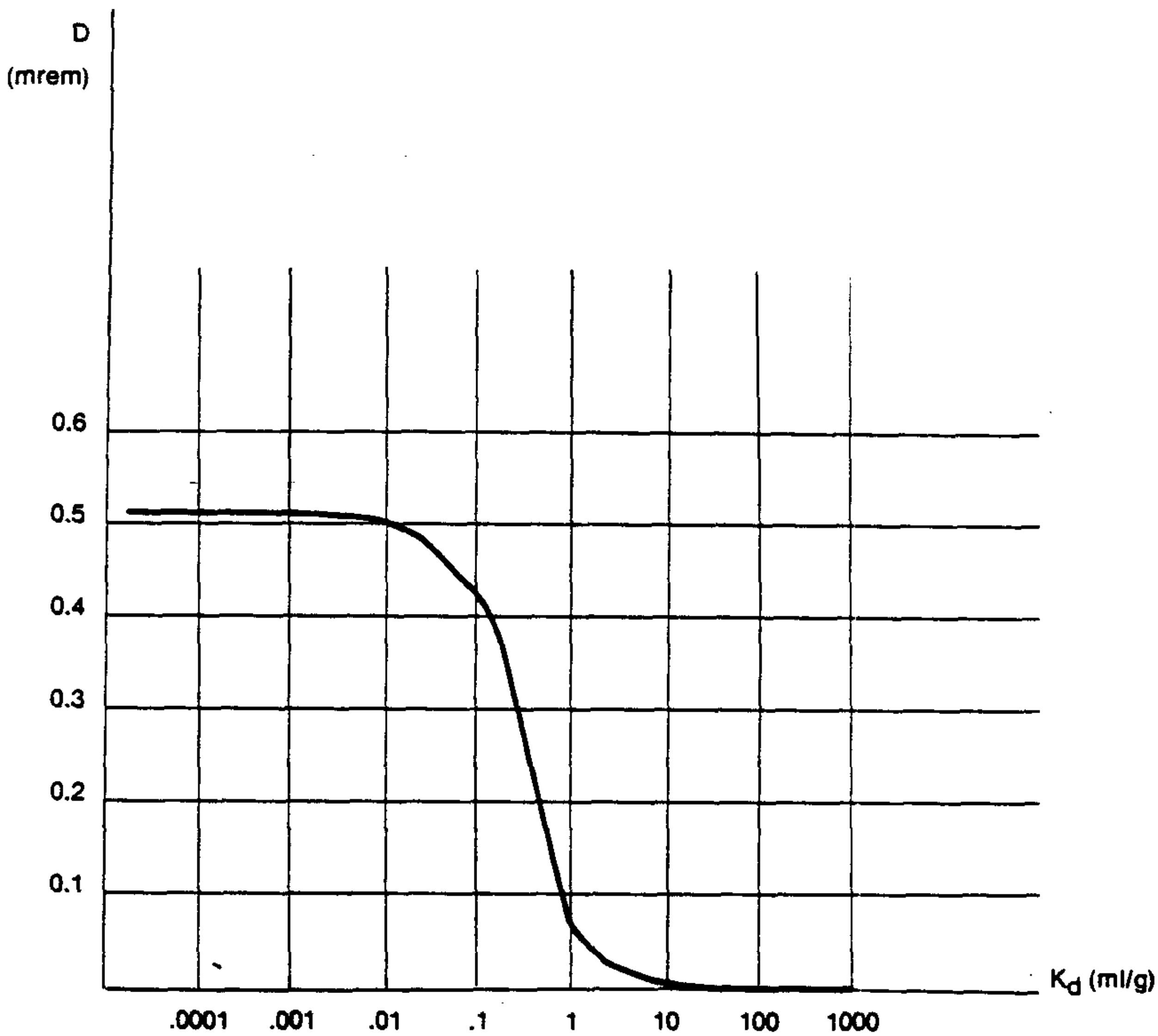


Figure 4. Fifty Year Total Body Dose Commitment D from Drinking 730 Liters of Pecos River Water in First Year, as a Function of Distribution Coefficient K_d.
(Breach time = 1000 yr.).

Table 1. Peak Pu-239 Concentration As a Function of Arrival Time

T_A (yr)		C (pCi/ℓ)	
0		41	
1		41	
10		41	
1	+2[1]	41	
1	+3	40	
5	+3	35	
1	+4	31	
2.4	+4[2]	20.5	
3.5	+4[3]	15	
5	+4	9.7	
1	+5	2.3	
5	+5	2.2	-5
1	+6	1.2	-11
1	+7	< 1	-99
1	+8	< 1	-99

[1] 1 +2 means 10^2.

[2] Pu-239 half-life.

[3] Pu-239 mean life.

Table 2. Peak Pu-239 Concentrations and Dose Commitments

	Modification of SAR Assumptions [1]	Peak Pu-239 Concentration in Pecos River Water [2] (pCi/1)	Adult Total Body 50-Year Dose Commitment from Drinking Water [3] (mrem)
1.	None	0 [4]	0
2.	Porosity θ= 0.01	0	0
3.	Hydraulic conductivity K = 10 ft/day throughout flow path	0	0
4.	K = 50 ft/day throughout flow path (*)	0	0
5.	Distribution coefficient K_d= 100 mℓ/g throughout flow path	0	0
6.	K = 10 ft/day and K_d = 100 mℓ/g throughout flow path	1.9 -13	2.7 -15
7.	K_d = 10 mℓ/g throughout flow path	2.6 -6	3.6 -8
8.	K = 10 ft/day and K_d = 10 mℓ/g throughout flow path	1.7	2.4 -2
9.	K_d = 1 mℓ/g throughout flow path (*)	7.0	9.8 -2
10.	K_d = 0 mℓ/g throughout flow path (*)	37.	5.1 -1
11.	1% of the Pu-239 moves at the velocity of water	0.37	5.1 -3
12.	10% of the Pu-239 moves at 0.1 times the velocity of water	1.7	2.4 -2
13.	10% of the Pu-239 moves at the velocity of water (*)	3.7	5.1 -2

---

(1) All modifications lead to faster nuclide movement.

(2) Based on equations (6) and (8).

(3) Based on equation (9).

(4) 0 means < 10^{-50}.

(*) Starred modifications are not considered plausible.

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ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-9

EEG-9

An Approach to Calculating Upper Bounds on Maximum Individual Doses From the Use of Contaminated Well Water Following a WIPP Repository Breach

[redacted]

Peter Spiegler, Ph.D.
Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

September 1981

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EEG-1 A Compilation of Site Selection Criteria, Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, Donna Goad, June 1979.

EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volumes I and II, December 1978.

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An Approach to Calculating Upper Bounds on Maximum Individual Doses From the Use of Contaminated Well Water Following a WIPP Repository Breach

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
P O Box 968
Santa Fe, NM 87503

September 1981

CONTENTS

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the Waste Isolation Pilot Plant (WIPP), a Federal radioactive waste repository proposed for construction underground in an area near Carlsbad, New Mexico. The objective of the EEG evaluation is to protect the public health and safety and ensure that there is no environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP. Analyses are conducted by EEG as well as reviews of reports issued by the U. S. Department of Energy (DOE) and its contractors, other Federal agencies and other organizations as they relate to the potential health, safety and environmental impacts of WIPP.

The project is funded entirely by the U. S. Department of Energy through Contract #DE-AC-04-79AL10752 with the New Mexico Health and Environment Department.

Robert H. Neill
Director

LIST OF FIGURES AND TABLES

ACKNOWLEDGEMENT

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SUMMARY

As part of the assessment of the potential radiological consequences of the proposed Waste Isolation Pilot Plant (WIPP), this report evaluates the post-closure radiation dose commitments associated with a possible breach event which involves dissolution of the repository by groundwaters and subsequent transport of the nuclear waste through an aquifer to a well assumed to exist at a point 3 miles downstream from the repository.

The concentrations of uranium and plutonium isotopes at the well are based on the nuclear waste inventory presently proposed for WIPP and basic assumptions concerning the transport of waste as well as treatment to reduce the salinity of the water. The concentrations of U-233, Pu-239, and Pu-240, all radionuclides originally emplaced as waste in the repository, would exceed current EPA drinking water limits. The concentrations of U-234, U-235, and U-236, all decay products of plutonium isotopes originally emplaced as waste, would be well below current EPA drinking water limits. The 50-year dose commitments from one year of drinking treated water contaminated with U-233 or Pu-239 and Pu-240 were found to be comparable to a one year dose from natural background. The 50-year dose commitments from one year of drinking milk would be no more than about 1/5 the dose obtained from ingestion of treated water.

These doses are considered upper bounds because of several very conservative assumptions which are discussed in the report.

I. Introduction

As part of the assessment of radiation risk associated with the proposed Waste Isolation Pilot Plant (WIPP), the Department of Energy (DOE) has considered ways in which the repository might be breached long after it is sealed. Four representative scenarios chosen for analysis (Refs. 1, 2) have the following assumptions:

1) A hydrologic breach event occurs.
2) Radioactivity is leached from the waste at the same rate as salt is dissolved into water. The contaminated water is transported to the Rustler aquifer formation through a connection.
3) The contaminated water enters the Rustler aquifer and moves with the aquifer water toward Malaga Bend, where it enters the Pecos River.

The transport of radioactive waste in the Rustler aquifer is considered by DOE to be the principal pathway which would result in radioactivity entering usable water in the shortest time and in the highest concentration.

II. Statement of Problem

This report considers the following scenario:

1) Saturated brine containing leached radioactivity from the repository enters the Rustler aquifer formation.
2) Radioactive brine is transported to a well assumed to exist at a point 3 miles downstream from the repository.
3) As the brine plume moves toward the well, it is diluted such that when the water reaches the well it is assumed to be usable for agriculture, without treatment, and for drinking, after treatment to remove most of the salts.

The dose commitment to average members of the public are based on the consumption of treated well water and of milk from cows drinking untreated well water. The quantity of well water was considered insufficient for use on crops, or for other agriculture; therefore, meat and vegetable pathways were not considered. The vegetable and meat pathways would probably result in only a small fraction of the water and milk pathway.

III. Method of Calculation

The calculations are based on the model illustrated in Figure 1. The repository is separated from the biosphere by a number of barriers which must be breached sequentially if radioactivity is to reach the biosphere. The penetration of a barrier can be achieved only at a cost that is expressed quantitatively in terms of a dilution factor, i.e., radioactive water can only be carried across a barrier by mechanisms which bring about a dilution of the radioactive concentration. Under the assumption that all barriers are breached, the concentration of radioactivity of water reaching the biosphere is given by

$$C_{b,i} = (1.0E{+}12)(D_n \; . \; . \; . \; . \; . \; D_2 \; D_1)\, C_{r,i} \qquad (1)$$

where:

$C_{b,i}$ = Concentration of radionuclide i in water that reaches the biosphere, pCi/ℓ

$C_{r,i}$ = Concentration of radionuclide i in the repository Ci/ℓ

D_j = Dilution factor associated with the breaching of barrier j

1.0E+12* = Conversion factor, Ci to pCi

The dose commitment is then calculated by

$$H_{50,i} = C_{b,i} \; U \; DCF_i \qquad (2)$$

*1.0E+12 + 1×10^{12}

$H_{50,i}$ = 50 year dose commitment for a one year intake of isotope i, mrem

U = the usage; the usage rate or consumption rate of contaminated water or milk, ℓ/yr

DCF_i = the 50 year dose commitment factor (Ref. 3), mrem/pCi

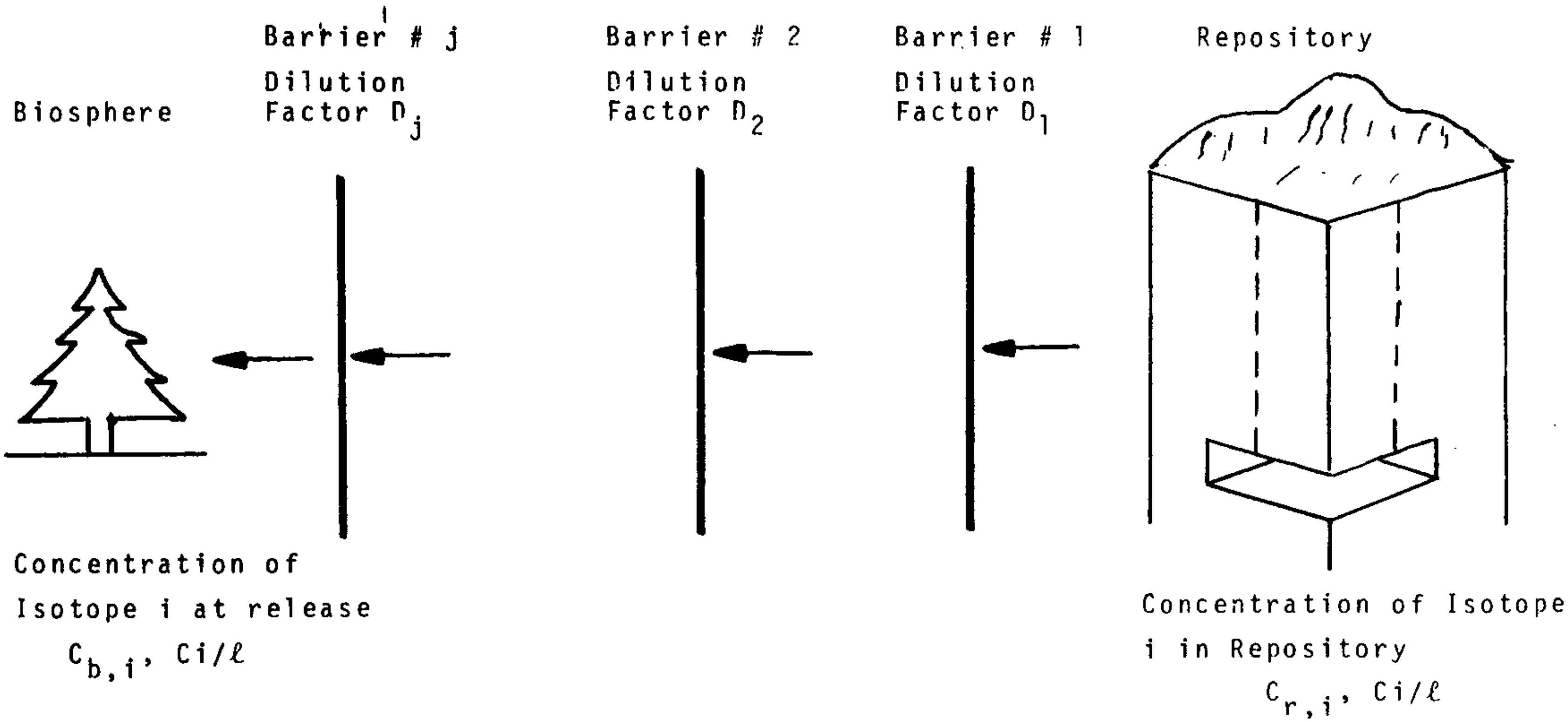

Figure 1. Schemetic of waste movement following a repository breach.

IV. Dilution Factors

1) Leaching of radioactivity from the repository by brine, D_1.

The hydrologic breach event considered is described as communication event 2 by DOE (Ref. 1, 2). Two wellbore connections are made between the Rustler formation and the repository as illustrated in Figure 2. The breach occurs 1,000 years after waste emplacement and decommissioning. Water from the Rustler aquifer flows down the upstream wellbore, through the repository, and then back to the Rustler via the downstream wellbore. Salt is continuously dissolved along the path of flow until the water becomes saturated brine. It is assumed that water leaves the Rustler with a total-dissolved-solids (TDS) concentration of 3000 milligrams per liter and reenters as saturated brine containing 410,000 milligrams per liter of TDS.* Since the density of salt is about 2, one liter of water will dissolve about 0.2 liter of salt when becoming saturated brine. It is further assumed that salt dissolution occurs uniformly along the 5500 foot flow path through the salt bed (see Figure 2) and that the leach rate of waste is equal to the leach rate of salt. The dilution factor to leach the salt/waste is then given by

$$D_1 = f_1 \, f_2 \, f_3 = 1.3E\text{-}02^* \qquad (3)$$

where:

f_1 = Volume of Salado formation dissolved per unit volume of Rustler water = 0.20

f_2 = fraction of breach path through repository = 3100/5500

f_3 = fraction of repository volume which is CH-TRU waste = 0.115

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*The TDS concentration of 3000 is based upon a similar value in a well found at the James Ranch, about 3 miles from the center of the WIPP site (Reference 1, Table 7-19).

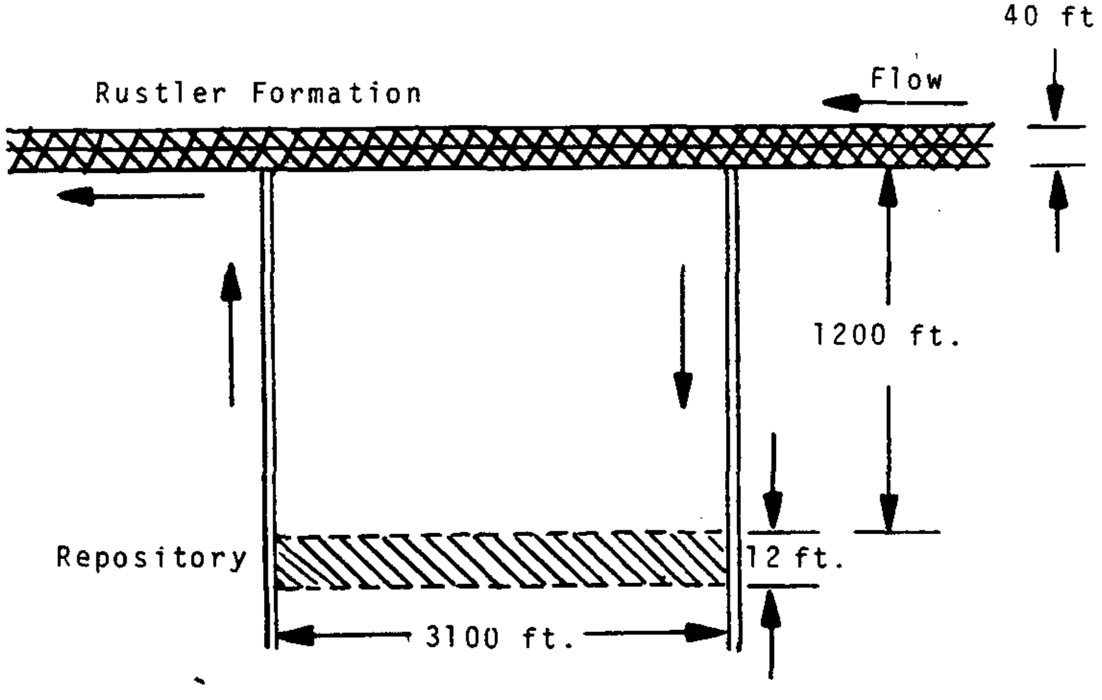

Figure 2. Schematic Diagram of Communication Event 2
Modified From WIPP FEIS Figure 9-11 (Ref. 2)

2) Dilution factor due to movement between repository and well, D_2:

Because of the adsorption and desorption of nuclides as they pass through the rock, the movement of nuclides in the aquifer is slower than the velocity of water.

The nuclide velocity is given by the water velocity divided by the retardation factor B

$$V_n = V_w/B \qquad (4)$$

$$B = 1 + \frac{\rho}{\theta} K_d \qquad (5)$$

where:

V_n = nuclide velocity
V_w = water velocity, 15 ft/yr.
θ = formation porosity = 0.1
ρ = formation density = 2 gm/cc
K_d = distribution coefficient = 1 mℓ/gm for all uranium isotopes and 2.4E+03 mℓ/gm for all plutonium isotopes (Reference 2, Table 2.5-12)

The values of the above parameters are from references 1 and 2. The time of travel between the repository breach and the well is then calculated from

$$T = \frac{dB}{V_w} \qquad (6)$$

where

d = distance between repository breach and well = 3 miles or 15840 ft.

If a repository breach occurs one thousand years after waste emplacement, all uranium isotopes and all plutonium isotopes will reach the well in about twenty thousand and fifty million years respectively (There are other radionuclides in the waste but their radiological impact is not significant compared to the plutonium and uranium isotopes).

Because of radioactive decay, the activity decreases as the nuclides travel in the direction of the well. The decrease in activity is given by the following dilution factor

$$D_2 = \exp(-\lambda T) \qquad (7)$$

where

λ = decay constant of isotope, $yrs.^{-1}$

T = time of travel between breach and well, yrs.

For Pu, the retardation factor is so large that all the isotopes decay before reaching the well. The dilution factor D_2 is zero. However, there is evidence that the transport model and the distribution coefficients do not account fully for certain observed phenomena. Thus, Seitz et al (Reference 4) observed in their studies of radionuclide migration in geologic media that 2.6% of the plutonium traveled at a relative migration rate (Vn/Vw) greater than 0.001. Dosch and Lynch (Reference 5) also observed that the K_d values for rare earth radionuclides decreased when plywood extract was added to the brine. This was attributed to the formation of more soluble complexes between radionuclides and organic molecules.

In this report, it will be assumed that 1% of the Pu-239 and Pu-240 in CH-TRU waste is in a chemical form which allows it to move with a Rustler water velocity of 15 ft/yr (K_d = 0). On the bases of the Seitz studies, this is highly conservative. Since the distance between the breach and the well is 3 miles, the travel time is thus 1,000 years. The dilution factors D_2 (including the assumption that 1% of Pu moves with water velocity of 15 ft/yr) for Pu-239 and Pu-240 are therefore 9.7E-03 and 8.9E-03 respectively.

The dominant uranium isotopes in CH-TRU waste after 21,000 years time of breach plus time of travel to the well for uranium nuclides are U-233 (from the initial inventory) U-234 (derived mainly from Pu-238) and U-235 (derived from Pu-239), and U-236 (derived from Pu-240).

Because of the long half-lives of U-233, U-234, U-235, and U-236, the dilution factors D_2 are 0.91, 0.94, 1.0 and 1.0 respectively.

3) Dilution factor to make brine potable, D_3.

The brine coming out of the repository and entering the Rustler aquifer is so saline that it cannot be used for irrigation or for drinking. It is assumed that the brine will be diluted in the aquifer as it travels toward the well. Several dilution mechanisms can be postulated but they will not be discussed in detail in this report.

Regional data on the quality of Rustler well water are sparse. However, a Rustler well at James Ranch, about three miles southwest of the center of the WIPP site is reported to have a TDS content of 3240 mg/ℓ (Ref. 1). In this report it will be assumed that saturated brine is diluted with water having a TDS content of 3000 mg/ℓ to form water with a TDS of 5000 mg/ℓ at the well.

Let w denote the number of units of water with a TDS content of 3000 mg/ℓ which must be added to one unit of saturated brine (at 410,000 mg/ℓ) to yield water with a TDS content of 5000 mg/ℓ. w is then found by solving the equation

$$\frac{(1 \times 410{,}000) + (w \times 3000)}{1 + w} = 5000 \text{ mg}/\ell$$

Rounded to two significant figures. w = 200 units. The dilution factor to make brine potable, D_3, is then 5E-03.

4) Treated water used for drinking, D_4.

Because of the relatively high salt content, it is assumed that water is treated before being used as drinking water for people. Such a treatment system could be reverse osmosis. In addition to the halite, treatment is assumed to remove 90% of any radium, thorium, uranium and plutonium in the water. The dilution factor for treatment of water, D_4, is thus 1.0E-01. The sludge resulting from reverse osmosis treatment will have a higher radioactive concentration than the aquifer water. The path of the sludge in the biosphere will not be studied in this report.

5) Dilution factor for water-cow-milk pathway, D_5.

In this case, it is assumed that the untreated well water is used as drinking water for a cow. The members of the farm family who own the cow drink the cow's milk.

It is assumed that the cow drinks 60 liters of water per day (Ref. 6, Table E-3) and the transfer coefficient used is 5E-04 and 1.5E-06 Ci/ℓ milk per Ci/day ingested for U and Pu respectively (Ref. 7, Table 3). The dilution factors for the water-cow-milk pathway, D_5, are thus 3.0E-02 and 9.0E-05 for uranium and plutonium respectively.

V. Isotope Inventory

The values for the activity concentrations in the repository at the time of the breach and the half-life of the nuclides are presented in Table I.

Table I

Radionuclide Concentrations at Time of Breach

Radionuclide	Half-life	Activity in Waste
	yrs	Ci/ℓ
U-233	1.6E+05	8.4E-06
U-234	2.4E+05	7.2E-08
U-235	7.0E+08	3.8E-08
U-236	2.3E+07	1.5E-07
Pu-239	2.4E+04	2.3E-03
Pu-240	6.5E+03	5.3E-04

The U-233 activity is based on 1500 Ci that originated from the light water breeder reactor core program. It is assumed that this activity is uniformly distributed in the repository. The U-234 activity is obtained by complete conversion of all the originally emplaced Pu-238 (concentration is 2.0E-04 Ci/ℓ at time of emplacement). The U-235 activity is based on the assumption that 45 per cent of the initially emplaced Pu-239 has been converted to U-235 (amount of Pu-239 converted in 21,000 years) and that this activity is available for travel to the well following the breach. This simplified source term is conservative and yields higher concentration at the well than the more rigorous source term resulting from the transport model of Lester et al (Reference 8). Similarly, the U-236 activity is based on the assumption that 89 per cent of the initially emplaced Pu-240 has been converted to U-236. The Pu-239 and Pu-240 activities are the concentrations in the repository 1,000 years after closure of the repository. As discussed on Page 8, it is assumed that 1% of this concentration moves with the speed of the Rustler.

VI. *Summary of Dilution Mechanisms for Different Pathways*

The dilution factors for the pathway of interest and the activity concentrations of water and milk prior to consumption are presented in Table II.

Table II

Summary of Dilution Factor Calculations

Path	Dilution Factor Formula	Dilution Factor	Activity Concentration in water or Milk pCi/ℓ	NRC limits * pCi/ℓ
Treated water used for drinking	D_1 D_2 D_3 D_4			
U-233		5.9E-06	5.0E+01	3E+04
U-234		6.1E-06	4.4E-01	3E+04
U-235		6.5E-06	2.5E-01	3E+04
U-236		6.5E-06	9.8E-01	3E+04
Pu-239		6.3E-08	1.4E+02	5E+03
Pu-240		5.8E-08	3.1E+01	5E+03
Water-cow-milk	D_1 D_2 D_3 D_5			
U-233		1.8E-06	1.5E+01	
U-234		1.8E-06	1.3E-01	see above
U-235		2.0E-06	7.6E-02	
U-236		2.0E-06	3.0E-01	
Pu-239		5.7E-11	1.3E-01	
Pu-240		5.2E-11	2.8E-02	

In studying Table II, it should be remembered that the concentrations for the Pu-nuclides appear 1,000 year after the breach while the concentrations for the U-nuclides appear 20,000 years after the breach.

*Reference 9

The EPA national interim primary drinking water regulations limit the gross alpha particle activity (including radium-226 but excluding radon and uranium) to 15 pCi/ℓ (Ref. 10). The EPA environmental protection standards for disposal of residual radioactive material from inactive uranium processing site limit the concentration in water of all uranium radionuclides to 10 pCi/ℓ. The water concentrations of U-233 exceed the limits of Ref. 11 while the water concentration of Pu-239 and Pu-240 exceed the limits of Ref. 10.

VII. 50-year Dose Commitments

The water and milk consumption values, and the dose commitment factors used in the calculations are presented in Tables III, IV and V.

Table III

Water and Milk Consumptions Values (6)

Exposed Individual	Annual Water Consumption ℓ/yr	Annual Milk Consumption ℓ/yr
Infant	330	330
Child	510	330
Teenager	510	400
Adult	730	310

Table IV

50-Year Ingestion Dose Commitment Factors for Bone from a one year intake (3), mrem/pCi

Exposed Individual	U-233 and U-234	U-235 and U-236	Pu-239 and Pu-240
Infant	5.1E-03	4.7E-03	1.5E-03
Child	3.7E-03	3.4E-03	1.4E-03
Teenager	1.2E-03	1.1E-03	8.3E-04
Adult	8.7E-04	8.0E-04	7.9E-04

Table V

50-Year Ingestion Dose Commitment Factors
for Total Body from a one year intake (Ref. 3), mrem/pCi

Exposed Individual	U-233 and U-234	U-235 and U-236	Pu-239 and Pu-240
Infant	3.9E-04	3.6E-04	3.5E-05
Child	2.3E-04	2.1E-04	3.3E-05
Teenager	7.5E-05	7.1E-05	2.0E-05
Adult	5.3E-05	5.0E-05	1.9E-05

The 50-year dose commitments were calculated using equation (2) and are presented in Tables VI, VII, and VIII.

Table VI

50-Year Dose Commitments Due to U-233
from Drinking Treated Water or Milk for one year (mrem)

Exposed Individual	Drinking of Treated Water		Drinking of Milk	
	Bone	Total Body	Bone	Total Body
Infant	8.4E+01	6.4	2.5E+01	1.9
Child	9.4E+01	5.9	1.8E+01	1.1
Teenager	3.1E+01	1.9	7.2	4.5E-01
Adult	3.2E+01	1.9	4.0	2.5E-01

Table VII

50-Year Dose Commitments Due to U-234, U-235, and U-236
from Drinking Treated Water on Milk for one year (mrem)

Exposed Individual	Drinking of Treated Water		Drinking of Milk	
	Bone	Total Body	Bone	Total Body
Infant	2.6	2.0E-01	8.0E-01	6.1E-02
Child	3.0	1.8E-01	5.8E-01	3.6E-02
Teenager	9.6E-01	6.1E-02	2.3E-01	1.5E-02
Adult	1.0	6.2E-02	1.3E-01	8.0E-03

Table VIII

50-Year Dose Commitments Due to Pu-239 and Pu-240 from Drinking Treated Water or Milk for one year (mrem)

Exposed Individual	Drinking of Treated Water		Drinking of Milk	
	Bone	Total Body	Bone	Total Body
Infant	8.5E+01	2.0	7.8E-02	1.8E-03
Child	1.2E+02	2.9	7.3E-02	1.7E-03
Teenager	7.2E+01	1.7	5.2E-02	1.3E-03
Adult	9.9E+01	2.4	3.9E-02	9.3E-04

VIII. Discussion

A simple model is used to calculate the dose commitments to individuals resulting from the use of well water contaminated by a breach of the WIPP repository. The safety factors of the barriers are quantified in terms of dilution factors. The calculations are kept simple but conservative. For example, it is assumed that a U-shaped connection can occur between the Rustler aquifer and the repository even though a recent hydrological study found this connection as unrealistic when the density of the brine is taken into account (Ref. 12). Also, it is assumed that the leach rate of waste is equal to the leach rate of salt, and that 1% of the Plutonium moves with the speed of the water. For plutonium these ultra-conservative assumptions may be partialy offset by the use of the EPA dose conversion factors for transuranic elements (Table A 3-5, Reference 13). These EPA factors for the mobile fraction of plutonium would result in doses 33 to 165 times higher than those based on NUREG-0172.

The concentrations of all radionuclides at the well are less than the NRC release limits to the uncontrolled environment (9). The concentrations in the treated well water of U-233, Pu-239, and Pu-240, all radionuclides originally emplaced with the wastes, exceed the EPA drinking water limits. The concentration of U-233 in treated water exceeds the EPA limits by a factor of 3 while the combined concentration of Pu-239 and Pu-240 in treated well water exceeds the EPA limit by a factor of 11. The Pu concentration exceeds the EPA limit because it has been assumed that 1 percent of the plutonium inventory moves with the speed of groundwater. The combined concentration of U-234, U-235, and U-236 in treated well water, all decay products of Pu isotopes, is a factor of nine less than the EPA limit.

Other barriers, that could lower the release of radionuclides, can be imagined in addition to the ones discussed. For example, the salt surrounding the WIPP repository contains significant amounts of clay which is known to selectively bind uranium and plutonium (Ref. 14). Two clay seams are reported at a depth of 2124 to 2134 feet which is 20 to 30 feet above the floor of the repository. The clay could thus act as a barrier with a significant dilution factor. Data from the planned WIPP experiment may help quantify this dilution factor.

Based on the conservative assumptions used, the planned inventory of radionuclides in the waste would not present a significant risk to health from a well three miles from the site, even if a breach and transport of the waste to the well is assumed. For this to be true, however, it is particulary important that the major fraction of the plutonium be retarded by adsorption on the rock during its passage from the repository to the well.

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ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-10

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EEG-10

NEW MEXICO
HEALTH AND ENVIRONMENT
DEPARTMENT

RADIOLOGICAL HEALTH REVIEW OF THE FINAL ENVIRONMENTAL IMPACT STATEMENT (DOE/EIS-0026) WASTE ISOLATION PILOT PLANT, U.S. DEPARTMENT OF ENERGY

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

January 1981

Environmental Evaluation Group
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EEG-5 Channell, James K., Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, November 1980.

EEG-6 Geotechnical Considerations for Radiological Hazard Assessment of WIPP. A Report of a Meeting Held on January 17-18, 1980, April 1980.

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(Continued on Back Cover)

NOTICE TO THE READER

The Environmental Evaluation Group (EEG) was assigned to the New Mexico Institute of Mining and Technology in October 1988 by the National Defense Authorization Act, Fiscal Year 1989, Public Law 100-456, Section 1433, and is no longer a part of the New Mexico Health and Environment Department, Environmental Improvement Division. Continued funding is being provided by the Department of Energy through Contract DE-AC04-79AL10752.

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Radiological Health Review of the Final Environmental Impact Statement

Waste Isolation Pilot Plant

Volumes 1 and 2

DOE/EIS-0026

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

January 1981
(Reprinted August, 1989)

CONTENTS

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of reports issued by the U. S. Department of Energy (DOE) and its contractors, other Federal agencies and other organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U. S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

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INTRODUCTION

The Environmental Evaluation Group has reviewed the Final Environmental Impact Statement on WIPP (DOE/EIS 0026) and has submitted written comments to the U.S. Department of Energy. Due to the length and complexity of the documents, the EEG was not able to complete, to its satisfaction, a comprehensive review in sufficient time to meet the deadline of December 8, 1980. Thus, preliminary comments were transmitted on December 8th and supported Governor King's November 4, 1980 request for a 45 day extension.

On January 15, 1981 the final and more detailed supplemental comments were submitted. Both of these transmittals are incorporated in this report.

RADIOLOGICAL HEALTH REVIEW OF FINAL ENVIRONMENTAL IMPACT STATEMENT ON WASTE ISOLATION PILOT PLANT, DOE/EIS-0026, VOL. I AND II, OCTOBER, 1980.

SUMMARY

Pursuant to the requirements of the National Environmental Policy Act of 1969, the Department of Energy has provided in the Final Environmental Impact State (FEIS) a comprehensive review of the potential radiological impact of the proposed Waste Isolation Pilot Plant, referred to in the FEIS as, "the authorized alternative." The EEG has reviewed this document to determine (a) the changes made in comparison with the Draft Environmental Impact Statement (DEIS); (b) the adequacy of the DOE's evaluation of the potential radiological impact; (c) the thoroughness of the DOE's response to the comments of the EEG on the DEIS; and (d) other issues which should be addressed by DOE more fully prior to beginning construction of the WIPP.

Based on our review of the FEIS, the Department of Energy has incorporated and addressed the majority of the concerns, questions and recommendations that the EEG provided to them in our August 1979 review (Reference 2) of the Draft Environmental Impact Statement on WIPP and the FEIS provides a generally satisfactory evaluation of the potential radiological impact. There are, however, a number of areas that have yet to be adequately treated by DOE and should be acted upon and resolved prior to beginning construction of the WIPP. The more important issues are listed below, and are discussed in more detail in our December 8, 1980 and January 15, 1981 comments on the FEIS.

1) EEG has referred to various statements and data in the FEIS, Geological Characterization Report on WIPP (Reference 12), and the Safety Analysis Report (Reference 8) which indicate possible instability in the area just north (1.2 to 3 miles) and southwest (less than 1 mile) of ERDA-9, and at depths near the repository horizon. EEG continues to have concern as to how this zone of anomalous seismic reflection data will

Preliminary

Radiological Health Review
of the Final Environmental Impact Statement (DOE/EIS-0026)
Waste Isolation Pilot Plant, U. S. Department of Energy

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

December 8, 1980

RADIOLOGICAL HEALTH REVIEW OF FINAL ENVIRONMENTAL IMPACT STATEMENT ON WASTE ISOLATION PILOT PLANT DOE/EIS-0026, Vol. I and II, October, 1980

INTRODUCTION

The Department of Energy appears to have incorporated and addressed the majority of the concerns, questions and recommendations that the EEG provided to them in our August 1979 review (Reference 2) of the Draft Environmental Impact Statement on WIPP.

There are, however, a number of areas that do not appear to have been adequately addressed. These and other areas are discussed in the following sections. The limited time available for this review does not permit us to determine with certainty the adequacy of either the FEIS or these preliminary comments.

INVENTORY OF RADIOACTIVE MATERIAL

EEG recommended in September 1979 that the Final EIS contain estimates of the radioactivity to be present in the repository and the uncertainty associated with the estimates. That was not done, although page 9-127 of the FEIS does show 539,000 curies of transuranic activity at 1000 years.

While the following table presents our estimates of the radioactivity, the information did not permit estimates of the uncertainties.

Radioactive Inventory of WIPP at the Time of Closure

	Radioactivity (Curies)	Emplacement	Volume (ft^3)
CH-TRU	2,800,000	Permanent	6,200,000
RH-TRU	5,100,000	Permanent	250,000
HLW	17,000,000	Temporary	150

RESOURCE EXTRACTION

There has been a slight shift in language in the Final EIS on the degree of mineral extraction that may be permitted in the various zones. Exact comparisons are not possible because various sections in both Draft and Final give different impressions of what may be permitted. The wording in the Final EIS appears to be predicting a greater degree of extraction, especially in the inner zones. These statements are paraphrased below.

Draft EIS - On page 3-6 it is stated that Zone IV will eventually be released for resource exploitation (no mention of other zones). On page 8-1 it is said that only DOE drilling would be permitted in Zones I & II; possible resource extraction would be allowed in Zone III pending outcome of studies; potash mining (no solution mining) and hydrocarbon extraction (no secondary recovery) may be permitted by DOE. On page 9-21 it is stated that mining and drilling may be permitted in Zone IV but hydrocarbons could be extracted from under Zone IV by deviated drilling from outside Zone IV. There is no mention of possible recovery from under Zones I, II, or III. On page 11-1 the statement is made that it may eventually be possible to recover hydrocarbons from beneath all zones by deviated drilling from outside Zone III.

Final EIS - The Executive Summary (page 6-14) says that hydrocarbon resources can be exploited by deviated drilling from outside zone IV or by vertical and deviated drilling within Zone IV. Potash reserves in Zone IV may be mined; the consequences of mining in Zones I, II, III are currently being evaluated. Page 4-5 says that mining for hydrocarbons and potash in Zone IV is expected and that all the natural gas could be recovered by deviated drilling from Zone IV. On page 9-27 the words "may" and "would" are both used in reference to potash and hydrocarbon extraction in Zone IV. Statements on page 11-1 say that potash and hydrocarbon extraction from Zone IV will not affect site integrity but it is not clear what the consequences would be of mining langbeinite from the inner control zones.

Our concerns with the issues are:

1. It is uncertain just what restrictions DOE presently plans to put on extraction from Zone IV and for deviated drilling beneath the inner zones.

2. The possibility of potash extraction in the inner zones of the site directly above or near the storage rooms is of particular interest. Mining activity, with possible blasting, 400 feet above the waste horizon could significantly reduce the safety factors that would be expected from storage at a depth of 2150 feet below the surface in a formation that is 2,000 feet thick.

3. We have not seen the evaluations that led to the language in the Draft nor the subsequent evaluations that apparently give DOE a greater confidence in the ability to extract minerals without threatening site integrity. It will be necessary to review these reports in order to be assured that DOE's conclusions are valid.

4. The time table for making these decisions and the procedure for doing so needs to be known so that EEG can have input into this process.

DENIAL OF MINERAL RESOURCES

Section 9.2.3.1 and related sections of the FEIS clearly describe the mineral and hydrocarbon reserves at the site, their relative economic importance, and attractiveness for potential extraction in the future. EEG still has concerns about this possible future attractiveness and the methodologies for mineral and hydrocarbon extraction currently proposed by DOE. These concerns are clearly stated in this FEIS review under sections entitled "Decommissioning" and "Resource Extraction."

EEG's comilation of references on "People-Made Penetrations" and "Conflict with Natural Resources" contained in EEG-1 (Reference # 10) inventoried in detail recommendations regarding repository sites with mineral and hydrocarbon resources. This and subsequent work in this major issue area has led EEG to emphasize the necessity to quantitate potential radiation risks associated with resource extraction at the site as currently proposed by DOE and the long-term risks with future extraction after site decommissioning.

WASTE ACCEPTANCE CRITERIA

Except for one change (the criterion for restricting toxic materials), Chapter 5 on Waste Acceptance Criteria is unresponsive to the comments of EEG. (See Reference 4 and pp. 4, and 20-24, Reference 2.) Because the SAR (Reference 8) makes it clear that the contents of the waste shipments will not be analyzed at WIPP to determine compliance with the criteria limiting toxic and corrosive material, sludges, pyrophorics, powders, and fissile material, the FEIS should have indicated how compliance will be assured, or evaluated the environmental impact assuming no compliance.

Page 15-36 of the FEIS states that the quality assurance system to insure compliance by the shippers with the WAC will be developed before the start of the WIPP operations. However, these procedures are germane to the hazard evaluation and environmental impact of the WIPP operations and therefore should have been included in the FEIS.

The FEIS discusses the possibility of processing the waste before shipment, and there is a strong implication that the waste will be processed by slag pyrolysis. If so, the WAC would be met. If the waste is not processed how will compliance be assured? What methods and what audit procedures will be used?

On page 9-176 of the FEIS, it is recognized that overpacking of the waste containers at INEL would not provide compliance with Waste Acceptance Criteria. Yet the overpacking procedures described in Section 9.8 indicate transfer of the packages to the rail car and then to the WIPP with no plans indicated for evaluation of the waste to assure compliance with WAC. There are also no plans to evaluate the waste at WIPP.

On page 8-26 of the FEIS, we note, also, that waste packages which would not meet the WAC may be shipped from WIPP to other sites for processing. Criteria are needed for such shipments, and DOE should evaluate the possible hazards associated with such shipments.

It was noted that the wording of the criteria in Chapter 5 remains ambiguous or misleading. There is clear implication that WIPP will analyze the waste to determine if it will be accepted, and have it returned if it is unacceptable. EEG objects to such wording, and urges that it be revised to clearly indicate that the shipper--not WIPP--is responsible if the criteria are not met. Furthermore ambiguities resulting from the phrase "will be accepted" or "will not be accepted" should not be used. The DOE legal staff should also review the criteria to be certain that the wording is construed as legally mandatory on the part of the shipper, and that vague statements will be revised as previously recommended by EEG (References 2 and 4).

We also note small inconsistancies between the FEIS Waste Acceptance Criteria and the criteria published in WIPP-DOE-069, Reference 5. For example, the criterion in the FEIS limiting gas generation states the total gas produced from contact-handled waste by all mechanism may not exceed 10 moles per cubic meter of disposal room in the WIPP. The WIPP-DOE-069 limits the gas to 10 moles per cubic meter of disposal room <u>per year</u> in the WIPP. Is this an inadvertent deviation or has the criterion been changed? Also the FEIS criterion for "immobilization" indicates that no dry powders "will be accepted," whereas WIPP-DOE-069 limits the dry powders to 1% of the waste matrix weight.

Neither the FEIS nor any other DOE report has provided criteria for the high level waste. These criteria also are needed for the evaluation of the environmental impact of WIPP.

Another concern which has not been addressed in the FEIS is how the WIPP facility will assure that the drums do not contain explosive gas mixtures at the time of retrieval, should retrieval prove necessary. (See p. 3-15, Reference 3.)

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TRANSPORTATION

We recommended that a number of dosage estimates be performed including acts of sabotage, doses to emergency workers, exposures to people in cars stopped next to a truck with radioactive waste. These estimates are included in the FEIS.

DOE did not include our recommendation to estimate doses from the ingestion of contaminated food following a transportation accident with a release of radioactive material based on their belief that corrective action measures including the condemnation of food and decontamination of farmland would be promptly taken. EEG believes that an assessment of possible radiation doses by these pathways is important for two reasons:

1) to indicate if radiation doses could be high enough to require short-term protective measures or long-term land use controls;
2) to estimate the amount of low-level, long-term dose that may be unavoidable if such a release occurs.

We have published such an analysis entitled Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, by Dr. James K. Channell, EEG-5 (Reference 6).

More detailed comments concerning information contained in Chapter 6 of the FEIS are provided below:

6-4* The Regulatory responsibilities of the New Mexico State Government and the Federal Government affecting the transportation of radioactive waste to WIPP need to be clarified. EEG will bring this matter up to the appropriate agencies.

6-12 According to the FEIS, CH-TRU waste shipped from Hanford, LASL and SRL will not be directly considered in the impact analysis. The following analysis indicates that 1/3 of the CH-TRU waste to be shipped by volume is not being considered in the impact statement for dosage estimates in transportation.

*These numbers refer to the chapter and page number of the FEIS.

CH TRU TO BE SHIPPED TO WIPP (10/1/86)

Source	Considered in FEIS	10^3 Cu ft	Dose Calculations in FEIS
INEL	yes	2376[a]	yes
Rocky Flats Plant	yes	100[b]	yes
Hanford	no	855[a]	no
LASL	no	249[a]	no
SRL	no	109[a]	no

[a]page 2-17
[b]page 6-17

6-13 The truck routing concept used by DOE for transuranic and high level waste appears different from NRC guides relating to the shipment of spent fuel. Both use interstate highways but NRC bypasses large cities such as Albuquerque whereas Figure 6-3 on page 6-15 appears to have the trucks pass through the cities.

6-15 According to the FEIS the transportation analysis will not include RH-TRU from ORNL, LASL and Hanford. From the following analysis, 78% (69/89) of the RH-TRU waste by volume to be shipped to WIPP is not being considered in the FEIS.

RH TRU (1986)

Source	Considered in FEIS	10^3 cu ft[a]	Dosage Calculation in FEIS
INEL	yes	20	yes
ORNL	no	52	no
Hanford	no	8	no
LASL	no	9	no
	Total	89	

[a]page 2-17

6-17 The FEIS calculations of the radiological impacts of waste transport under normal condition assume that 370,000 ft^3 of CH waste and 4,200 ft^3 or RH waste will be transported annually from INEL and RFP to WIPP (page 6-17). The breakdown of the data is given in tables 6-2, 6-6, 6-7, and 6-8 of the FEIS.

The calculations may not be conservative for the following reasons: The WIPP design criteria report, WIPP DOE 7L, states that for a three-shift-per-day operation, the annual design capacity will be 1,200,000 ft^3 of CH-waste and 10,000 ft^3 of RH-waste; for a one-shift-per-day, the annual design capacity will be 500,000 ft^3 of CH waste and 4,000 ft^3 of RH-waste (the last number is estimated by EEG; it is not mentioned in the design criteria). The design criteria also state that the estimated rate of shipment for CH-waste for 9 years (year 4 to year 13) will be 500,000 ft^3/y. Further, most of the RH-waste is stored at ORNL which is considerably further away from WIPP than INEL and RFP (Table 2-3, page 2-17).

It is possible that waste will be shipped to WIPP at rates greater than 370,000 ft^3/y because of the large backlog.

The title of Table 6-2 "Volume of Waste Shipped per Year" is mis-leading since it identifies only 2 of the 8 sites shipping waste to WIPP.

6-18 According to the FEIS, very small quantities of HLW will be shipped to WIPP for experiments." This is not so. Our calculations show this to be 17 million curies which is more than twice as large as the combined CH and RH TRU waste to be permanently emplaced.

6-19 The waste volume being shipped from INEL by truck in Table 6-4 should be 1,100 ft^3 RH-TRU, not 110,000 ft^3.

6-19;1 Clarification is needed to evaluate the impact of high-level waste for experiment. Section 6.5.3 of the FEIS estimates the equivalent of 40 canisters of high-level waste. The SAR mentions 60 canisters. Section 8.9.5 (p.8-48) of the FEIS mentions 20 canisters per waste form. Clarification is needed between the FEIS and the SAR.

6-24 5
6-15 The collective doses for INEL and RFP in tables 6-6, 6-7, and 6-8 are the same as those shown in table 6-9 and 6-10 of the DEIS. The collective doses for shipments from Hanford, LASL, and SRP have been omitted even though in the DEIS they amount to about 50% of the total collective dose. One might conclude that the radiological impact has been underestimated in the FEIS. This should be clarified.

6-26 The statement that the most-exposed person receives an annual dose of 0.15 mrem from the normal transport of radioactive waste requires clarification. In fact, in the same paragraph a dose of 1.[illegible] mrem is quoted for a person waiting 2 hours behind a stalled truck. EEG has obtained doses greater than 0.15 mrem for the following four plausible scenarios:

Case	mrem/yr	Assumptions
I	0.26	Individual is exposed to 20% of all trucks stopped for 1 minute at a distance of 25'
IIa	1.2	Individual is exposed to all trucks stopped for 1 hour at a distance of 100'
IIb	2.9	Individual is exposed to 25% of all trucks stopped for 1 hour at a distance of 50'
III	32.	Service station attendant gassing up 25% of all trucks at a distance of 5 feet for a time interval of 2 min/truck

6-18 It appears that the radiological impact for high level waste is based on a one-way scenario of 40 canisters distributed in 6 shipments over the lifetime of the repository. It should include an equal number of shipments leaving the repository after the experimental phase is over. Furthermore, the description of the high level waste experiment (in Chapter 8, pages 8-48,49) suggest that more than 40 canisters might be necessary.

6-31 & 6-34 In the accidents analyzed in the FEIS, it is assumed that inhalation of radionuclides is the primary pathway to people. It is assumed that administrative procedures used in the clean up procedure will prevent radionuclides from reaching the food chain. EEG disagrees with this assumption and has pointed out in the report EEG-5--Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, by J. K. Channell --that doses through food pathways are greater than zero even after protective measures are taken.

6-41 The emergency procedure section does not address itself to the following questions: If an accident occurs and the shipment is damaged, will the damaged shipment be forwarded to WIPP or will it be returned to shipper? If forwarded to WIPP, is the design of the waste handling building adequate to handle large damaged shipments?

A number of additional dosage calculations had been identified by EEG in report EEG-3. The status of these calculations is as follows:

1. Sabotage	Included in FEIS
2. Emergency Workers	Included
3. Stopped Automobile	Included
4. Retrieved wastes	Not Included
5. Contamination of Food Supply	Not Included
6. D & D of Hanford	Not Included
7. Individual doses as well as population	Included
8. Diffuse sources	Not Included in FEIS (We agree)

GEOLOGY, HYDROLOGY AND SITE CHARACTERIZATION

Our preliminary review of the geology, hydrology and site characterization information as contained in the FEIS indicates that several sections have been expanded and better explained than that presented in the DEIS. However, there is still insufficient treatment of potential problem areas as discussed in more detail below:

1) <u>Disturbed Zone or Zone of Anomalous Seismic Reflection</u>

This topic is briefly mentioned in the Geology Summary on pages 7-16 to 7-19 as "an anticline...on the upper Castile is located at the northern edge of Control Zone II." Although more details concerning this zone is provided on page 7-42, the FEIS should have more clearly reflected the uncertainty, controversy and concern regarding the potential implications of this zone to the future integrity of the repository. The EEG has provided discussion of this issue in commenting on the DEIS (See EEG-2 published as Appendix III, EEG-3, Reference 2). The FEIS has not adequately addressed these comments. For example, on page 7-29, the FEIS discusses various suspected dissolution features present in sections 9 and 17 of T22S, R31E, but fails to point out that these features coincide with the zone of anomolous reflection, the depression in MB 124, and is close to the apparent anticline in the Castile. Also, on page 7-42, the FEIS explains the anomolous seismic reflections as "relatively tight folding or a discontinuity in the upper Castile." This does not adequately explain the phenomena and EEG believes that a more definitive explanation based on additional data is necessary before the site is judged acceptable for the repository.

2) <u>Brine Reservoirs</u>

This subject is discussed in the FEIS on pages 7-33 to 7-4[illegible], particularly section 7.3.5. Although this topic has been treated more extensively in the FEIS, it should have contained more data on the location of known artesian brine flows, and the differing views as to their origin and significance to the adequacy of the WIPP site. (Further discussion of this issue is contained in EEG Reports, References 7 and 9).

3) <u>Dissolution Processes</u>

The FEIS provided a clearer discussion of this issue than did the DEIS, but did not provide new data, nor were the various contrasting views adequately presented. For example, the discussion on page 7-29 failed to mention the Bell Lake Sink and Slick Sink, and the views of Anderson as to their possible deep'seated origin. Also on page 7-100, the last paragraph is misleading with respect to the Anderson citation. His 1978 paper indicated that the active dissolution front in the Salado could reach the WIPP site in 50,000 years, but he believes the advance effects of deep dissolution may already have affected the repository area and vicinity. Page 7-27, paragraph 4 refers to the lamprophyre dike which is shown in Figure 7-13. Is it not possible that offshoots of the dike and perhaps sills may exist in the Salado near the site? Would this provide a preferential path for fluids in the event of a breach? The zone of anomolous seismic reflection may be evidence of deep dissolution. (For further discussion by EEG of this issue see References 7 and 9).

4) Effect of Impurities in Salt

Page 7-35, paragraph 5, indicates that the halite beds at the repository horizon are 97% halite, however there are also present many clay seams. What is the fraction of halite in the repository mass? The effect of these clay minerals on the repository should be based on in situ studies and should be known before a final decision is made on the adequacy of the site.

5) Site and Preliminary Design Validation Program (SPDV)

Under section 8.9, the FEIS provides very useful information on the research and development program for the proposed repository, including the in situ validation program. We recognize the need for the SPDV program, and note that it will obtain valuable data for site validation which cannot be obtained by other means. We hope that more details will be made available on the experiments in order that other groups might provide comments on these anticipated experiments. We note that one of the objectives will be to explore the undeveloped portion of the planned repository by horizontal core holes. Our preliminary evaluation of these plans indicate that the horizontal core will not extend into the zone of anomolous reflection discussed in section 1 above, and therefore definitive data concerning the significance of this zone to the repository integrity will still be needed. How will this issue be resolved? We note that the underground area covered by the SPDV program will be located within about 14 acres or about 10% of the total repository. At what point and on what bases will a final decision be made on construction of the complete repository?

THE WIPP AND ITS OPERATION

The following comments address the more important operational uncertainties that have been noted in our review of the information in Chapter 8.

Shaft

8-11* The 12' shaft will be bored to a depth of 2300 feet. This is inconsistent with 8-14 paragraph 2 which makes the following statement: "Starting at the bottom of the 12-foot-diameter shaft, horizontal excavation in the Salado salt will produce a network of underground cavities." The repository is at a depth of 2150 feet. Also, the hoist drop accident assumes that there is only 40' between the repository level and the bottom of the shaft.

Since the repository will be located at 2150 feet, why drill the SPDV shaft to 2300 feet? This additional depth may decrease the factor of safety of a vertical connection if a brine reservoir is located in the upper Castile similar to ERDA-6.

Facility Layout

8-17 The FEIS indicates that the underground development of the repository will be due north from the shafts (page 8-17, Figure 8-9). In the DEIS the direction is due west (page 8-16, Figure 8-11). Is there a final decision on the orientation to the north? If so, why? If no decision has been made, what criteria will be used to determine the direction of development?

8-19 Figure 8-10 of FEIS shows a significantly different layout in the eastern area of the waste-handling building different from the drawings of Section WBE-41 of the Title I study. Which is more up to date?

*These numbers refer to the page numbers of Chapter 8 of the FEIS.

Ventilation

8-21 The paragraph states the following: "To confine radioactive material, the air-cleaning system will pass the air through banks of high-efficiency particulate air (HEPA) filters." This statement is too general since the disposal exhaust filtration building is a surface facility in which the air will pass through HEPA filtration only if radioactivity is detected by monitors. More information is needed on the delay time for conversion from an unfiltered system to a filtered system. How much unfiltered air would be released during this transition?

8-32 "The first stage of the filtration system in the waste-handling building will consist of 200 HEPA filters in parallel." The Title I study reveals that the filtration system of the waste-handling building consists of 17 customized two stage HEPA filters. Each unit will also have a prefilter. the units will be customized and their drawings do not exist at this time. The conclusion that 200 HEPA filters are required appears incorrect.

Rad-Waste and Gaseous Releases

8-25 The paragraph at the top of the page states the following: "These systems have sufficient surge capacity to handle waste produced during postulated accidents..." This is contradicted by the paragraph at the bottom of the page which states the following: "In the unlikely event of a fire...., contaminated water will be processed by a portable liquid-radwaste-processing system brought onto the site after the fire." The portable system is not mentioned again. Its availability and possible location of use should be clarified.

8-28 The FEIS discusses possible pathways for the release of CH and RH TRU waste but does not address HLW. ("Surface contamination of HLW canisters are available for release," page 8-31). Information is needed on the possible pathways for HLW.

8-30 Table 8-5 estimates that the curies of radon gas released from the repository will be much greater than that due to man-made radiation.

EEC pointed out in commenting on the DEIS that these estimates were not obtained from site-specific data and recommended that radon measurements be taken at the site before and after construction to evaluate the amount of radon present. DOE did not respond to this comment. We still believe that radon should be measured to see if levels might be high enough to be a problem for underground workers and to estimate radiation doses to the public.

8-36 While the FEIS estimates the amount of gas produced from the underground waste experiments of 150 ft^3/y, it does not present the estimate of 6,000,000 ft^3/y from decomposition of the CH and RH TRU waste.

Waste Experiments

8-50 The paragraph suggests that the retrieval process will be a difficult task since the "volume of contaminated salt is expected to equal the volume of waste removed." Large volumes of salt might be involved.

If necessary to retrieve wastes, where will they be sent? Will DOE establish criteria for retrieval of CH and RH, and when will these be available? This information is necessary to evaluate the radiological impact of the retrieval process.

8-51 We are pleased to see the expanded section of 8.10.3 on the retrieval of HLW. The section does not state the destination of the waste. We believe that this should be included in the experimental plan.

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HIGH LEVEL WASTES

We were pleased to note that the information on the Defense High Level Waste (HLW) experiments has been expanded in Chapter 8. The purpose and justification of these experiments is well stated in sections 8.9.3 and 8.9.4. However, the methods described in section 8.9.5, do not allow a clear evaluation of the radiological impact. Two classes of experiments are described but it is not clear if there will be more than one waste form per class. Therefore, it is difficut to estimate the total amount of radioactivity involved. It is emphasized that the HLW will be retrieved after the conclusion of the experiments, but since the waste handling building has only overpacking capability, it is difficult to envision how the HLW will be repackaged so that it can leave the plant in compliance with transportation regulations and DOE criteria.

The radiological impact of shipping these wastes from the repository at the end of the experiments has not been evaluated and it should be. Also, there is a need for shipping criteria for the HLW, both to the site and after retrieval.

More information is needed on the fate of the HLW at the end of the experiments. The impression given in the FEIS (page 15-45) that DOE has no idea where the waste will go is troubling. What laboratories might receive these wastes shipments for analysis? Where would any full-sized canisters that did not need laboratory evaluation be sent? Might some of these canisters remain at the WIPP site if a radiological evaluation at the end of the experiment indicated this would result in the lowest radiation doses to workers and the public?

EEG believes the HLW experiments have more potential for significant occupational doses and site contamination than the other operations and we plan to thoroughly review the detailed plans for individual experiments as they become available.

EFFECTS OF PLANT OPERATION, ACCIDENTS, AND LONG TERM EXPOSURE

We are pleased that the FEIS has addressed a number of our suggestions for expanding the potential scenarios necessary to better assess the potential radiological risks both during the operational phase and over the long-term.

One of our primary concerns centers around the potential for eventual human intrusion. We believe this is a credible scenario particularly because of the mineral and hydrocarbon resources in the region.

In addition to the intrusion scenarios addressed in the FEIS we repeat our recommendations made in the DEIS review for the following scenarios:

1) A connection is made between the repository, a high pressure brine reservoir and the surface.

2) Effects of high pressure gas formation, generated by organic decomposition of the waste, acts as a driving mechanism in bringing waste to the surface. (General Population)

3) Generate dosage estimates using the DOE generic Waste Isolation Safety Assessment Program (WISAP) model currently under development by the Battelle Northwest Laboratories. (General Population)

4) Solution mining for sylvite or langbeinite takes place leading to breach of the decommissioned repository and release of radionuclides.

These comments and others relating to the information contained in Chapter 9 of the FEIS are discussed below:

I. Operational Exposures

9-40 Routine occupational radiation exposures (man-rem) expected during normal operations are given in Table 9-26. In order to evaluate these estimates we will need the assumptions upon which these were based.

9-107 Doses and dose commitments from accident scenarios were calculated to an individual living at James Ranch (Table 9-52). The EEG recommendation in the DEIS review that doses be computed at the NW site boundary and for transients in Zones II, III, and IV was ignored. We still believe these should be made.

9-117 The Chapter 9 assumption that exhaust air from underground waste handling and storage areas passes through HEPA filters is inconsistent with statements in Chapter 8. Since the absence of filters can result in a substantial increase in doses from particulates, it is important to clarify this point. In addition, more detailed information is needed on the response sensitivity levels which activates the switching of the ventilation air stream through the HEPA filters, including response times, for both fires and increased radioactive particulates in the mine atmosphere.

The following areas of concern were raised on the DEIS (EEG-3) but were not addressed in the FEIS report by DOE and we request that they be addressed:

1) Is there a possiblity that Radon-222 and daughters could pose an occupational problem?

2) Is there any possibility of encountering a methane gas pocket in bedded salt which could cause an explosion?

II. <u>Long-Term Exposures</u>

In evaluating the long-term radiological consequences of the WIPP repository, the FEIS has considered the same 5 scenarios for release of radionuclides as considered in the DEIS. In commenting on the DEIS, EEG had recommended the following additional scenarios be considered (Reference 2, pages 81,90):

1) Build-up in the environment from radionuclides in water removed from the Pecos River for irrigation, incorporated into soil and plants, and cycled in food and man over long periods of time.
(General Population)

2) Generate dosage estimates using the DOE generic Waste Isolation Safety Assessment Program (WISAP) model currently under development by the Battelle Northwest Laboratories.
(General Population)

3) A connection is made between the Delaware Mountain Group aquifer, the repository and the surface.
(General Population)

4) A connection is made between the repository, a high pressure brine reservoir and the surface.

5) Effects of high pressure gas formation, generated by organic decomposition of the waste, acts as a driving mechanism in bringing waste to the surface.
(General Population)

6) Well water becomes contaminated and is used for irrigation or stock watering.

7) Solution mining for salt takes place.

Scenario Recommendation 1

The FEIS indicates on page 15-30 that the consequences of using contaminated water below Malaga Bend for irrigation purposes as recommended is being studied, and the results will be included in the WIPP Safety Analysis Report SAR. The DOE should provide an estimate as to when the results will be available.

Scenario Recommendation 3

Our recommendation # 3 is discussed on p. 15-29. DOE concludes that a connection between the delaware Mountain Group aquifer, the repository and the surface is not realistic, because the hydraulic head of the aquifer is too small to allow direct releases of brine to the surface. We will review this conclusion.

Scenario Recommendation 4

Page 15-29 also rejects the brine-pocket scenario in recommendation #4 as being highly unlikely. We disagree with this conclusion for two reasons: (1) the well at ERDA-6 involved the "accidental" contact with a pressurized brine pocket that did flow to the surface; and (2) there have been several other encounters with brine reservoirs in the Castile in the Delaware Basin, which have involved surface flow, and at least one of these encounters (the Hudson-Belco) was not associated with the "deformation zone." (See additional discussion under "Geology and Site Characterization.") Therefore, we remain convinced that there is insufficient information on the origin and location of brine reservoirs to conclude that a connection at some future date between a brine-pocket, the decommissioned repository, and the surface (through a well) is not a plausible means for radionuclide release.

Scenario Recommendation 6

We were pleased to note on page 15-30 of the FEIS that our recommendation #6 concerning the radiation dose incurred by the use of well water taken downstream from a breached repository is to be analyzed by DOE. The EEG is also evaluating this scenario. Target dates for completion of studies in progres or to be initiated by DOE should be provided.

Scenario Recommendation 7

Page 9-145 (Section 9.7.1.6) of the FEIS provided a helpful discussion of the potential for solution mining in the vicinity of the decommissioned repository. We agree that such a scenario in our recommendation # 7 for halite has a very low probability. Nonetheless, the difficulty of predicting the conditions far into the future, and the availability of minerals sylvite and langbeinite warrant evaluation of this scenario for these minerals. No reasons were given in the FEIS for rejecting scenarios 2 and 5. We continue to believe that these scenarios should be considered.

III. Additional Comments

9-127 We are pleased that DOE has followed our suggestion to show the inventory of radioactive waste. At 1000 years it is 539,000 curies. DOE should also have indicated the activity at the time of closure which we estimate to be 7,800,000 curies. Also helpful would be an estimate of the error bounds associated with the inventory.

9-107 Table 9-52

The source terms in Table 9-50 and 9-51 of FEIS are considerably higher than those in Table 9-23 and 9-24 of the DEIS. The dose commitments in Table 9-52 of FEIS are also substantially higher than those in Table 9-25 of DEIS. However, for the CH-area accidents, the ratios of the source terms (FEIS/DEIS) do not equal the ratios of the dose commitments (FEIS/DEIS). This is questionable since the quantity of activity has changed, not the isotope spectra.

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RADIOACTIVE WASTE VOLUMES

The FEIS states the repository would receive over a 25-year period 6.2 million cubic feet of CH-TRU wastes. This would include all wastes presently stored at INEL, two-thirds of all waste generated at DOE facilities from the present until 1990, and all DOE wastes generated from 1990 to 2003. Similar (though not exact) statements are made on pages 2-17,18. The transportation analyses assume wastes will come only from INEL and RFP and would be shipped at a rate of 370,000 (Table 6-2, page 6-17) or 390,000 (Table 6-4, page 6-19) cubic feet per year. The amounts of new waste produced per year and the length of time it takes to fill the repository do not agree completely between these references but the differences are probably not important.

These statements lead to the following specific questions:

1) Why design a waste handling capacity of 500,000 cubic feet per year for a one-shift operation and 1,200,000 for a 3 shift operation (SAR Table 3.1-5) when plans are to ship less than 400,000 cubic feet per year?

2) Why is an operating life of 25 years assumed, when the 6.2 million cubic foot capacity would be filled in 16 or 17 years at the planned shipping rate?

3) Why are only 2/3 of the retrievable wastes generated at DOE facilities between the present and 1990 assumed to be shipped to WIPP? What plans are there to dispose of the other 1/3 of the waste?

4) Why are the presently stored retrievable wastes at DOE facilities other than INEL not going to be shipped to WIPP? Where will these wastes be disposed?

5) Why does the transportation analysis assume that wastes will come only from INEL and RFP?

As presently defined the WIPP project would be unable to dispose of TRU wastes that are presently stored at DOE facilities other than INEL, stored after the year 2003, buried, and generated by decontamination and decommissioning activities.

Since the above facts suggest that a larger repository is possible, the following questions should be answered:

1) What is the probability that this volume will be increased substantially? What might the maximum volume be?

2) What effect would an increased waste storage volume have on the environmental and radiological health aspects of waste transportation, facility operation, and a repository breach?

3) What procedural requirements under the NEPA process would be necessary before the radioactive waste storage capacity could be substantially increased?

DECOMMISSIONING

The Final EIS expanded the discussion of controls after decommissioning and this considerably strengthened the section and satisfactorily addressed some of our concerns. Our requests for more information on long-term controls over shallow well drilling and resource extraction were not answered. Neither was a commitment made to our recommendation for long term monitoring.

We believe that drilling into the repository could occur from a variety of activities (e.g. for hydrocarbon recovery at greater depths, from exploration of the repository for possible recovery of gas or other minerals, and from potash extraction) and this may be the most likely way that a repository breach would occur. Furthermore, well drilling into the Rustler aquifer could also be a problem if breaching has previously occurred. The plans for written records, markers, and monuments are an important aspect of control since they minimize the likelihood that drillers would have no knowledge of the repository. However, we are not fully convinced (page 15-46) that knowledge of a repository would be an adequate deterrent to man-made intrusion. Consequently, we believe there should be further evaluation of the need for positive control of drilling at the site.

An effective control period of up to 400 years (as suggested on page 15-46) might be optimum. The initial hazard from the estimated repository inventory is dominated by Strontium-90 until about 300 years and thereafter decreases slowly because Plutonium-239 is dominant.

HEALTH EFFECTS

The issues involving health effects appear to have been adequately addressed in the FEIS.

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Radiological Health Review

of the Final Environmental Impact Statement (DOE/EIS-0026)

Waste Isolation Pilot Plant, U. S. Department of Energy

Supplementary Comments

to

Review of Dec. 8, 1980

Environmental Evaluation Group

Environmental Improvement Division

Health and Environment Department

State of New Mexico

January 15, 1981

The Executive Summary of the FEIS was checked for consistency with Volumes I and II and for any misleading statements. The following items were noted.

3-3*

The security and sabotage statement about experimental HLW fails to mention there will also be a similar number of shipments leaving the site at the end of the experiments.

3-6

The one chance in 40,000 per year probability used here and in Chapter 6 gives a misleading impression of the expected rarity of a severe accident. The probability of this severe an accident occurring is actually about 1 in 140 per year. The 1 in 40,000 number comes from multiplying the 1 in 140 probability by probability factors for occurrence in: (1) an urban area (0.3); (2) with restrictive meterology (0.2); and (3) with proper wind direction (0.06) to obtain maximum population doses. The accidents occurring with probabilities between 1 and 140 and 1 in 40,000 per year would be expected to result in the release of radioactive material and some radiation dose to people.

4-5 to 4-8

The section on geology is brief, and does not include any reference to pressurized brine reservoirs or to the zone of anomalous reflection (mentioned on p. 7-29, Volume I).

4-8

We do not believe the statement on this page "It is believed that deep dissolution will not affect the site for the next million years (Anderson, 1978)" accurately portrays Dr. Anderson's concerns about deep dissolution at the WIPP site. A more thorough review of his 1978 paper (Reference 13), as well

* This numerical designation refers to the page number in the FEIS.

as his more recent publications, indicate his view that the site may be breached at the repository horizon before the overlying salt is removed by surface water and groundwater flow. Hence, estimates of site stability based upon the rate of movement of a surface dissolution front may not be pertinent.

6-1

While the sanitary waste discharge is estimated as 25,000 gallons per day, the same volume used in the DEIS, page 8-33 of the FEIS uses 45,000 gallons per day.

1-4; 6. Hvdrology

The conclusion that there is no deep dissolution active within 10 miles of the site should not be made until the zone of anomalous reflection, near the edge of Zone II, has been adequately explained.

1-5; 4. *Alternative 2. The authorized WIPP facility.*

The statement is made that "the SPDV program has been planned to confirm the geologic adequacy of the site and to verify the engineering properties of the salt at the depth of the WIPP repository." We agree that the SPDV program will provide valuable information as to the engineering properties of the salt at the repository horizon. However, our review of the available information on the SPDV does not indicate how the program will resolve all of the questions relative to the geologic adequacy. For example, the zones of anomalous reflection needs further investigation to clarify this phenomenon. These questions should be resolved, since these zones could be interpreted as potential artesian brine pockets or advanced stages of deep dissolution in proximity to the repository horizon.

1-7; 2

This paragraph fails to point out that the maximum occupational 50 year dose commitment calculated (p. 9-108) was 130 rem to the bone. This is about 20 times the 50 year background dose.

1-8; 5

The statement is made that the characteristics of the Los Medanos site do not appear to conflict with the draft criteria of the National Waste Terminal Storage (NWTS) program for qualifying sites for the disposal of commercially generated high-level waste (Reference 14). As indicated in our comments on Appendix D, there are several questions raised concerning whether the site meets certain of the criteria.

CHAPTER 2

References for Chapter 2.

Several reference citations in the text are not listed in the reference list for Chapter 2. For example, Griswold 1977; Snow and Chang 1975; Jones. 1974a; Jones, 1974b, Jones et al, 1973; ORNL, 1972; and others. It appears that all references with a first letter beyond "D" in the alphabet were omitted. This makes it difficult to evaluate the information and data cited in the Chapter.

CHAPTER 4

4-12;2

This paragraph states that a solution mining release scenario was not considered conceivable in the bedded salt at WIPP, "because of the relationship of the repository to geologic features (i.e., the presence of numerous thin layers of relatively impermeable anhydrite and polyhalite in the Salado) lack of economic incentive as compared to other salt deposits, and lack of large quantities of water." The FEIS contains no data to support the contention that the thin layers of anhydrite would be totally impermeable during solution mining. There are presently economic incentives to mine potash in the area, and if at some future date, a source of water becomes available, solution mining would become more likely.

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CHAPTER 7

The FEIS contains additional information on site surface water and ground-water hydrology. This information included responses to specific comments by EEG (Reference 2) on surface water use and on site storm water runoff. The additions are very helpful. Also, the planned hydrologic studies (p. 7-96) will address two items mentioned in a later report of EEG (Reference 7) as needing additional information (recharge areas and hydrologic systems and transit times.)

We have two additional concerns that may not be addressed by currently planned studies and evaluations. One is the need to quantify as much as possible the uncertainties that exist in such key parameters as K_d, hydraulic conductivity, and porosity. There may be enough data presently available to do this in approximate form. The uncertainty analysis would give a range of possible values that would be much more meaningful than the single numbers used in various scenarios involving radionuclide transport. The second concern is whether the effects of future climatic changes on the current hydrologic regimen may be significant. One aspect of climate change could be a change in hydraulic head relationships in the various aquifers. Planned future studies may provide an answer for this part of the problem. The second aspect is the possible increase in fracture permeability that might occur from further dissolution within the Rustler aquifers. The statement was made at EEG's January 1980 Geotechnical Meeting that it may be possible to estimate the rates that permeability will increase (Reference 7, page 9).

The following specific questions and comments are offered:

7-82.

The description of Pecos River water use below Carlsbad and below Red Bluff reservoirs is helpful. However the use of water in Pecos County, Texas and downstream lacks detail. Also, it is stated that the water, with a discharge-weighted TDS exceeding 15,000 mg/ℓ is used for irrigation and stock watering. Is this high TDS water used only after blending with better quality water?

7-83.

If stormwater runoff drains into Nash Draw, might it also be a source of recharge to the Pecos River as the potash-refinery effluents are said to be (page 7-93)? Consideration should be given to estimating the quantities of radionuclides that might be carried offsite by stormwater runoff. Also the possibility that the nuclides might be concentrated in sediment at some point offsite should be investigated.

7-89.

This statement (lines 5 and 6) "Groundwater movement in the Rustler near the site is westward toward Nash Draw and then southward toward the Pecos River," is inconsistent with the sentence on pages 7-87, 88 "...the average groundwater gradient of the Magenta Dolomite and the Rustler-Salado contact is to the southwest and that of the Culebra Dolomite is to the southeast and then to the southwest."

7-89.

Several questions arise from the description of the Santa Rosa Sandstone aquifer:

(1) Is groundwater flow to the south (first paragraph and conclusion 8 on page 7-96) or "into the Pecos River rather than to the south into Texas" (second paragraph)?

(2) Where is the recharge area for the portion of the Santa Rosa aquifer overlying the WIPP site? What is the possibility that a wet hydrologic cycle would increase the saturated thickness of this formation? If this occurred it could place an aquifer with good quality water immediately over horizons containing wastes.

7-96.

When might information concerning hydrologic studies 1 and 2 be available?

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CHAPTER 8

8-4: Section 8.1.2

From Figures 9-1, and 9-2, one can calculate that a shift in the site of 0.5 miles to the southwest would still meet the one mile borehole criterion and would reduce the area of langbeinite mineralization inside of Zone IV by more than one square mile while increasing the amount of lease grade sylvite inside of Zone IV by less than one quarter square miles. Also this would be moving away from the zone of anomalous reflection. What considerations are being given to shifting the location or underground orientation of the repository as more data become available?

CHAPTER 9

General Comments

If the dose rates and dose commitment detailed in the FEIS are reasonable estimates for the scenarios considered it appears that there are few radiological problems of concern. In a number of instances, however, we need more definitive information concerning the fact that the kinetics and parameters used in arriving at these dose estimates indeed reflect actual environmental conditions at the site.

The following examples illustrate the lack of supportive data needed to perform independent analyses to confirm dose calculations.

9-105

Following the narrative of accident R15, one obtains a release of 2×10^{-3} curie. Is there an assumption omitted that 1% of the waste released is suspended in the air? A factor of 10^{-2} is not explained.

9-107 Table 9-52

The source term in Table 9-50 and 9-51 of FEIS are considerably higher than those in Table 9-23 and 9-24 of the DEIS. The dose commitments in Table 9-52 of FEIS are also substantially higher than those in table 9-25 of DEIS. However, for the CH-area accidents, the ratios of the source terms (FEIS/DEIS). This is questionable since the quantity of activity has changed, not the isotope spectra. Also, the natural background dose in Table 9-52 is a 50-year dose.

9-112;1

The last line of the paragraph states that all the radioactivity is released instantaneously. Table 9-55 lists a release rate in pCi/sec. We have not been able to arrive at the numerical values in Table 9-55 from the information provided.

9-130 (flow rates through wellbore)

It appears that the data in Figure K-11 applies to scenarios 1, 2, and 3. Presumably, the data was obtained with the SWIFT code although it appears to be a combination of Darcy's law and Poiseuille's formula. The flow numbers in the three scenarios in section 9.7.1.3 cannot be obtained from Figure K-11. Some further explanation might be helpful.

Specific Comments

9-6

In designing the size of the diked area to contain fluid runoff was the interception of a geopressurized brine reservoir considered? What is the total containment volume?

9-100: 4

The last line mentions a total release of 6.9×10^{-8} curie for accident C 10. The correct number should be 2.2×10^{-9} as given in Table 9-50.

9-101: 2

The paragraph mentions a total activity of 376 curies. Calculations suggest that the correct value should be 326.

9-104: Table 9-51

What is the numerical value of the air volume of the cask, transporter, and waste cage that is displaced from the pit? This value is needed in verification of the C-13 consequences.

9-127

The curies of U-235 in Table 9-59 should be 0.36 rather than 36.

9-137 Nuclide Transport

The FEIS states. "The highly sorbed plutonium nuclides do not contribute to the discharge even at 3 million years; these species are retained in the aquifer near the repository, while their much less sorbed uranium daughters are transported at about one-tenth the aquifer flow speed." This statement does not reflect the uncertainty associated with the distribution coefficients for many of the radionuclides. A member of the EEG has recently evaluated the significance of certain Rustler aquifer parameters for predicting long-term radiation doses from WIPP (Reference 15). This report has considered the uncertainty associated with plutonium distribution coefficients (K_d). If a portion of the plutonium moves with a lower K_d, the radiological consequences in all of the liquid breach scenarios may be significant.

APPENDIX D
SELECTION CRITERIA FOR THE WIPP SITE

D-2; 4.5 Lateral extent

The discussion in the FEIS of this criterion implies that there are no questionable structures or dissolution features near the repository horizon. As indicated in previous comments, the areas about 1 to 3 miles north and 1 mile southwest of ERDA-9 at the level of the Castile, and below, has yielded anomalous seismic reflection data, and possible structural faults in the Castile. This data raise questions about the integrity of the structure in these areas. The repository will extend almost to the northern boundary of Zone II which would be within ½ mile of the northern zone of anomalous reflection. Therefore there is insufficient data at this time to be certain that this criterion is met.

D-2; .10 Structure.

WIPP-12 is at the edge of a possible anticlinal structure in the Castile, and the hole is also located at the southern edge of one of the zones of anomalous reflection discussed above. Seismic reflection data also suggest faults in the area north of Zone II and southwest and south of ERDA-9. The seismic data has insufficient resolution to know if geologic faults extend into the Salado. Until more information is available, one cannot conclude that the WIPP site meets the structure criterion.

D-3; 5 Dissolution.

We agree that the edge of regional dissolution in the basin is in the vicinity of Nash Draw, and therefore would not pose a problem for the proposed repository. However the seismic reflection data, as discussed in the preceding paragraphs may be indicative of dissolution features in proximity to the repository horizons.

D-5; 9 Faulting and Fracturing.

This paragraph states that there are no known faults in post Permian rocks at the site area. As discussed above, the seismic reflection data do indicate the possibilit of faults in the Castile. Therefore, it is not yet possible to know whether this criterion is met.

D-6; Salt-Flow Anticline.

As discussed in the preceding paragraphs, there could be a major anticline in the Castile beginning at the northern edge of Zone II and extending north. There is a definite steepening and the seismic data do not permit an adequate resolution of the extent of this steepening toward the north. Such structure is indicative of possible effect on long-term safety of the repository.

D-8; 7 Natural Resources.

The statement is made that "very little potash exists above the repository (Zone II) itself." This statement conflicts with the information in Figure 2.7-6 of the SAR (Reference 13) which states that the McNutt member at ERDA-9, "contains potassic rock rich in sylvite, langbeinite and other hydrous minerals." Also Figure 9-1 would suggest that at least 1/3 of Zone II contains lease grade sylvite.

D-9; 2 Man-made Penetrations.

As indicated in other EEG comments on the FEIS, the possibility of human intrusion is of considerable concern, and therefore additional information is needed as to how-control will be maintained.

M

APPENDIX E
DESCRIPTIONS OF WASTE TYPES

The activity curve for U-234 and Ra-226 in Figure E-2 can only be explained if there is a substantial amount of U-238 in the waste; this is not apparent in table E-3. The total activity curve in the time interval between 10^5 and 10^6 years seems to include Th-230 and all the radioactive daughters of Ra-226 that are in secular equilibrium. Some clarification might help.

APPENDIX J

EFFLUENT AND ENVIRONMENTAL MEASUREMENTS PROGRAMS

The FEIS did not acknowledge or respond to EEG's comments concerning radiation monitoring programs. We believe these comments are still applicable and need to be addressed. The more important ones are:

Present Program

(1) "Radon emissions from natural radioactivity in the repository have not been measured in soil, mined rock, and the proposed waste horizon. Radon should be measured to see if levels might be high enough to be a problem for underground workers and a source of radiation exposure to the public...." (page 53, Reference 2).

(2) "It will be necessary to obtain sufficient samples and analyses before operation to ensure that the variations in the background (naturally occurring and from weapons testing fallout) levels of actinides,....and fission products are adequately known. These values are needed in order to be able to detect contamination from site operations." (page 60, Reference 2)

Pre-Operational and Operational Programs

(3) "It is noted that no air particulate station is planned for Hobbs. Since it is a major population center, with a calculated long-term X/Q only 10% lower than at Eunice, this omission should be reconsidered. Also, the three days per week of sampling should be randomized in order to measure levels on work days, and nonwork days." (page 60, Reference 2).

(4) "Consideration should also be given to monitoring radioactivity in rainfall and runoff (when it occurs) at the site as well as surface water and biota in Nash Draw." (page 57, Reference 2)

(5) "In several cases...the types of analyses are not specific enough. Gross analysis is useful as a screening mechanism for detecting significant contamination. However, it usually will not detect trace migration of radionuclides. All media being sampled should have periodic

analyses of the actinides...and long-lived fission products." (page 58. Reference 2)

Post-operational Program

(6) "The outline of a post-operational program...appears reasonable. However, the borehole radionuclide analyses should be for specific radionuclides rather than gross alpha and beta analyses for the reasons discussed above." (page 61, Reference 2)

Several changes have been made in Appendix J between the Draft and FEIS. One of these is substantive. In the DEIS (page J-30 and Tables J-5, J-6) it is stated that "In general, state-of-the-art techniques and instruments will be used." In the FEIS (page J-32) it is stated "The equipment used for measurement during operation will meet or exceed the sensitivities required to detect radiation levels below the limits described in 10CFR 20, Appendix B." The 10CFR 20 criteria would permit minimum detection levels that are one to three orders of magnitude less sensitive than would occur from state-of-the-art techniques. We believe that use of the 10CFR 20 criteria is unacceptable for environmental samples since it could result in some trace radionuclide releases not being detected. This position is consistent with the Nuclear Regulatory Commission Regulatory Guide 4-1 which states "the detection sensitivity of environmental measurements should be the most sensitive that is practically achievable for measuring plant contributed radionuclides in the environment."

All the TLDs stations are along a line going N-E from the center of the WIPP facility. Some data points near the James Ranch might be desirable since it is the reference location for accident analysis.

M

Water Quality

p. 8-33

The estimated rate of sewage discharge is 45,000 gallons per day. This disagrees with the DEIS and the Executive Summary, both of which use 25,000 gpd. Which is correct? Also, the statement in the DEIS that all treated waste water would be used for landscape irrigation or evaporated has been deleted. Has there been a change in the earlier plan to evaporate all excess water?

p. 14-7

The term Water Quality Division used twice in section 14.2.5 should be Water Pollution Control Bureau. The Water Pollution Control Bureau notified DOE on October 7, 1980 that a ground water discharge plan was not needed for the SPDV program.

Air Quality

p. 14-8

The appropriate New Mexico Air Quality Regulation for new sources is 702, not 100. A permit was granted by the New Mexico Air Quality Bureau of June 6, 1980 for the SPDV phase of the WIPP project.

Noise

The FEIS was largely unresponsive to EEG comments on noise aspects in the DEIS. Of the 5 items we pointed out as needing clarification only one was partially responded to. None were acknowledged. The 4 possible mitigation measures suggested were ignored. We still believe these mitigation measures have the potential for reducing noise exposure of workers and those living along right-of-way and should be considered.

1) busing of workers to drastically reduce auto traffic;

2) muffling of construction equipment and use of low noise products where available;

3) a requirement that all trucks meet the Federal noise regulations required for inter-state commerce; and

4) housing of various fixed noisy equipment and operations.

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ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-11

M

EEG-11

NEW MEXICO
HEALTH AND ENVIRONMENT
DEPARTMENT

CALCULATED RADIATION DOSES FROM RADIONUCLIDES BROUGHT TO THE SURFACE IF FUTURE DRILLING INTERCEPTS THE WIPP REPOSITORY AND PRESSURIZED BRINE

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State of New Mexico

January 1982

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Calculated Radiation Doses from Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine

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Contents

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site, the design of the repository, its planned operation, and its long-term stability. These analyses include assessments of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

Robert H. Neill
Director

INTRODUCTION

If brine filled the void space in the waste storage areas of the proposed WIPP repository sometime after closing, it could initiate leaching and exchange actions between the brine, the waste, and the salt used for backfilling. This action would result in a radionuclide contaminated brine. A subsequent penetration of the repository, could bring contaminated brine to the surface if there was adequate pressure.

Several pressurized brine reservoirs have been encountered by drilling in the vicinity of the WIPP site and significant discharges have occurred at the surface. At the time this report was written in draft form all except one of the known brine reservoirs were associated with the Capitan Reef and its deformation front, rather than the Delaware Basin (where the proposed WIPP repository is located). However, this report was written because of the belief that the location and occurrence of these reservoirs is not well enough understood to completely rule out their existence under the site.

On November 22, 1981 a pressurized brine reservoir was encountered at the WIPP-12 borehole. The point where this brine reservoir was intercepted was only 558 feet horizontally and 786 feet vertically from the proposed location of the northernmost waste storage room. Since more definitive information on this brine reservoir will not be available for several weeks or months, it was decided to proceed with this report using the original assumptions and to prepare a new report in the future if the data from WIPP-12 suggest that significant changes in the assumptions are appropriate.*

---

*Preliminary information indicates that the WIPP-12 brine reservoir will affect at least the following two assumptions:

(1) The probability per borehole of hitting a brine resevoir beneath the site will be greater than the value of 0.04 used in this analysis.

(2) Greater than 75,000 cubic feet of brine may be brought to the surface during normal drilling operations.

This report describes a scenario in which an exploratory borehole connects an underlying brine reservoir with the repository and results in saturation of the waste storage area. A subsequent borehole brings portions of this radionuclide contaminated brine to the surface. Radiation doses are calculated for time periods of 125, 400, and 1,000 years after repository closing for the following:

(1) external radiation doses for workers at the borehole location

(2) inhalation doses for workers at the borehole location,

(3) external and inhalation doses for a resident located 360 meters downwind,

(4) ingestion doses for the downwind resident from locally grown produce, milk, and meat, and

(5) Population doses from inhalation within a 50-mile radius.

The probability of the various calculated doses occurring was estimated. Probability was included in the report because of a belief that probability considerations are useful in evaluating the acceptability of unlikely events and to encourage others to provide a more detailed evaluation using more sophisticated methodology. Since the probabilities presented in this report were calculated using a simple methodology, with some parameter values chosen arbitrarily, they should be considered as approximate examples, not accurate numbers.

The reasonableness of the scenario and the significance of the results are also discussed.

SUMMARY AND CONCLUSIONS

1. Calculated radiation doses from radionuclides brought to the surface from a postulated interaction between a pressurized brine reservoir, the repository, and an exploratory borehole are summarized below.

Radiation Doses From Brine Reservoir Scenario
(50-year Dose Commitment from One Year's Intake)

	tc+125y*		tc+400y		tc+1000y ***	
	w.b**	Bone	w.b.	Bone	w.b.	Bone
Drilling crew			Rem			
inhalation	0.049	1.3	0.30	12.	0.78	32.
external	0.045	-	0.084	-	0.084	-
Downwind Resident						
inhalation	0.049	1.3	0.30	12.	0.80	32.
external	<.001	-	<.001	-	-	-
produce	0.47	1.9	0.001	0.026	-	-
milk	0.032	0.13	-	-	-	-
meat	0.009	0.035	-	-	-	-
			Person - rem			
Area population	1.0	24.	5.9	220.	15.	600

*tc+125y = 125 years after closure of the repository

**w.b. = whole body

***The tc+1000y doses are not considered plausible

2. Inhalation and external radiation doses increase with time after the repository is flooded due to the continued leaching of long-lived actinides. Ingestion doses are dominated by the 29-year half-life of ^{90}Sr and become negligible in less than 300 years after closure of the repository (tc+300y).
3. Preliminary estimates were made of the cumulative probabilities of doses equal to or greater than the tc+125y doses occurring during the lifetime of the repository. The estimated probabilities were 5×10^{-7} for the inhalation pathway and 5×10^{-8} for the ingestion pathway. The estimated probability of some radionuclides being brought to the surface and resulting in doses between zero and those summarized above is much greater, about one part in 4,000.
4. A preliminary estimate indicated a probability of 3×10^{-5} that 175 Ci of ^{239}Pu (or equivalent) would be brought to the surface by this scenario. Since the draft EPA HLW standards would be violated only if the probability of bringing this quantity of radionuclides to the surface in 10,000 years is $> 10^{-4}$--the estimate indicates the standard would be met. However, since the values are only a factor of 3 apart a more refined analysis would be worthwhile.
5. The ingestion dose estimates are not great enough to be of particular concern after tc+125y because they: (a) have a low probability of occurrence; (b) are below recommended guidelines for accidental releases; and (c) decrease rapidly (2.4%/y) with time.
6. Calculated inhalation doses to workers about the site and to residents 360m downwind are undesirably high at tc+400y. The bone dose exceeds that permitted for the general population either for routine exposure or accidental conditions. However, the dose from one year's inhalation is well below that which would result in noticeable health effects to an individual.
7. Inhalation doses calculated for tc+1000y years are even higher than those at tc+400y. However, because of pressurization and solubility limitations these doses would not be expected to occur. Consequently, the tc+400y calculated doses are considered to be the highest that would occur.
8. Radiation doses to the population residing within 50 miles of the WIPP site due to inhalation are low on an annual basis but, in the absence

of remedial measures, would be expected to continue for hundreds of years as resuspension continues. The total cumulative dose over 1500 years might result in 1 or 2 cancer fatalities (compared to an estimated 500,000 cancer fatalities from all other causes).

9. The calculated amounts of surface contamination and resuspended radionuclide concentrations are great enough to warrant a more detailed evaluation of the probability of this scenario occurring.

10. The maintaining of sufficient active institutional controls over the site to be able to detect surface contamination for up to about 600 years after closure should be considered unless the probability of occurrence can be shown to be less than estimated here.

PROCEDURE

Scenario Description

An exploratory borehole is drilled through the repository at a future time when institutional control has been lost. This borehole strikes a pressurized brine reservoir in the Castile formation and portions of this brine reach the surface. The well is capped to stop the brine flow, subsequently plugged, and then abandoned. Geopressurized brine infiltrates into the void space in the repository before the reservoir is plugged because the backfilled material is much more permeable than surrounding formations. The brine remains in contact with the salt and the waste for an extended period of time (25 years or more). During this time exchange occurs between brine, salt and waste.

A second exploratory bore hole at least 25 years later, penetrates backfilled portions of the repository. Some of this brine, which is still pressurized from the brine reservoir, from gases generated in the repository, or from salt creep is carried to the surface before the borehole can be capped. This brine is unrecognized or ignored as a possible radiological problem and is ponded with subsequent evaporation of the liquid.

The residue of this brine, which contains radionuclides from the repository, remains in the pond after evaporation and is available for resuspension. A largely self-sufficient farm family resides downwind and produces most of its produce, milk, and meat from the surrounding land. Annual radiation doses received by an adult from inhalation, ingestion and external radiation are calculated. Radiation doses received by drilling crew workers in the brine pond area from inhalation and external radiation are also calculated. Doses received by the population within a 50-mile radius from inhalation of resuspended radionuclides were estimated.

Assumptions

General

Several institutional assumptions must be made in order for the calculated doses to occur:

1) There must be a loss of institutional control so that drilling can occur without any requirements for determining the existence of a radiological hazard.
2) Drilling must occur and the drillers, either through ignorance of the repository or complacency about radiation dangers, do not determine if a radiological problem exists or take any protective measures.
3) Residence must be occurring on the land. The residence must be in the maximum downwind direction for the calculated doses to occur. Conditions (especially the availability of adequate water) must exist where subsistence farming is possible in order for calculated ingestion doses to occur.

Specific

The key physical and technical assumptions that must occur are:

1) A geopressurized brine reservoir must exist below the repository, be intercepted by a borehole and enter the repository. This event occurs 100 years or more after repository closure.
2) The exchange that occurs between waste and brine in a 25 year period results in all of the ^{90}Sr going into solution. The fraction going into solution is 0.01%/y for the actinides and 0.12%/y for cesium. These leaching values come from data reported in Reference 2.
3) A second borehole intersects the repository at least 25 years after the first borehole brings brine into the repository. For the maximum ^{90}Sr dose this event is assumed to occur 25 years after the first event (tc+125y).
4) Seventy-five thousand cubic feet of brine escapes to the surface before the well is sealed, the brine is diverted to a 20,000 m^2 pond and evaporated, leaving a residue of solids that is ≈3 cm thick. This volume of brine represents 0.93% of that in the repository and carries with it 0.93% of the ^{90}Sr. The fraction of the actinide inventory in the brine brought to the surface is .0023% after 25 years of leaching and 0.028% after 300 years.

5) The amount of this residue that is resuspended and carried downwind to the residence is assumed to be 0.2% per year of the total residue. Radionuclides are evenly mixed in the residue and are resuspended at the same rate. This value is more conservative than the value of 0.07% found at Rocky Flats (Ref. 3) but is less than the 0.7% expected to be lost from the top 3 cm of the WIPP salt pile (Ref. 7).

6) The downwind residence and farm is located 360m from the center of the 2 hectare evaporation pond. Since the source term is modeled as a virtual point source it is appropriate to use an annual $\frac{\chi}{Q}$ value for 804m. The value used (from the Final EIS) is $(5.0 \times 10^{-5})\ \frac{s}{m^3}$

7) Radionuclide transit, adult intake, and dose conversion factors are taken from Regulatory Guide 1-109 and NUREG-0172 (References 4 and 5).

FINDINGS

Source Term. The total curies of each significant radionuclide reaching the surface 125, 400 and 1000 years after closure are shown in Table I.

Table I
Quantity of Radionuclides Brought to Surface
(Curies)

Radionuclides	Radionuclide Quantities - Ci			
	Repository Total, t_c	t_c+125y	t_c+400y	t_c+1000y
^{90}Sr	2.5 + 6*	1,200.	1.5	-
^{137}Cs	1.3 + 4	0.21	-	-
^{238}Pu	3.5 + 4	0.34	0.51	
^{239}Pu	3.9 + 5	9.0	110.	310.
^{240}Pu	9.3 + 4	2.1	27.	79.
^{241}Am**	4.5 + 3	1.7	14.	14.

*2.5 + 6 = 2.5×10^6

**^{241}Am ingrows from decay of ^{241}Pu, inventory at t_c+125y = 7.5 + 4

Concentration in Air. The assumption is made that 0.2% of the radionuclides brought to the surface are resuspended and carried downwind per year. The amount of atmospheric dilution occurring at 360m in the maximum downwind direction is assumed to have an annual average of $(5.0 \times 10^{-5}) \frac{s}{m^3}$ Resulting concentrations are shown in Table II.

Table II
Atmospheric Concentrations of Radionuclides
at Downwind Residence

Radionuclide	t_c+125y		t_c+400y		t_c+1000y	
	Ci/y resuspended	pCi*/m³	Ci/y resuspended	pCi/m³	Ci/y resuspended	pCi/m³
^{90}Sr	2.4	3.8	.0032	0.0051	-	-
^{137}Cs	0.0004	0.0007	-	-	-	-
^{238}Pu	.0007	.0011	.0010	.0016	-	-
^{239}Pu	.018	.029	0.22	0.35	0.62	0.99
^{240}Pu	.0043	.0068	.054	0.086	0.16	0.26
^{241}Am	.0034	.0054	.028	0.045	0.024	0.045

*pCi/m^3 = 1.6 (Ci/y resuspended)

Inhalation Dose. The inhalation dose that the maximum individual would receive for 100% occupancy at the nearest residence is shown in Table III. An annual intake of 8000 m^3 of air is assumed. The calculated whole body and bone doses use dose conversion factors from Reference 5 and are expressed as the 50 year dose commitment in rems resulting from one year's inhalation. Since the residence time for actinides in the body is very long the dose actually delivered in the maximum year from a one-year intake is only about 2.2% of the dose commitment.

The inhalation dose that would be received by drill crew operators working in the brine pond area is shown in Table IV. This calculation assumes 200 hours per year of presence on site, a breathing rate of 1.25 m^3/hr, and a resuspension factor of 6×10^{-9}/m of the radionuclides in the top centimeter of the brine pond.

Table III

50-Year Dose Commitment From One Year's Inhalation at Downwind Residence (Rem)

Radionuclide	Dose Conversion F. mrem/pCi*		t_c+125y			t_c+400y			t_c+1000y		
			Intake	Dose		Intake	Dose		Intake	Dose	
	w.b.	Bone	pCi/y	w.b.	Bone	pCi/y	w.b.	Bone	pCi/y	w.b.	Bone
^{90}Sr	7.6 - 4	1.2 - 2	3.0 + 4	0.023	0.36	4.1+1	-	-	-	-	-
^{137}Cs	5.4 - 5	6.0 - 5	5.3 + 0	-	-	-	-	-	-	-	-
^{238}Pu	6.9 - 2	2.7 + 0	8.8 + 0	.0006	.002	1.3+1	0.001	0.035	-	-	-
^{239}Pu	7.8 - 2	3.2 + 0	2.3 + 2	.018	0.74	2.8+3	0.22	9.0	7.9+3	0.62	25.
^{240}Pu	7.7 - 2	3.2 + 0	5.5 + 1	0.004	0.18	6.9+2	.053	2.2	2.1+3	0.16	6.6
^{241}Am	6.7 - 2	1.0 + 0	4.3 + 1	.003	0.043	3.6+2	.024	.36	3.6+2	0.024	0.36
		TOTALS		0.049	1.3		0.30	12.		0.80	32.

*From Reference 5, Table 8.

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Table IV
50-Year Dose Commitment From One Year's Inhalation
for Workers at the Brine Pond
(Rem)

Radionuclide	t_c+125y			t_c+400y			t_c+1000y		
	Intake pCi/y	Dose w.b.	Dose Bone	Intake pCi/y	Dose w.b.	Dose Bone	Intake pCi/y	Dose w.b.	Dose Bone
^{90}Sr	3.0 + 4	.023	.36	4.0+1	.0001	.0005	-	-	-
^{238}Pu	8.5 + 0	.0006	.023	1.3+1	.0009	.035	-	-	-
^{239}Pu	2.3 + 2	.018	.74	2.8+3	.22	9.0	7.8+3	.61	25.
^{240}Pu	5.3 + 1	.0041	.17	6.8+2	.052	2.2	2.0+3	.15	6.4
^{241}Am	4.3 + 1	.0029	.043	3.5+2	.023	.35	3.5+2	.023	.35
	TOTALS	.049	1.3		.30	12.		.78	32.

Ingestion Doses. Ingestion doses are calculated assuming the downwind resident obtains 76% of his fruits, vegetables, and grain; 100% of his milk; and 100% of his meat from the surrounding land which is contaminated by deposition of the resuspended radionuclides. A deposition rate of (8.0×10^{-5}) per meter of plume length is assumed (Ref. 6). Stable element transfer data, annual consumption rates, maximum individual intake rates, and other parameters are taken from Tables E-1, E-3, E-9, and E-15 of Reference 4.

Table V

Radionuclide Intake From One Year's Ingestion of Fruits, Vegetables, and Grain (Picocuries)

Radionuclides	t_c+125 years			t_c+400y		
	$Q(\frac{pCi}{s})$	$C(\frac{pCi}{kg})$	Intake (pCi)	$Q(\frac{pCi}{s})$	$C(\frac{pCi}{kg})$	Intake (pCi)
^{90}Sr	7.7 + 4	5.9 + 2	2.5 + 5	1.1 + 2	8.4 - 1	3.3 + 2
^{137}Cs	1.3 + 1	1.0 - 1	4.3 + 1	-	-	-
^{238}Pu	2.1 + 1	1.6 - 1	6.6 + 1	3.2 + 1	2.5 - 1	1.0 + 2
^{239}Pu	5.7 + 2	4.4 + 0	1.8 + 3	6.8 + 3	5.2 + 1	2.1 + 4
^{240}Pu	1.4 + 2	1.1 + 0	4.4 + 2	1.8 + 3	1.4 + 1	5.6 + 3
^{241}Am	1.1 + 2	8.5 - 1	3.4 + 2	9.0 + 2	6.9 + 0	2.8 + 3

$$C_{crops} = .0077 \frac{s}{kg} \; Q \frac{pCi}{s}$$

$$Q \frac{pCi}{s} = (3.17 + 4) \; \frac{pCi - y}{Ci - s} \left[\frac{Ci}{y} \text{ resuspended} \right]$$

Table VI

50-Year Dose Commitment From One Year's Ingestion of Fruits, Vegetables, & Grain

Radionuclide	Dose Conversion* Factors (mrem/pCi)		Dose in millirem			
			t_c+125y		t_c+400y	
	w.b.	Bone	w.b.	Bone	w.b.	Bone
^{90}Sr	1.9 - 3	7.6-3	4.7 + 2	1.9+3	6.3 - 1	2.5+0
^{137}Cs	7.1 - 5	8.0-5	3.0 - 3	3.4-3	-	-
^{238}Pu	1.7 - 5	6.8-4	1.1 - 3	4.5-2	1.7 - 3	6.8-2
^{239}Pu	1.9 - 5	7.9-4	3.4 - 2	1.4+0	4.0 - 1	1.7+1
^{240}Pu	1.9 - 5	7.9-4	8.4 - 3	3.5-1	1.1 - 1	4.4+0
^{241}Am	5.4 - 5	8.2-4	1.8 - 2	2.8-1	1.5 - 1	2.3+0
		Totals, mrem	4.7 + 2	1.9+3	1.3 + 0	2.6+1
		Rem	0.47	1.9	0.001	0.026

*From Reference 5, Table 4.

Table VII
Radionuclide Intake From One Year's
Ingestion of Milk
(Picocuries)

Radionuclide	Fm (d/ℓ)	t_c+125y			t_c+400y		
		Cpast ($\frac{pCi}{Kg}$)	Cmilk ($\frac{pCi}{\ell}$)	Annual Intake (pCi)	Cpast ($\frac{pCi}{kg}$)	Cm($\frac{pCi}{\ell}$)	Annual Intake(pCi)
^{90}Sr	8.0 - 4	1.4 + 3	5.5 + 1	1.7 + 4	1.9 + 0	7.3 - 2	2.3 + 1
^{137}Cs	1.2 - 2	2.3 - 1	1.3 - 1	4.1 + 1	-	-	-
^{238}Pu	1.5 - 6	3.7 - 1	2.8 - 5	8.7 - 3	5.8 - 1	4.3 - 5	1.3 - 2
^{239}Pu	1.5 - 6	1.0 + 1	7.5 - 4	2.3 - 1	1.2 + 2	9.0 - 3	2.8 + 0
^{240}Pu	1.5 - 6	2.6 + 0	1.9 - 4	5.9 - 2	3.3 + 1	2.5 - 3	7.8 - 1
^{241}Am	5.0 - 6	2.0 + 0	5.0 - 4	1.6 - 1	1.6 + 1	4.0 - 3	1.2 + 0

Fm = pCi/ℓ in milk per pCi/day ingested by the animal

Cpasture = .018 $\frac{s}{kg}$ (Q $\frac{pCi}{s}$)

Cmilk = 50 Cp Fm

Intake = 310 ℓ/y

Table VIII
50-Year Dose Commitment From One Year's
Ingestion of Milk
(millirem)

Radionuclide	t_c+125y		t_c+400y	
	w.b.	Bone	w.b.	Bone
^{90}Sr	3.2 + 1	1.3 + 2	4.4 - 2	1.7 - 1
^{137}Cs	3.0 - 3	3.4 - 3	-	-
^{238}Pu	1.5 - 7	5.9 - 6	2.2 - 7	8.8 - 6
^{239}Pu	4.4 - 6	1.8 - 4	5.3 - 5	2.2 - 3
^{240}Pu	1.1 - 6	4.7 - 5	1.5 - 5	6.2 - 4
^{241}Am	8.6 - 6	1.3 - 4	6.5 - 5	9.8 - 4
Total Doses (mrem)	32.	130.	0.044	0.17

Table IX
Radionuclide Intake From One Year's
Ingestion of Meat
(Picocuries)

Radionuclide	Ff (d/kg)	t_c+125y		t_c+400y	
		Cmeat (pCi/Kg)	Annual Intake (pCi/y)	Cmeat (pCi/kg)	Annual Intake (pCi/y)
^{90}Sr	6.0 - 4	4.2 + 1	4.6 + 3	5.7 - 2	6.3 + 0
^{137}Cs	4.0 - 3	4.6 - 2	4.9 + 0	-	-
^{238}Pu	3.0 - 6	5.6 - 5	6.2 - 3	8.7 - 5	9.6 - 3
^{239}Pu	3.0 - 6	1.5 - 3	1.7 - 1	1.8 - 2	2.0 + 0
^{240}Pu	3.0 - 6	3.9 - 4	4.3 - 2	5.0 - 3	5.5 - 1
^{241}Am	3.0 - 6	3.0 - 4	3.3 - 2	2.4 - 3	2.6 - 1

Ff = pCi/kg in meat per pCi/d ingested by the animal

Cmeat = 50 (Cpast) Ff

Intake = 110 kg/y

Table X

50-Year Dose Commitment From One Year's Ingestion of Meat

(millirem)

Radionuclide	t_c+125y		t_c+400y	
	w.b.	Bone	w.b.	Bone
^{90}Sr	8.7 + 0	3.5 + 1	1.2 - 2	4.8 - 2
^{137}Cs	3.4 - 4	3.9 - 4	-	-
^{238}Pu	1.1 - 7	4.2 - 6	1.6 - 7	6.5 - 6
^{239}Pu	3.3 - 6	1.3 - 4	3.9 - 5	1.6 - 3
^{240}Pu	8.3 - 7	3.3 - 5	1.1 - 5	4.4 - 4
^{241}Am	1.8 - 6	2.7 - 5	1.4 - 5	2.1 - 4
Totals	8.7	35.	0.012	0.050

External Radiation

External radiation can occur at two locations: (1) the brine pond area where the radionuclide will be deposited once the brine has evaporated; and (2) the residence located 360m downwind. The maximum dose at the pond would occur during the first year following the release. The year when the maximum concentration would appear in the brine is a function of leaching rate and half-life and will vary for each nuclide. The maximum soil concentrations at the downwind residence would occur many years later since resuspension from the pond and deposition downwind is an on-going process. In this case the half-life of the nuclide is a factor, with the maximum concentration occurring when the decay of the deposited radionuclides equals the rate of deposition. Key assumptions are: (1) the 0.2%/y resuspension and transport rate will continue indefinitly; (2) 20% of the amount deposited each year will attach to foliage and be removed from the site; (3) the remaining radionuclides at the residence will be evenly mixed in the top 15 cm of soil and appropriate soil attenuation factors will be used for the various energy gamma radiations; and (4) occupancy factors are .023 for the pond area (based on 200 hours per year for an occupational worker) and 0.7 for the residence area.

Table XI
Maximum External Radiation Doses

Nuclide	Brine Pond Area		Downwind Residence	
	Max dose mrem/y	Time of ocurrence	Max dose mrem/y	Time of Occurrence
$^{90}Sr/^{90}Y$	26.	t_c+125y	0.014	t_c+165y
^{137}Cs	6.6	t_c+140y	0.005	t_c+180y
^{154}Eu	.056	t_c+125y	-	-
^{241}Am	97.	t_c+700y	0.70	t_c+1100y

Population Dose

The population about the WIPP site would receive some radiation dose if the scenario described in this report were to occur. The inhalation dose is expected to be much greater than the other pathways because:

(1) It is the dominant pathway near the site where the ingestion and external pathways are assumed to be plausible;

(2) The mechanism (i.e. winds and atmospheric dispersion) exists for the inhalation pathway whereas an ingestion pathway is not expected to impact the population as a whole since food crops are not extensively grown in the area. Also a logical water supply pathway does not exist for the population.

Table XII shows an estimated population dose (50-year dose commitment from one year's inhalation) within a 50-mile radius of the site for the tc+400y release. Annual χ/Q values are taken from Table H-49 of Reference 7. Plume depletion was taken from Figure 3 in Reference 6. The projected 2010 population values from Table M-6 in Reference 7 are assumed to be applicable at tc+400y. Population doses for tc+125y and tc+1000y can be obtained by ratio of actinide activities brought to the surface (Table 1).

Although Table XII shows the dose commitment for only one year and uses the quantities calculated for a tc+400y breach it should be recognized that the release could occur anytime after about tc+125y. This projected tc+400y dose is expected to be the maximum that could occur (because of repository pressurization and radionuclide solubility considerations) although the assumption used in the calculation suggest greater doses for several thousand years. Resuspension and transport of the contaminated material would continue for many years. If the depletion rate of 0.002 per year continued indefinitely this would eventually lead to an integrated dose commitment to a stable population at about 500 times the annual calculated dose. About 95% of this dose would be delivered in the first 1500 years. However, it is more likely that the depletion rate would decrease with time and that significant amounts of the radionuclides would never be resuspended because of fixation or migration into the soil.

Table XII

Population Doses within a 50-mile Radius of the WIPP Site from Inhalation of Resuspended Contamination (50-year Dose Commitment From One Year's Inhalation)

Location*	χ/Q s/m^3	Fraction Remaining in Plume	Max Adult whole body dose (mrem)	Projected** 2010 Population	Population Dose (person-rem)***	
					w.b.	Bone
Carlsbad	(1.7-8)	.57	0.056	49,465	2.7	100.
Loving	(3.5-8)	.66	0.14	2,645	.35	13.
Artesia	(3.2-8)	.48	0.088	15,770	1.4	53.
Hobbs	(8.6-10)	.48	0.0024	52,850	.12	4.8
Lovington	(2.0-8)	.48	0.055	21,800	1.2	46.
Other Locations		.53	-	11,825	.16	6.4
			Totals	154,355	5.9	220.

* includes populations in the vicinity. In some cases χ/Q values are averages of more than one section.

** projected 2010 population from Appendix M of Reference 7.

*** population dose assumed to be 0.95 (adult dose) (population) from Reference 4 population mix and inhalation rate assumptions.

PROBABILITY CONSIDERATIONS

There are a chain of events that must occur before the doses calculated above would be incurred. Each of these events has a probability of occurring that may be near zero or approach one. The probability of all the necessary events occurring is:

$$P\ total = (P_1)\ (P_2)\ (P_3)\ (P_{n-1})\ P_n$$

The following events are the key ones that must all occur for the doses to materialize:

(1) Institutional control of the repository is lost 100 years after closure.

(2) A geopressurized brine reservoir of sufficient size must exist under the Site.

(3) The brine reservoir and the repository must both be intersected by an exploratory borehole which is capped shortly after discovery.

(4) This brine reservoir must saturate the pore space in the repository where it is in intimate contact with salt and waste.

(5) The assumed amount of leaching and exchange between the waste and salt occurs.

(6) A second borehole must intercept the repository.

(7) There must be sufficient pressure in the reservoir to drive 75,000 cubic feet of brine to the surface.

(8) The drilling crew must require approximately 16 hours before capping the well in order for 75,000 cubic feet to flow to the surface (assuming a flow rate of 20,000 barrels/d).

(9) The possibility of a radiological hazard is not recognized by the drillers and no radiological analyses are made of the brine. (This requires either loss of knowledge of the repository or a complacency about potential hazards).

(10) There is a home located 360m in the maximum downwind direction from the center of the evaporation pond.

(11) This home is inhabited by a largely self-sufficient farm family.

The absence of some of these assumptions (e.g. 1, 2, 3, 4, 6, and 7) would prevent any radiation dose from occurring. The other conditions could be less critical than estimated here and still lead to some radiation exposure (less than calculated above).

The values assigned to each event are given below with an explanation of why they were chosen.

(1) 1.0 DOE assumes this may occur in their evaluations. Also, EPA's draft HLW standard would require that credit cannot be taken for longer periods of control.

(2) 0.04 per drill hole. This value was chosen from the map on page 146 of Reference 8 which shows that 1 out of 27 holes drilled into the Castile formation in the Delaware Basin (not including those on the reef or deformation belt) struck a brine reservoir.

(3) 0.049 bore holes penetrate the backfilled area of the repository in each century. This estimate is taken from an EPA suggested value of 2.0 boreholes per century for an 8 km^2 area (Ref. 9). The effective cross-sectional area of the repository is the sum of the backfilled rooms, subentries, and main entry areas in the waste storage portion of the repository and is about 0.19 km^2. Because of pressurization and closure phenomena in the repository the time period when this borehole would be effective is 100 to 500 years after closure (see Appendix A).

(4) 0.5 There is a possibility the brine would go into other permeable zones.

(5) 0.5 The 25 year period may be too-short a time for all of the ^{90}Sr to go into the brine solution. Longer time periods would reduce the probability and dose but not eliminate the pathway. Also, the assumed degree of equilibration may be less. The value of this event is taken as 1.0 for the transuranic elements since an annual leach rate is used in that calculation.

(6) Same assumptions as in (3) except that the effective period is 125-600 years after closure of the repository.

(7) 0.5 There is a possibility that much of the pressure would be lost during the first borehole penetration and movement of brine to the repository. However, this could be offset by pressure from gases generated within the repository from organic decomposition or by the pressure generated from salt creep (see Appendix A).

(8) 0.4 It should be possible to cap the borehole in a period shorter than 16 hours. A shorter capping time would reduce the consequences, but not eliminate the scenario.

(9) 0.5 Either lack of knowledge of the repository or a lack of appreciation for possible radiological problems could cause the contamination to go unrecognized. However, it is possible that the unusual occurrence will result in recognition of the problem. Recognition of the problem would drastically reduce, but not eliminate radiation doses.

(10) 0.01 There is only a 6% probability that a nearby house would be located in the maximum downwind direction. The probability that any housing will occur within one-half mile of the repository is certainly less than one. Lesser doses would occur to residents located in any direction and greater distances away. Also, agricultural use of the land, without residency, would lead to lesser doses.

(11) 0.2 The area is more conducive to ranching and not self-sufficient farming. This factor would effect the ingestion dose only.

Probability Calculation Examples

The overall probability can be determined by combining the above probabilities. The calculation of events (2), (3), and (6) (which gives the probability that a borehole will hit a brine reservoir and the repository followed by a second borehole hitting the repository later) varies depending on the time frame chosen for the first hit and that chosen for the second hit. For example, to calculate the cumulative probability that a dose equal to or greater than the tc+125y inhalation dose would occur during the lifetime of the repository, it is necessary to determine the summation of:

$$\sum \ .04\ (P_i/y)t_i\ P_2/y\ [600-(t_i+25)]$$

for each year i between tc+100y and tc+500y. This cumulative probability is about 0.001.

The overall probability of this minimum tc+125y inhalation dose occurring after closure is then:

$$P_{(tc+125y\ dose)} = (1.0)\ [0.001]\ (0.5)\ (1.0)\ (0.5)\ (0.4)\ (0.5)\ (0.01)$$
$$= 5\times10^{-7} \text{ for inhalation}$$

The probability that both the inhalation and ingestion dose would occur in 5×10^{-8}. The probability that there will be some dose delivered is somewhat greater than this because several of the events [(5), (8), (9), (10), and (11)] are ones that are non-critical, i.e. they affect the magnitude of the doses assumed, not the existence of any dose. The possibility there will be some dose to either drillers, clean-up personnel, or to nearby residents or agricultural users can be estimated by setting the non-critical event probabilities to 1.0.

$$P \text{ some dose} = (1.0)\ [0.001]\ (0.5)\ (0.5) = \underline{0.00025}$$

An example of a dose that may be plausible is for an individual to reside 1/2 time at a distance of 800m in any direction from the brine pond. This would raise assumption (10) by a factor of 16 but the value would still be only 0.16 rather than 1.0. This would give a probability of 8×10^{-6} that an inhalation dose $\geq$ 0.07 or the maximum dose would occur.

Draft High Level Waste Standard

Another use of the probabilistic approach is to determine whether the release would meet the Draft EPA High Level Waste Standard for quantities of radionuclides released to the environment in a 10,000 year period. The draft standards would permit 100 Ci of ^{239}Pu, 10 Ci of ^{241}Am, and 80 Ci of ^{90}Sr to be released per 3 million curies of alpha emitting TRU wastes initially in the repository for a "reasonably foreseeable release" ($p \geq .01$ during 10,000 year period) and 10 times these amounts for a "very unlikely release" ($.01 > p > .0001$).

Since the WIPP repository is projected to have an initial inventory of 0.52 million curies of alpha emitting TRU waste, a total of 175 Ci of $^{239+240}Pu$, 17.5 Ci of ^{241}Am, or 140 Ci of ^{90}Sr would be permitted for a "very unlikely release". Combinations of these nuclides must meet the following relationship:

$$\frac{\text{Ci Pu}}{175} + \frac{\text{Ci Am}}{17.5} + \frac{\text{Ci Sr}}{140} \leq 1.0$$

When the assumed leaching rate of 10^{-4}/y for the actinides is factored into this expression it is found that the minimum leaching time necessary to exceed the standard is about 225 years. The probability that a second borehole would hit the repository 225 or more years after the first hit is about .0003. When this probability is combined with those parameters necessary to bring waste to the surface one gets.

$$P = 1.0\ (.0003)\ (0.5)\ (1.0)\ (0.5)\ (0.4) = \underline{\underline{3 \times 10^{-5}}}$$

This calculated probability is one-third of that allowed in the draft standards and (considering the crudeness of the approximation) suggests that a more refined analysis would be worthwhile.

Discussion

This probabilistic approach is a simplified one and the values chosen for some of the parameters are arbitrary (although they are considered plausible). Consequently, undue value should not be placed on the probabilities calculated in the above examples.

This approach is presented here for several reasons:

(1) A probabilistic approach is considered preferable to a consequence analysis because it gives some basis for estimating whether a scenario is reasonable or incredible.

(2) It is time to begin applying this approach to analyses of long-term releases from repositories. Hopefully, reaction to this approach will lead to a more sophisticated methodology and a sounder basis for values chosen.

(3) The approach can be useful in pointing out key parameters that need to be better quantified in order to assess the probability. For example, in this case a greater understanding of brine reservoir occurrence might change the value chosen for this probability by an order-of-magnitude or more. Or, the implementation of a positive institutional control program could reduce that probability by 1 to 2 orders-of-magnitude.

DISCUSSION

Reasonableness of Assumptions

The existence of a brine reservoir beneath the site is considered unlikely but possible. Further investigations of the brine reservoir phenomena and the structure beneath the site may significantly change the estimated probability of 4% per borehole used in this report.

In the absence of institutional control over drilling after time of closing plus 100 years, it must be assumed some exploratory drilling will occur. The values chosen for the frequency of drilling were taken from Reference 9.

The probability that a plugged borehole connecting repository and brine reservoir would result in flooding of the more permeable void space in waste storage rooms throughout the repository was assumed to be 0.5. This phenomena is reasonable, unless the repository is backfilled so that the waste storage rooms are hydraulically isolated from each other. Also, other highly permeable zones along the borehole could receive the brine before it entered the repository.

The presence of sufficient pressure to bring repository brine to the surface is another uncertainty because much pressure may be lost due to the venting of the first borehole. However, another possible source of pressure is the generation of gases in the repository from decomposition of the organic wastes. The possibility of near lithostatic gas pressures developing within a few hundred years has been estimated (Ref. 10). Also, salt creep of the backfilled area over a period of perhaps 200 years will cause pressurization of any brine present. This probability was taken as 0.5.

It should be noted that, if repository generated gas pressures develop, this scenario could occur without the presence of a pressurized brine reservoir. All that would be needed would be for water to enter the repository (from whatever sources) to be followed some years later by a single borehole into the repository. The probability of a scenario developing in this manner was not estimated.

Leaching rates of the actinides and cesium were taken from experimental work carried out on fuel fragments and borosilicate glass in various waters, including WIPP "B" brine (Ref. 2 and 11). It was assumed that CH-TRU wastes would leach at the same rate as these materials, which may or may not be conservative. Solubility considerations would probably limit the concentrations of actinides in brine to less than the tc+400y values. (Experimental solutions were typically <0.02 mg/ℓ which would have been reached in less than ten years at the assumed leaching site. However, these experiments were not carried to saturation).

The assumption that all strontium would go into solution was taken from Reference 12. The choice of a 25-year period for the reaction to occur was arbitrary.

There is a possibility that some of the leached radionuclides would become sorbed onto the 1-2% of clay present in the salt backfill, settle out of solution, and not be brought to the surface along with the brine. The percentage of radionuclides that might be removed from solution by this mechanism was not estimated.

The presence of administrative control over the site longer than 100 years after closing has not been assumed by DOE for the WIPP site. Also, both the NRC and the EPA policies are currently using the philosophy that controls after 100 years should not be relied upon.

It seems probable that knowledge of the repository would not be lost. Plans to have an extensive marker system and maintenance of records should give a high probability that drillers would know there is a repository in the vicinity. However, knowledge of the repository does not assure that drillers will forego the drilling or take the necessary precautions to minimize radiation exposure. Recent history shows numerous cases where persons who should have had knowledge of the presence and dangers of radiation acted foolishly. For example: (1) use of uranium mill tailings for household construction purposes; (2) diversion of radioactive material from a low-level waste disposal site; and (3) careless use of industrial radiography sources.

The quantity of brine (and radionuclides) reaching the surface is dependent on how long it takes to control the brine flow. At a flow rate of 20,000 barrels per day (which has been observed in nearby brine reservoirs) the assumed volume of brine would be released in 16 hours. The probability that it would take longer than 16 hours to stop the flow was taken as 0.4. This is probably conservative but is certainly not an upper limit.

No separate probability was calculated for the presence of occupational workers about the brine pond. However, if a well is developed, there will be some occupancy at the site, perhaps for several years. Also reuse of the site many years later could still result in a significant dose due to the presence of long-lived radionuclides and relatively slow removal by wind erosion.

The presence of a residence 370m away in the maximum downwind sector is of low probability. The low probability is partially because there is only a 1 in 16 probability that the residence would be located in the maximum downwind sector. However, the presence of a residence in some direction within about 1 mile of the brine pond is not considered unlikely. Inhalation doses at 1 mile would vary from 0.02 - 0.19 times those calculated here.

The existence of a full-pledged family farm at this location is considered unlikely because of the absence of economically recoverable water of good quality. However, the meat pathway exists at the site now and could be expected to continue.

Significance of Calculated Radiation Doses

General Background

At present the consensus in the health physics profession is that any radiation dose received probably has the potential to harm an individual. The possibility of harm, however, becomes very small as the annual dose received becomes less than the dose that man has always received from natural background radiation.

The relation between health effects (H.E.) and dose received (D) can be expressed by:

$$H.E. = CD^n$$

where C is a constant. If the value of n=1, the relationship is linear; if n<1 the resulting health effects are greater than for the linear condition (super linear); if n>1 the health effects are sub-linear. Most mandatory or advisory standards assume the relation is linear although many professionals believe the relationship is actually sub-linear and that the linear assumption is conservative.

Regardless of the actual shape of the response curves at low radiation doses, the following philosophies are pertinent:

(1) Radiation doses should be maintained as low as reasonably achievable because the possibility of damage even at very low levels cannot be ruled out.

(2) Annual doses received by non-radiation workers from routine (or expected) releases should be a fraction of that received from natural background radiation. Thus EPA's Uranium Fuel Cycle (40 CFR 190) and Drinking Water (40 CFR 141) Standards allow maximums of 25 and 4 mrem/y (to the whole body or any organ except the thyroid) to the population (compared to a natural background average of about 100 mrem/y.

(3) Allowable doses to nonradiation workers from accidents can be set much higher than this because an individual is not expected to receive such a dose more than once in a lifetime. Typically, guidance limits the dose to less than the lifetime dose a person would receive from natural background (e.g. 1 to 5 rem might be permitted, compared to lifetime natural background doses of 5-10 rem).

(4) Contamination of the accessible environment with long-lived radionuclides is in itself undesirable because there are many ways these nuclides can eventually get back to man. Also, contamination from multiple sources could result in a radionuclide buildup in the environment. This is the reason that limits are set on the quantities of long-lived radionuclides released in both EPA's Uranium Fuel Cycle Standard and in their draft High Level Waste Disposal Standard (40 CFR 191).

The radiation doses calculated in this report are more appropriately considered to be accidental doses because the events are not expected to happen. However, if the event were to occur and these long-lived radionuclides were brought to the surface, they could be a potential source of radiation exposure for decades or centuries. Consequently, the potential exists for a few individuals or a larger population to receive radiation doses over a number of years. For this reason, it should be recognized that these doses may not really be a one-shot event and to treat them as such is non-conservative.

Ingestion Doses

The 50-year dose commitments from one year's intake total only 0.51 rem to the whole body and 2.0 rem to the bone at 125 years after closure. While the whole body doses are high compared to those permitted from continuous exposure to routine planned releases (25 mrem/y) they are an order-of-magnitude below the suggested guidelines for a once-in-a-lifetime accident. Furthermore, since the calculated doses would decrease with the 29-year half-life of ^{90}Sr a whole body dose greater than 25 mrem/y would not occur after tc+250y. The calculated probability of this event occurring before tc+250y would be about ($4x10^{-9}$). Note that with shorter time before breach the ^{90}Sr could become more of a problem, e.g. at tc+75y the whole body 50-year dose commitment would be 1.7 rem, and for tc+50y it would be 3.1 rem.

The calculated bone dose is about 4 times the whole body dose and would not fall below the 25 mrem/y limit until about tc+310y. Also, the dose at tc+125y is within the 1-5 rem range suggested by EPA as a protective action guide for accidential releases. However, it is not reasonable to equate bone dose to whole body doses since the relative health effect ratio (H.E. whole body/H.E. bone) has been estimated to be as high as 20 (Ref. 13).

Because of the above considerations of a relatively low dose commitment and unlikely occurrence it is concluded that after tc+100y plausible doses via the ingestion pathway are not significant enough to require protective measures.

Inhalation Doses

Inhalation doses are somewhat greater than ingestion doses and have a higher probability of occurrence. Consequently, they are of greater concern than ingestion doses.

The dose to occupational workers about the brine pond at tc+400y is significant (a 50-year dose commitment of 0.30 rem to the whole body and 12 rem to the bone from one year's exposure). Since approximately 2.2% of the 50-year dose commitment from these radionuclides would be delivered in the maximum year, the maximum annual dose resulting from a tc+400y breach would be .0066 rem to the whole body and 0.26 rem to the bone. The bone dose is below permissible standards for radiation workers (5 rem/y) but is above the lower dose limits applicable to the general population and to non-radiation workers (which the drillers would be). Even though these calculated doses are undesirably high they should not be considered as hazardous, since they represent only an estimated one in 6,000 probability of inducing a fatal cancer (compared to a natural incidence of about one in 6 from all causes). Also, it is unlikely that one individual would spend more than 200 hours about the site.

The downwind 50-year dose commitment from one years inhalation at tc+400y is 0.3 rem whole body and 12 rem to the bone. If the resident was exposed for only one year the maximum annual dose delivered would be 7 mrem to the whole body and 260 mrem to the bone. The annual bone dose would remain well above any permissible standard or guideline for non-radiation workers as long as the recipient lives. Clearly this is an undesirable situation. However, the probability that the dose commitment from one year's inhalation would result in a fatal cancer to an individual is slight, only about one in 6,000.

Population dose estimates for the population within a 50-mile radius total 5.9 and 220 person-rem to the whole body and the bone at tc+400y. These doses represent a negligible hazard to any of the 154,000 individuals (projected 2010 population) in the affected population. However, if this resuspension rate continued for a period of 1500 years it would deliver a cumulative dose to a stable population about 480 times the first year dose. This would result in cumulative doses of about 110,000 person-rem to the bone and 2,800 to the whole body and might result in 1 or 2 fatal cancers. However, it is unlikely that all of the material would be resuspended; most studies show that significant amounts of material become fixed or migrate int the soil.

These consequences are small when one considers the large number of persons involved and the number of generations over which any health effect would occur. For example, a stable population of 154,000 persons would be expected to incur over 500,000 cancer deaths in 1500 years if present cancer mortality rates continue. Obviously, any health effect that actually did occur would not be visible among the much more prevelant effects from other causes.

Nonetheless, the presence of significant undetected contamination remaining on the surface for long periods of time must be considered as undesirable and precautions should be taken to minimize its occurrence. This concern comes from the realization that over a period of several hundred years large numbers of persons could come and go about the site and within the 50-mile radius. Prediction of all the human activity that might be impacted by the contamination would be very speculative. For these reasons steps should be taken to avoid situations where significant surface contamination could exist for decades without detection and remedial action.

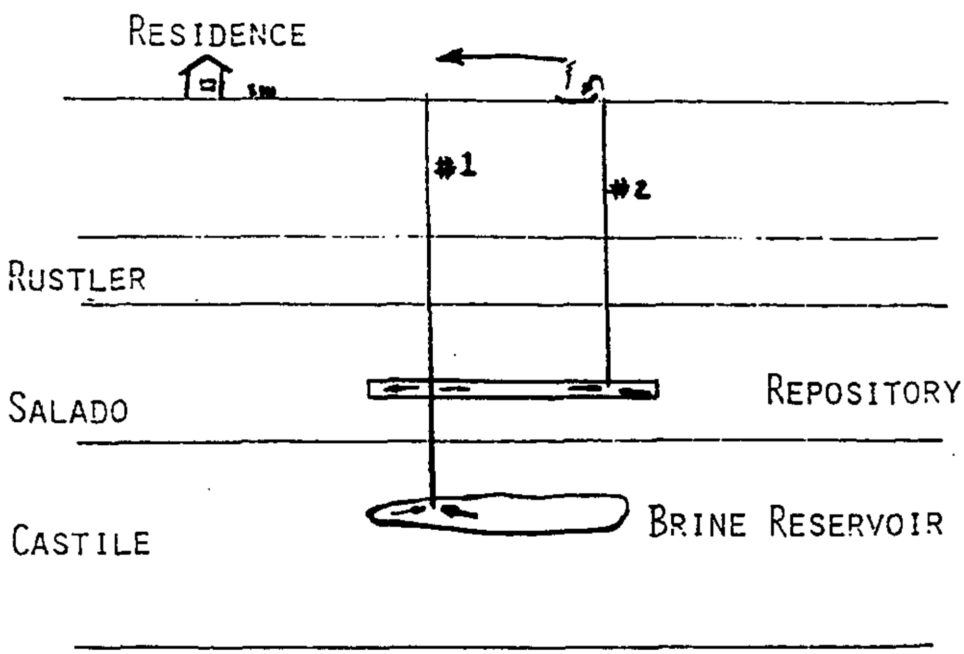

FIG. 1. SCHEMATIC OF SCENARIO

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APPENDIX A

REPOSITORY PRESSURIZATION CONSIDERATIONS

Key assumptions in this scenario are that brine would be able to flow into the repository and would be under sufficient pressure to enable it to flow to the surface in the event a borehole penetrated the backfilled area. This appendix examines several mechanisms that affect this assumption.

Initial Brine Reservoir Pressure

If the initial borehole through the repository struck a brine reservoir that was under near-lithostatic pressure (which have been observed in nearby brine reservoirs) there would be sufficient pressure to infiltrate the repository (after the well was capped) if the pore space were not under greater pressure at the time. Since it is presumed the borehole will be sealed down to the brine reservoir level within a few weeks, any infiltration would have to occur during this interval.

The brine would not occupy all pore space even if the inflow from the brine reservoir were completed before sealing the well. This is true for several reasons:

(1) The initial gas in the repository, even if at atmospheric pressure, would become pressurized as it was being reduced in volume and would eventually equal the pressure of the inflowing brine.

(2) A portion of the inflow would be dissolved gases rather than brine.

(3) The pressure in the brine reservoir would drop significantly as the reservoir expands into the repository. Also, the size of the brine reservoir may be limiting.

(4) Prior pressurization may exist in portions of the repository either from salt creep or from organic decomposition of the wastes (see discussion below).

From the above considerations it is concluded that while some brine inflow to the repository is reasonable, it will not be sufficient to fill the entire pore space of the repository. However, it is difficult to relate this conclusion to the degree of conservatism in the scenario since none of the dose assumptions directly address the effect of brine-to-waste ratios, fraction of repository saturated, etc.

Pressurization by Salt Creep

Arthur D. Little, Inc. estimated that in a site with favorable salt creep characteristics the pore space of backfilled material would decrease linearly with time to approximately zero in about 200 years. A site with unfavorable salt creep characteristics might require 1000 years to decrease to zero (Ref. 9).

Assume that: (1) salt creep is the only pressurization mechanism; (2) the time for closure is 200 years and the rate is linear; (3) initial gas pressure in the pore space is 1.0 atmospheres; (4) pressurization of the gas is inversely proportional to original volume; and (5) the brine reservoir inflow pressure is 80% of lithostatic (.8 x 140 = 112 atmospheres). Brine inflow to the repository would continue until the final pore volume was 1/112 (0.0089) of the original. This inflow would have to occur before about tc+190y in order for a significant portion of the voids to be filled with brine. Therefore if salt creep is the dominant pressurization mechanism, the first borehole must strike the brine reservoir and bring brine into the repository during the period 100-190 years after repository closure. Pressurization above the 0.5 (lithostatic pressure) level (which is required to bring saturated brine to the surface) might persist for 100-200 years, depending on the gas permeability of the surrounding salt.

Pressurization From Organic Decomposition

The possibility of significant gas buildup in the WIPP repository due to decomposition of organic materials in the waste has been predicted (Ref. 10). Assumptions were made that gas generation would occur for 400 years, then cease abruptly. The generation of gas will slow down or stop the closure of the repository due to salt creep during the time of operation. The pressure in the repository at equilibrium depends on the permeability of the salt formations. In the more feasible ranges of 0.5 - 5.0 μdarcy (the only 2 measured values being 11 and 21 μdarcy) the pressure during the period from about 100 to 400 years varied from about 2/3 to 1/4 lithostatic pressure. After 400 years the pressure drops off exponentially with a half-life of about 100 years (see Figure A-1).

If gas generation is the dominant mechanism, it appears that the pressure in the repository during the period from 100 to about 500 years could be both low enough to permit brine to flow into the repository and high enough to bring brine to the surface. Salt creep between tc+500 years and tc+600 years would probably maintain sufficient pressure to bring brine to the surface.

Conclusions About Repository Pressures

1. It is reasonable to assume that void space in the repository could be present during the period of 100 to 500 years with low enough gas pressure to permit at least partial flooding by a brine reservoir.
2. It is reasonable to assume that sufficient gas pressure may exist in the repository from the period 100 to 600 years to bring some brine to the surface in the event the flooded repository is struck by a second borehole.
3. The probability that brine under sufficient pressure to reach the surface will exist in the repository becomes less likely as post-closure times increase past 600 years.
4. The limited "time window" in which the necessary pressures might exist, decreases the probability of such an event occurring at all and makes the occurrence of this scenario at 1000 years after closure highly improbable.

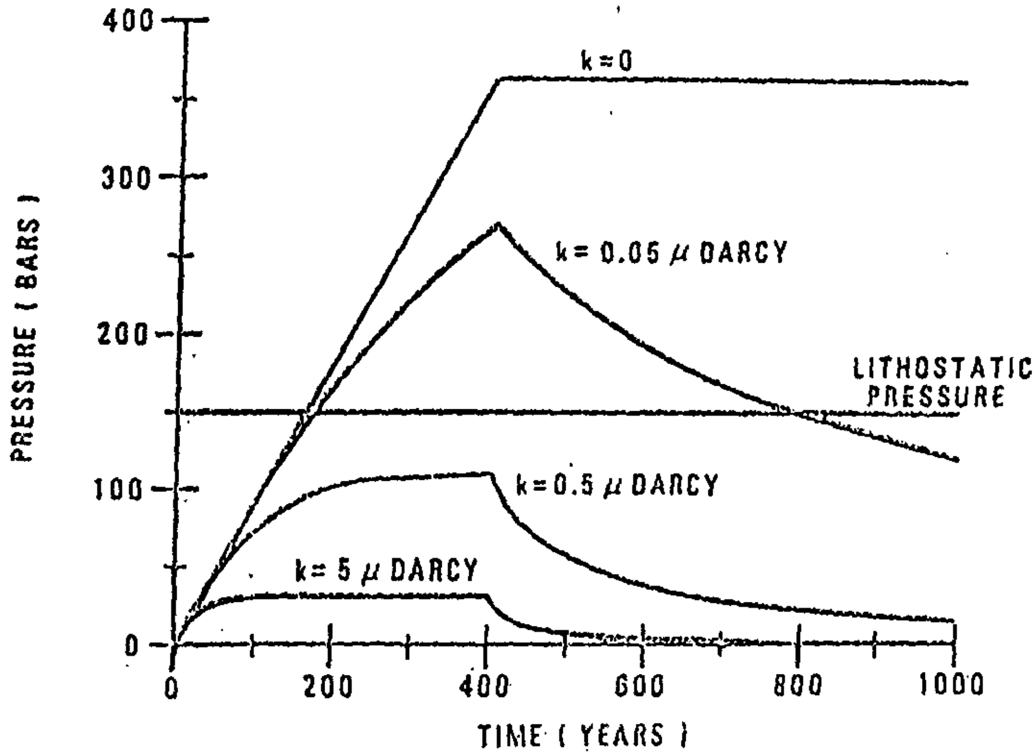

FIGURE A-1 ONE DIMENSIONAL DRIFT GAS PRESSURE FOR FOUR PERMEABILITIES

(Figure 3-13 from Reference 10)

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ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-12

EEG-12

NEW MEXICO
HEALTH AND ENVIRONMENT
DEPARTMENT

POTENTIAL RELEASE SCENARIO AND RADIOLOGICAL CONSEQUENCE EVALUATION OF MINERAL RESOURCES AT WIPP

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Environmental Improvement Division
Health and Environment Department
State of New Mexico

May 1982

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Environmental Evaluation Group
Reports

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Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP

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May, 1982

CONTENTS

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site, the design of the repository, its planned operation, and its long-term stability. These analyses include assessments of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

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INTRODUCTION

In providing a technical evaluation of the potential radiation doses and health effects resulting from the nuclear waste repository (Waste Isolation Pilot Plant) being considered for southeastern New Mexico, the Environmental Evaluation Group attempts to consider all credible pathways of exposure of the population to the waste, including those events which might occur long after the repository is sealed, controls over the site are abandoned and records are lost. Some of these potential long-term breach events were considered by the U.S. Department of Energy in its Final Environmental Impact Statement and in other reports (Refs. 1, 2, and 3), and it was pointed out that these events might be associated with exploration or mining of the important resources located at the site. EEG evaluates the radiological health consequences of these and other scenarios which may reasonably be expected to lead to release of the waste to the biosphere. The DOE has considered the following long-term breach scenarios, all of which might arise as a result of exploration or mining of the resources at the site, or from certain natural geologic events:

Scenario 1: A hydraulic communication connects the Rustler aquifers above the repository, the Bell Canyon aquifer of the Delaware Mountain Group below the repository, and the repository.

Scenario 2: A hydraulic communication allows water to flow from the Rustler, through the repository, and back to the Rustler.

Scenario 3: A stagnant pool connects the Rustler aquifers with the repository. In contrast to scenarios 2 and 3, which involve flowing water, this communication permits radionuclide migration to the Rustler only by molecular diffusion.

Scenario 4: A hydraulic communication connects the Rustler aquifers with the repository; all the Rustler water normally moving above the repository flows through the repository and back to the Rustler. In contrast, scenarios 1 and 2 establish only a limited hydraulic connection.

Scenario 5: A drill shaft penetrates the repository and intercepts a radioactive waste container; the radioactive material is brought directly to the surface.

This report discusses the implications of the above scenarios which might arise as a result of exploration or mining of resources. The first four of the foregoing scenarios involve a liquid breach of the repository and transport of the dissolved waste through the Rustler aquifer, above the repository, to the Pecos River at Malaga Bend. Only Scenario 5 brings a fraction of the waste to the surface at the WIPP site. The DOE has concluded that scenario 5 provides a worst-case consideration of transport of the waste to the surface, and does not consider a breach of the repository from the mining of halite as credible.

EEG agrees that (1) the shortage of water and processing facilities for salt in the area, (2) impurities present in the salt of the Salado, and (3) vast amounts of salt available in other areas of the U. S. lead one to conclude that the salt at the WIPP site could not be economically extracted in the foreseeable future. However, EEG believes that significant climatic and social changes could make such mining more plausible. Therefore this report analyzes the potential radiological consequences of solution mining of halite 250 years after decommissioning. The report also discusses the reasons why solution mining of potash or drilling for natural gas are believed to be bounded by other scenarios considered by DOE in the Final Environmental Impact Statement (Ref. 2).

SUMMARY

This report has reviewed certain of the natural resources which may be found at the site of the nuclear waste repository being considered for southeastern New Mexico, and discussed the scenarios which have been used to estimate the radiological consequences from the mining of these resources several hundred years after the radioactive waste has been emplaced.

It has been concluded that the radiological consequences of the mining of potash or hydrocarbons (mostly natural gas) are probably bounded by the consequences of hydrologic breach scenarios already considered by the U. S. Department of Energy, (Ref. 2), and by reports of EEG (Refs. 4, 5). These studies conclude that the resultant doses would not constitute a significant threat to public health.

This report also evaluates the radiological consequences of solution mining of halite at the WIPP site. Although such mining in the Delaware Basin and particularly at the WIPP site, is not likely at the present time, significant economic, social or climatic changes a few hundred years after emplacement may make these resources more attractive. The DOE did not consider such mining at the site credible (Ref. 2, p. 9-145).

The fifty-year individual dose commitment from the ingestion of the average adult consumption of salt (contaminated with the radioactive waste from the repository) was 72 millirems for one year. This might be compared to an average lifetime dose from natural background radiation of 7500 millirem. Assuming that 0.2% of the radioactive inventory was mined and contaminated the salt during the solution mining event, and that about 2.5% of the total salt was consumed in food products, the total whole body dose to a population at risk of 300 million would be 0.9 million person-rems. This represents about 0.06% of the 50 year dose commitment from natural background. Although this population dose may not be considered insignificant, the small probability of such an event, and the very conservative assumptions used would lead one to conclude that the risk of such an event is small.

It is unlikely that the small doses resulting from this solution mining breach event would produce any detectable biological effects. It is possible that the long term consequences would be an increase in the normal incidence of cancer in the population, but such an increase would be within the range of statistical variation. Based on the recent conclusions of the National Academy of Sciences BIER Committee (Ref. 5, Table V-3) the total risk of such cancers would be about 0.32 fatal cancers per million population over the 50 years. This can be compared with the current incidence of 167,000 cancers per year per million population, or 8.35 million cancers over 50 years.

NATURE OF RESOURCES AT WIPP SITE

Mineral resources at the site include potash in the form of the potassium salts, sylvite and langbeinite; hydrocarbon resources, which, if present, may include crude oil, but mostly natural gas and distillate (liquid associated with natural gas). The potassium salts are found in strata 400 to 700 feet above the repository which is 1400 to 1700 feet below the surface; the hydrocarbons most likely would be found 8,000 to 12,000 feet below the repository which is 10,000 to 15,000 feet below the surface. Although other minerals such as salt, caliche, and gypsum are also in this area in quantity, there are enormous quantities in many other areas. Of these only halite is in close enough proximity to the repository to warrant considertion of a breach scenario. The size and economic value of potash, halite and hydrocarbons which may exist at the WIPP site are summarized below:

(a) Potash

Potash resources were estimated by the U.S. Geological Survey (USGS), the U.S. Bureau of Mines (USBM), and Agricultural and Industrial Minerals, Inc. (AIM) (Refs. 7, 8, and 9). In reference to potash, the terms "resources," and "reserves" as used here are defined as follows:

> Resources are considered minerals that are currently or potentially of economic value; this includes seams that are thicker than 4 feet and contain sylvite or langbeinite with a potassium oxide richness greater than 8% or 4% respectively.
>
> Reserves are the portion of the resources that are economically recoverable at today's market prices and removable with existing technology; this includes seams that are thicker than 4 feet and contain sylvite or langbeinite with potassium oxide richness greater than 13% or 9% respectively. The current estimates of resources and reserves under the four zones of the WIPP site are shown in Table 1.

TABLE 1

POTASH WITHIN WIPP SITE*

Deposit	Resources (million tons)	Reserves (million tons)	% of Resources recoverable in Zone IV	% of Reserves recoverable in Zone IV
Sylvite	133	27.4	71	100
Langbeinite	351	48.5	65	73

Since the surface value of mined potash ore at the present time is about $15/ton, the total surface value of the reserves is about $1.14 billion. The in-place value of the ore is much less, but more difficult to estimate. The U.S. Department of Energy has estimated in-place value of the potash ore as 14 cents per ton for sylvite and 5 cents per ton for langbeinite (Ref. 2, Table 9-16). The DOE has stated that mining in Zone IV of the WIPP site is possible without adverse impact on the proposed repository (Ref. 2, p. 9-118), and such recovery may be allowed before decommissioning. If this is the case, then 83% of the potash reserves (100% of 27.4 million tons of sylvite and 73% of 48.5 million tons of langbeinite) would be authorized for removal.

The Department of Energy has considered the impact of several mechanisms of liquid breach of the repository and transport of the radionuclides to the Pecos River at Malaga Bend (Refs. 1, 2, 3 and 10), or to a well in the Rustler, located about three miles downstream from the repository (Ref. 10). The EEG has independently calculated doses resulting from the transport of the radionuclides to Malaga Bend or to a well following a liquid breach and agrees that the doses would represent only a small fraction of the natural radiation background, even if very conservative (designed to increase severity) hydrologic parameters are assumed (Refs. 4, 5). Therefore, if the mining of potash leads to a liquid breach with transport of radionuclides to the Rustler at the WIPP site, the results would be bounded by the long-term scenarios

*This table is adapted from Table 9-19 of the FEIS (Ref. 2).

already considered. Because the potash ore is located at least 400 feet above the repository horizon, it is likely that the ore could be removed by conventional techniques without disturbing the repository; however EEG has requested that DOE provide a detailed plan and consequence evaluation if the decision is made to allow such removal.

Solution mining of the potash is not economical in the area because of the limitation of suitable water, absence of processing facilities and thinness of the ore beds. However, if water and facilities did become available, and solution mining were attempted, it is likely that the potash could be successfully solution-mined without breach of the repository during the operation. Nonetheless, such techniques near a nuclear repository might constitute a risk because the liquid-filled caverns may weaken the formations leading to breach after thousands of years, possibly resulting in transport of the radionuclides to one of the underground aquifers (Ref. 11).

To remove the potash ore by solutioning or brining techniques involves drilling two or more large diameter wells to the ore zone, establishing a circulation between the wells through hydrofracturing or hydrocarbon padding and recovering the dissolved brine. Because these ores are found in quantity considerably above the repository horizon, it is not plausible to believe that the hydrofracturing and brining would accidently extend 400 feet down into the repository horizon, unless some pathway already existed. The presence of horizontal clay seams in the salt would tend to move the hydrofractures up or horizontally along the clay seams, and current techniques permit shaping of the cavern to follow closely the ore horizon (Refs. 12, 13, 14, 15). If abandoned drill holes were present in the area and extended down into the repository, the effect of such a communication would be readily detected because of the retarding effect of such undesirable hydraulic communication on the solutioning of the potash ore. (The returning solution generally is monitored for potassium content.) For these reasons, a breach associated with potash mining resulting in transport of the radioactive material to the surface is not considered credible.

(b) Solution Mining of Halite and Consequence Analysis

Dickinson estimates that halite (sodium chloride) production in the U.S. for a variety of applications is over 40 million tons per year, valued at $300 million. Another 20% or more of salt is being imported from Canada, Mexico, and to a lesser extent, from other countries (Ref. 16).

There are extensive deposits of bedded halite in many areas of the Delaware Basin. The thickest and purest salt beds at the site are found in the Castile, although the Salado contains from 80 to 90% halite. The New Mexico Bureau of Mines and Mineral Resources has estimated that there are 118 billion tons of salt in the Salado within the WIPP boundary (Ref. 17). The Castile formation would add approximately 80 billion tons of additional salt resource. Along with gypsum and caliche, the halite deposit was not considered by the DOE to have any economic significance, because of the prevalence of salt deposits throughout the Permian Basin and other areas within the United States (Ref. 18). Because of the purity, domed salt usually is preferred to bedded salt. Approximately 56% of the halite produced in the United States is derived from the salt domes of Louisiana and Texas (Ref. 14). Within the Permian Basin, salt is being recovered by mechanical or solution-mining techniques at locations in Kansas, Texas and southwestern Oklahoma. No mining of halite has occurred in the Delaware Basin, and commercial mining is not considered economical in the WIPP area in the near future, because of the shortage of water, the remote location of the site from processing facilities and the presence of anhydrite and polyhalite beds intermingled with the bedded halite formations. It is conceivable, however, that in the long-term, climatic and social changes may render these deposits more attractive. For example, in the United States during the Pleistocene epoch, 1 to 2 million years ago, several lakes were formed or expanded during periods of increased precipitation, especially in the western United States in areas that are now deserts (Ref. 10, Sec. 2.3.4.1).The climate of New Mexico during such periods was characterized by more precipitation (about 60% more than at present), less evaporation (only about 70% of present) and a mean June - September temperature about 18°F lower than at present. Flooding was probably more frequent. Given greater access to water, there would be increased probability that industry supportive of solutioning techniques would be available to the area. Therefore, although mining of halite at the WIPP site is considered highly unlikely, it is sufficiently plausible to warrant evaluation of the potential radiological consequences of a breach resulting from this activity.

This is considered in the following way. It is assumed that a commercial brining operation is initiated 250 years after decommissioning, directly over the 100 acres which house the abandoned repository. Initial exploratory and drilling operations fail to detect the repository, and two or more wells are drilled to produce hydraulic fracturing and to establish solutioning of salt. A cavern in the Salado is produced of approximately one million cubic feet, and the dissolved brine is routed to a nearby chemical processing plant for removal of the salt and recycling of the reconstituted unsaturated water. It is assumed that the radionuclides dissolve at the same rate as the salt, and that 0.2% of the 100 acre column of the Salado salt is removed by brining. Any more than this fraction might lead to some collapse of the overlying formations. It also would be reasonable to assume that detection of radioactive impurities occurred after 1 year. The scenario is illustrated by a typical cavern as shown in Figure 1. The radionuclide inventory at 250 years after storage is shown in Table 3.* Table 4 provides the resultant whole body dose from ingestion of the contaminated salt for a period of 1 year (1800 gms).

The 50-year individual dose commitment provided in Table 4 is considered conservative for at least two reasons: (1) It assumes the ingestion of 1800 gms of the unrefined salt extracted entirely from the solution mining breach event described. In other words, the salt is undiluted with other salt obtained from uncontaminated sites. (2) It neglects the potential reduction of plutonium contamination which is likely to occur as a result of adsorption to the clay constituents of the Salado, as follows:

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*This inventory is calculated from the initial inventories of TRU waste provided in Tables 3.1-2, and 3.1-4 of the SAR (Ref. 10).

To a rough approximation, the distribution of radioactivity between brine and suspended solids is given by

$$C_s = K_d C_\ell \qquad (1)$$

C_s = concentration per unit mass of a given nuclide sorbed on solids, Ci/gm

C_ℓ = concentration per unit volume in the liquid phase, Ci/mℓ

K_d = distribution coefficient, mℓ/gm

As the water dissolves the repository, conservation of activity also is maintained. This is expressed by the following equation

$$m_s C_s + C_\ell = A \qquad (2)$$

m_s = mass of solid in volume of repository suspended by a unit volume of H_2O (gm/ml)

A = activity in volume of repository dissolved or suspended by a unit volume of H_2O. C_s and C_ℓ are as previously defined. Combining equations (1) and (2) one obtains

$$C_\ell = \frac{A}{m_s K_d + 1} \qquad (3)$$

$$C_s = \frac{A K_d}{m_s K_d + 1}$$

Equation (3) can be interpreted as follows:

Of the activity, A, leached by a unit volume of water (assuming the saturated brine contains total dissolved solids of 0.4 gm/ml), a fraction

$$\frac{1}{m_s K_d + 1}$$

remains in the water and a fraction

$$\frac{m_s K_d}{(m_s K_d + 1)}$$

is resorbed on the suspended clay freed by the brining of the water. If 5% of the Salado is material other than salt, and 1% of this material is clay for which K_d for Plutonium can range from 40,000 to 180,000 mℓ/gm (Ref. 10, Table 2.5-12); then m_s is 2×10^{-4} gm/mℓ and between 90 to 97 percent of the Plutonium is resorbed on the clay. The clay in the Salado is thus an effective barrier against bringing plutonium to the biosphere.

An important question that must be resolved is what fraction of the insoluble material is brought to the surface as suspended particulates and what fraction remains in the subsurface cavity.

In summary, therefore, the 72 millirem individual fifty-year dose commitment might be compared with normal background radiation of about 100 millirem each year, or a lifetime dose of about 7,500 millirem. The total population dose may be conservatively estimated by assuming that each member of a population of 300 million consumes 1800 gms of salt per year. It also is assumed that 1/24 of this salt for food is derived from this solution mining event. (If the annual production in the nation is 48 million tons, only about 1/50 of a year's production is consumed as food.)

Based on one year's production of the contaminated salt, the total population 50-year dose commitment would be 0.9 million person-rems. This might be compared to a background 50-year dose commitment of about 1.5 billion person-rems. Therefore, there would result from this breach event a 0.06% increase over background.

It might be of interest to compare these results to those obtained from a halite solution mining scenario involving a salt dome (Ref. 19). That scenario assumed a breach 1000 years after emplacement and a total of 2.6 million tons mined from nine wells over a period of one year. It was assumed that three percent of this salt was consumed as food (1800 gms/individual). The resulting 70-year whole-body dose commitment, for spent fuel nuclear waste, was 390 millirems, and for reprocessed high-level waste the dose was 100 millirems. This was converted into a 70-year total population dose commitment of 16 million person-rems from spent fuel, or four million person-rems from reprocessed waste.

It is unrealistic to assume a production rate at the WIPP site in excess of one million tons/year, because of the water limitations in the area - even if much more favorable climatic conditions occurred. Assuming an average flow of the Pecos of 2000 liters/second, the fresh water required for mining of one million tons/year is about equal to four percent of the total annual Pecos flow.

If solution mining of halite should occur in the WIPP site area at some time after termination of controls, it is likely that the scenario considered in this report provides the upper limit of dose consequences from solution mining at WIPP for the following reasons:

1. Most of the transuranic nuclides would probably be bound to the clay impurities in the salt formation and would not be contained in the processed and purified salt.
2. The limitation of fresh water in the area, even under conditions of favorable climatic change, is likely to discourage solution mining of salt because of the large reserves in other areas more accessible to water.
3. Because the salt is located at considerable depth, solution mining would require high technology to achieve economic return, and such technology would be expected to include the ability to recognize and remove radioactive impurities, if present.

Health Effects of Radiation Consequences

It is unlikely that any adverse health effects would occur from small doses resulting from the present scenario. If the 900,000 person-rems are assumed to be uniformly spread over the population of 300 million. The average 50 year dose would be only 3 millirems. Such doses are far too low to produce detectable effects. Using the data provided in the most recent report of the National Academy of Sciences BIER Committee (Ref. 6, Table V-3) and using a linear extrapolation from dose-effect curves provided by high doses, there would be about 96 fatal cancers resulting from this population dose over the 50 years, or 0.32 per million population. These values should be compared to the current cancer risk of 167,000 per million population per year, or 8.35 million cancers over 50 years.

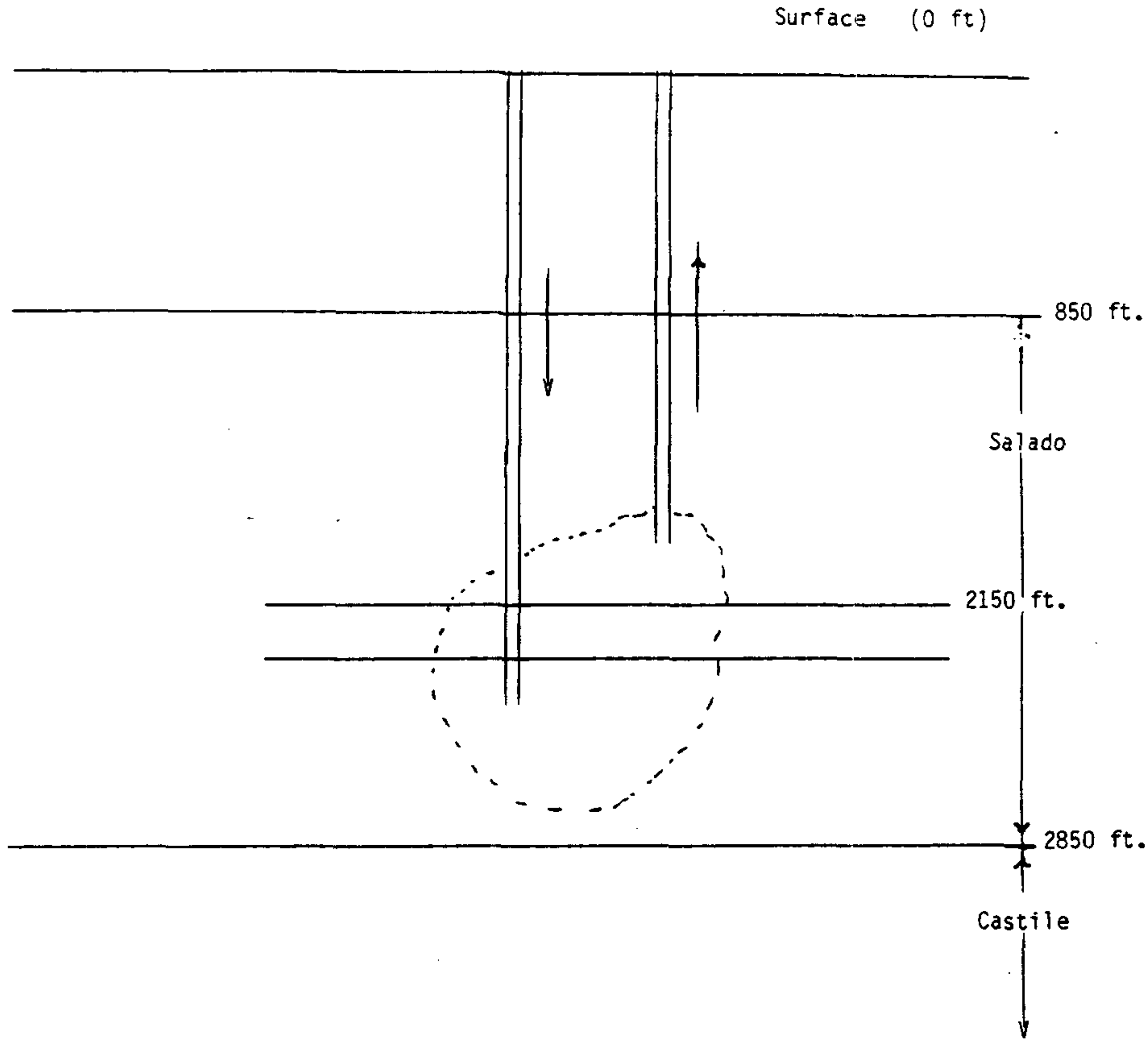

Figure 1. Breach of repository from solution mining of halite.

TABLE 2

PARAMETERS FOR SOLUTION MINING (BRINING)
OF HALITE SCENARIO

1. Area of Repository Site: 100 acres
2. Thickness of Salado Salt at Site: 2000 ft. (600 m)
3. Volume of Salt ore under 100 acres of the Salado at site: 8.7×10^9 ft^3 (2.5x10" ℓ)
4. Volume of CH waste: 1.7×10^8 liters
5. Volume of RH waste: 7.1×10^6 liters
6. Volume of repository: 5.2×10^7 ft^3 (1.5×10^9 ℓ)
7. Fraction of salt which is repository: 6×10^{-3}
8. Fraction of repository which is CH waste: .113
9. Fraction of repository which is RH waste: .0047
10. Production rate: or 1×10^6 metric tons of solid salt/year (1.6×10^7 ft^3)
11. Fraction of total Salado at WIPP site removed by brining in 1 year: 0.002
12. Volume of salt in the Salado under entire area of WIPP site (Zones 1, 2, 3, 4): $4.6 \times 10^{13}\ell$ (1.6×10^{12} ft^3)
13. Density of recovered and dried salt: 2.2 gm/ml
14. Annual Adult Consumption of salt: 1800 gms
15. Total population at risk: 300 million

TABLE 3

NUCLIDE INVENTORIES OF TRU WASTE AT 250 YEARS

Nuclide A	CH TRU (Ci/ℓ) B*	CH TRU Total (Ci) C*	RH TRU Ci/ℓ D*	RH TRU Total (Ci) E*	Final Total (Ci) F*
Pu-238	2.9 - 5**	4.9 + 3	1.2 - 5	8.5 + 1	5.0 + 3
Pu-239	2.2 - 3	3.7 + 5	1.1 - 3	7.8 + 3	3.8 + 5
Pu-240	5.2 - 4	8.8 + 4	2.4 - 4	1.7 + 3	9.0 + 4
Am-241	3.3 - 4	5.6 + 4	2.0 - 4	1.4 + 3	5.7 + 4
Sr^{90} + d			1.4 - 3	1.0 + 4	1.0 + 4
C_s^{137} + d			1.1 - 5	80.	80.
				Total	5.4 + 5

*Explanation of columns:

B = Average inventories from SAR at 250 years

C = (B) (1.7×10^8 liters)

D = Average inventories from SAR at 250 years

E = (D) (7.1×10^6 liters)

F = C + E

**2.9 - 5 = 2.9×10^{-5}

TABLE 4

FIFTY-YEAR DOSE COMMITMENT FROM ONE YEAR'S INGESTION OF SALT

Nuclide G	Concentration PCi/gm of salt H*	Dose (50 yr.) Commitment (mrem per Pci) I*	Whole Body Dose/ (mrem) J*
Pu-238	8.9	1.7 - 5	.27
Pu-239	7.0 + 2	1.9 - 5	24.0
Pu-240	1.7 - 2	1.9 - 5	5.8
Am-241	1.0 + 2	5.4 - 5	10
Sr^{90} + d***	1.9 + 1	9.3 - 4	32.
C_s^{137} + d	1.4 - 1	3.6 - 5	.009
		Total:	72

*Explanation of columns:

$$H = \frac{(F)\ (10^{12})\text{pCi/Ci liter}}{2.5 \times 10^{11} \text{ liters} \times 2200 \text{ gm}}$$

I = NUREG 0172 dose conversion factors (Ref. 20)

J = (H) (I) (1800)

**7.0 + 2 = 7.0×10^2

***d = including daughters

(c) Hydrocarbons

The New Mexico Bureau of Mines and Mineral Resources (BMMR) evaluated the hydrocarbon resources at the earlier WIPP site, about five miles northeast of the current site (Ref. 17). This evaluation was based upon known reserves of crude oil and natural gas, and on the probability of discovering new reservoirs. The estimate of natural gas was 16.5 billion cubic feet per 640 acres, which amounts to a total of 490 billion cubic feet for the present site. Since the hydrocarbon estimate relies on statistical probabilities, this value would not be as accurate as the potash values. This volume also assumes that the quantity of hydrocarbon resources at the current WIPP site are about the same as at the old site, five miles away. A later evaluation of hydrocarbon resources of the present site was made by Sipes, Williamson and Aycock, Inc. (Ref. 21), in which they relied on information gained from nearby exploration. To protect the site no hydrocarbon drilling has occurred in Zones I, II, and III of WIPP. The area evaluated was 400 square miles centered on the present site. They concluded that a single zone, between 14,000 and 15,000 feet below the surface is worthy of exploratory risk, based on current economic considerations. Only natural gas is estimated to be present in quantities that are economical. The potential resources and reserves of natural gas are summarized in Table 5.

TABLE 5

POTENTIAL NATURAL GAS WITHIN WIPP SITE

	Total BCF*	In Zones I, II III BCF*	In Zone IV BCF*
Resources 100%	490 (100%)	211 (43%)	279 (57%)
Reserves	44.6	21 (47%)	23.6 (53%)

*BCF = billion cubic feet

At a value of $4.40/1000 cubic feet, the total surface value of the natural gas reserves is about $200 million.

Sipes, Williamson, and Aycock, Inc. have also evaluated the extra cost of extracting the natural gas through directional drilling. If drilling is allowed in Zone IV, 23 directional boreholes from the boundary of Zone III would be necessary to extract the natural gas from Zone I, II, and III (Ref. 22).

The DOE has considered the radiological consequences of drilling for hydrocarbons and drilling directly through a canister containing either contact-handled or remote-handled TRU waste (Ref. 2, p.9-143). Since the hydrocarbons, if present, are located 8,000 to 12,000 feet below the repository, a breach of the repository as a result of extraction of these resources would be bounded by either the liquid breach or direct drilling scenarios already considered in the FEIS.

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ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-22

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EEG-22

NEW MEXICO
HEALTH AND ENVIRONMENT
DEPARTMENT

EEG REVIEW COMMENTS ON THE GEOTECHNICAL REPORTS PROVIDED BY DOE TO EEG UNDER THE STIPULATED AGREEMENT THROUGH MARCH 1, 1983

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

April 1983

Environmental Evaluation Group
Reports

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EEG Review Comments on the Geotechnical Reports Provided by DOE to EEG Under the Stipulated Agreement Through March 1, 1983

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
P.O. Box 968
Santa Fe, New Mexico

April 1983

CONTENTS

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site, the design of the repository, its planned operation, and its long-term stability. These analyses include assessments of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

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INTRODUCTION

As part of the Stipulated Agreement signed on July 1, 1981 between the Department of Energy (DOE) and the State of New Mexico, the DOE agreed to provide the following reports to the State of New Mexico to help in the State's evaluation of the suitability of the WIPP site.

Deep Dissolution
Disturbed Zone
Breccia Pipes
DMG Hydrology
Regional Hydrology
Natural Resources
Results of SPDV Site Validation Experiments
Plans for SPDV Design Validation
Results of SPDV Design Validation Experiments
Plans for Simulated Wastes Experiments
Brine Reservoir Report
Horizontal Exploration of the Disturbed Zone
Fracture Flow in the Rustler Aquifers
Study of Aquifer Characteristics

The Environmental Evaluation Group had received the following reports in draft form by March 1, 1983:

Deep Dissolution
Breccia Pipes
DMG Hydrology
Natural Resources
Plans for SPDV Design Validation
Plans for Simulated Waste
Brine Reservoir Report
Disturbed Zone Exploration
Fracture Flow in the Rustler Aquifers

This publication is a compilation of the written comments on each of these reports provided by EEG to DOE. Where DOE responded to EEG comments in writing, they are included here. On others, meetings were held between the appropriate EEG staff and the author(s) of the reports and the authors agreed to make changes in the final version of the reports, based on EEG comments. Only in the case of Breccia Pipe report prepared by the U.S. Geological Survey for DOE, no changes were made in the final version of the report.

EEG's conclusions on each of these issues will be provided in a forthcoming EEG report to be published in May, 1983.

NATURAL RESOURCES

TME-3156

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

NOV 03 1981

Dr. George S. Goldstein
Chairman
Governor's Task Force on WIPP
P. O. Box 968
Santa Fe, NM 87503

Dear Dr. Goldstein:

Interim Policy Statement on Resource Recovery at the WIPP Site

Enclosed for your information is the Department of Energy's Interim Policy Statement on Resource Recovery at the Waste Isolation Pilot Plant (WIPP) Site. The interim policy will be used as the basis for the performance of dose consequence analyses related to resource recovery at the site as required by Item 6 of Appendix "B" of the Stipulated Agreement. This interim policy may be amended based upon the results of the analyses currently being performed and expected to be available in December, 1981.

Should you have any questions, please contact us.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 81-5046

Enclosure

cc w/enclosure:
See Page 2

INTERIM POLICY STATEMENT

By

U.S. Department of Energy

Resource Recovery at the Waste Isolation Pilot Plant Site

The primary concern of the U.S. Department of Energy (DOE) in the development of the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico is both the short and long-term protection of public health and safety. As a major element of this policy, the DOE has delineated buffer zones around the WIPP Site in which resource recovery will be strictly controlled or prohibited (Figure 1). The incorporation of multiple buffer zones in the present design is a conservative approach to maintaining the integrity of the site and ensuring that emplaced wastes remain isolated from the environment. The DOE recognizes, however, that the state of New Mexico relies upon the royalties generated from resource recovery as a significant source of revenue and that other adverse economic and social impact may result if access to the resources at the WIPP Site is permanently denied.

Accordingly, the DOE is issuing this Interim Policy Statement on resource recovery at the WIPP Site to clarify its present position relative to those resource extraction activities that the DOE believes may eventually be allowable within various portions of the WIPP Site. This interim position is based on the previously conducted long-term waste isolation assessment that utilized all available site geologic, hydrologic, and other pertinent data.

It is the policy of the DOE to maximize the opportunity for resource recovery at the WIPP Site, consistent with the requirements to isolate the emplaced radioactive wastes from the biosphere. The interim policy is temporary denial of all resource extraction within the four control zones of the WIPP Site until the decision is made relative to which, if any, of the emplaced waste will be retrieved. Within five years after the first emplacement of each type of waste (i.e., contact and remotely handled), separate decisions will be made about the retrieval of each kind of waste. Should DOE decide that all waste is to be retrieved, the site will be available for complete resource recovery. As an additional part of the interim policy, the DOE is currently undertaking analyses to identify the potential for possible radiation dose consequences of resource development within Control Zone IV of the WIPP Site. The interim and final Statements of Policy will be revised to include additional detail if the results of these studies indicate that the allowable extraction activities could cause an unacceptable hazard to the public health and safety.

The criteria for the final DOE policy is that permanent denial of resources should be limited to those areas in which extraction activities could potentially lead to radiation dose consequences or which are necessary to satisfy institutional requirements; with the exception of those areas required by insitutional considerations, all extraction activities that would not lead to unacceptable effects with the waste permanently emplaced will be defined as "allowable" under the anticipated final DOE policy. From a radiation dose consequence point of view, the timing of resource extraction activities is not critical; the radioactive wastes decay very slowly so that minor differences in waste age do not affect the potential radiation dose consequences of exposure.

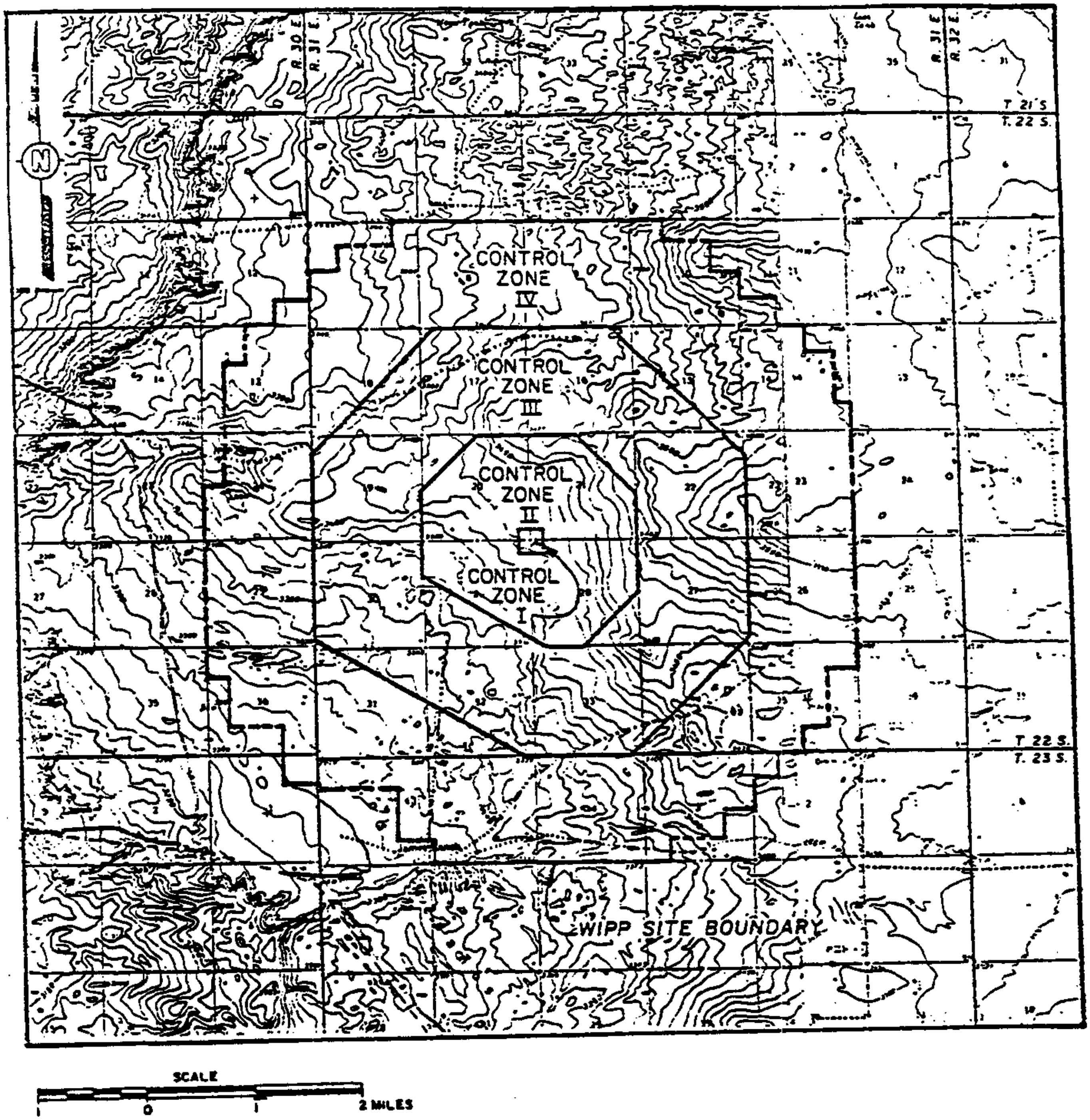
Potash (i.e., sylvite and langbeinite) and hydrocarbons (i.e., natural gas and distillate) comprise the resources present at the WIPP Site that are of interest, considering the technology and market conditions in the foreseeable future. These resources and the methods available to recover them are described in detail in the WIPP Final Environmental Impact Statement (Sections 7.3.7, 9.2.3, and 9.6.5).

The DOE anticipates that extraction of potash within Control Zone IV will be "allowable" if traditional underground mining methods are employed. Traditional methods include drill-and-blast, continuous mining, shortwall, and longwall techniques. If mining of potash is allowed, it is not reasonable to prohibit those mining techniques that make such an activity economically viable. To limit potash ore extraction ratios to low values is, in effect, to preclude such mining. Accordingly, it is anticipated that extraction ratios can be maximized in any mines developed within Control Zone IV of the WIPP Site consistent with mine safety considerations and other state and federal requirements. Solution mining is not now and will not be "allowable" within the limits of the WIPP Site. This restriction does not affect langbeinite recovery because langbeinite is less soluble than the surrounding minerals (i.e., halite, sylvite) so that solution mining for this material would be ineffective. The lack of existing solution mining for sylvite in the Carlsbad potash district confirms that this restriction does not place a significant economic hardship on the producers or significantly affect state revenues.

The DOE anticipates that recovery of hydrocarbon resources from Control Zone IV will be "allowable" following a final decision on waste retrival. This activity includes drilling, production stimulation, and, possibly, secondary recovery. Resources located beneath Zone IV may be accessed by vertical drilling; resources located beneath the inner three control zones may be accessed by drilling vertically in Zone IV to a depth of 6,000 feet and then deviating from vertical at the angle required to reach the target resource zone. It is not realistic to allow drilling for hydrocarbon resources and, if oil or gas is found, to prohibit those techniques available to the producer that maximize recovery. It is the anticipated postion of the DOE that analyses will confirm the acceptability of enhancing production from drilled wells by hydraulically fracturing the reservoir rock, acidizing the formation, or other applicable techniques. These types of production stimulation are used primarily to increase the permeability of the rock that contains the hydrocarbons. Secondary recovery methods (i.e., techniques used to enhance or replace the natural driving force that "pushes" the oil to the production well) may also be employed, but because the resources present are primarily natural gas and not oil, such techniques are not expected to be useful.

DOE intends to amend the present interim policy following completion of the impact analyses. This amendment will expand upon the present policy by identifying the extent to which resource recovery is anticipated to be "allowable" if radioactive waste is permanently emplaced. The amendment will not affect the interim policy that no resource recovery will be allowed until all retrieval decisions are made.

The final DOE policy on resource recovery will be based upon the interim policy, institutional requirements in effect at that time, and data obtained during development and operation of the facility.



REFERENCE:

USGS 15 MINUTE TOPOGRAPHIC QUADRANGLES: NASH DRAW, NEW MEXICO (1965) AND HAT MESA, NEW MEXICO (1972).
SCALE 1:62,500.

FIGURE 1

WIPP SITE CONTROL ZONES

2-19-1-1 6

STATE OF NEW MEXICO
GOVERNOR'S CABINET
SANTA FE
87503

BRUCE KING
GOVERNOR

GEORGE S. GOLDSTEIN, PH.D.
SECRETARY FOR HEALTH & ENVIRONMENT

November 17, 1981

Mr. D. T. Schueler
Assistant Manager for Project
and Energy Programs
U. S. Department of Energy-ALO
P. O. Box 5400
Albuquerque, NM 87115

M

Dear Mr. Schueler:

This is in response to Mr. Joseph McGough's November 3, 1981 letter containing DOE's Interim Policy Statement on Resource Recovery at the WIPP Site to be used as the basis of dose consequence analyses as required by item 6 of Appendix B of the Stipulated Agreement.

The State is very interested in this Interim Policy as well as with other land withdrawal and land use aspects at the WIPP site. Since we believe that a resource recovery policy should only be adopted after a thorough consequence analysis, we will not comment in detail on your Interim Policy until we have had the opportunity to review your analysis scheduled for release in December, 1981. We have the following observations on the Interim Policy:

1. The policy statement implies that Zone IV will be withdrawn and under the control of DOE. It is our understanding that at the present time the Department of the Interior is not transferring Zone IV to DOE but only Zones I - III. The question of who will have control over activities in Zone IV needs to be answered.

2. The statement is silent on what resource recovery may be permitted in Zones I, II, and III and implies that the current analyses will not consider this. From a radiological health standpoint, resource recovery activity in these zones is more important than in Zone IV and should be evaluated in detail. At some date in the future, DOE will relinquish administrative control over Zones I-III and the consequences of resource recovery should be published.

3. The policy states that resource recovery will be controlled or prohibited in the buffer zones. How long a period is DOE using for planning purposes?

4. The statement that secondary recovery of hydrocarbons may be permitted in Zone IV is more permissive than the statement on page 9-27 of the FEIS: "Hydrocarbon exploration in control Zone IV would be permitted by DOE, but nc

water flood recovery methods or extensive hydrofracture stimulation would be allowed."

5. The terms "unacceptable hazard" and "unacceptable effects" need to be defined. Is it based on exceeding a predetermined limit of exposure or on the presence of radiation effects in people?

Thank you for sending the Interim Policy Statement. While we look forward to the receipt of your analyses next month, we would appreciate your comments at this time.

Sincerely,

George S. Goldstein, Ph.D.
Secretary

GSG:teb

cc: Joseph M. McGough, Project Manager on WIPP, DOE
Larry kehoe, Secretary, Energy and Minerals Department
Joe Hewett, Secretary, Highway Department
Jeff Bingaman, Attorney General
L. Woodard, BLM, DOI
Chuck Little, SEA, Westinghouse
C/C File, TSC
Joe Canepa, Deputy Attorney General

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

RECEIVED
DEC 31 1981
ENVIRONMENTAL EVALUATION GROUP

DEC 29 1981

Dr. George S. Goldstein
Secretary
Health and Environmental Department
P.O. Box 968
Santa Fe, NM 87503

Dear Dr. Goldstein:

Interim Policy Statement on Resource Recovery at the WIPP Site

This is in response to your November 17, 1981 letter providing observations on and requesting clarification of some of the points made by the subject document.

We are in complete agreement that a resource recovery policy should be adopted only after a thorough consequence analysis has been performed. The Interim Policy was not, and is not intended as, a DOE position on resource recovery that would allow resource extraction companies to begin planning for future mineral recovery at the WIPP Site. Instead, the Interim Policy provides a basis from which pertinent breach scenarios can be developed and analyzed; it will be modified before publication as a final Interim Policy, if necessary, to reflect the results of consequence studies presently underway.

Specific issues raised in your recent letter are addressed below:

1. At present, we have pending, an application for temporary withdrawal of lands in Zones I, II and III. This application was filed so that land could be withdrawn, thus, protected for the duration of the Site and Preliminary Design Validation (SPDV) Program. Zone IV is not included in this application but will be protected from some nonDOE activities (e.g., deep drilling) by a Cooperative Agreement between DOE and DOI. We have also filed a permanent land withdrawal application with the intent of obtaining DOE administrative control over the lands within all four zones of the WIPP Site.

2. Allowing resource recovery from Zones I, II and III is not currently planned and consequently was not addressed in the Interim Policy. The report, presently in preparation, discussing the effects of resource extraction activities in Zone IV will not provide analyses of short-term consequences of extraction activities in the other zones. The report will, however, address indirectly the potential long-term consequences of resource extraction at any location within the Zone IV boundary. No discussion of potential short-term consequences of extraction in Zones I, II and III was felt necessary because it is unlikely that DOE will allow such activities while it retains administrative control over the lands.

If DOE does desire, in the future, to allow some types of resource extraction in Zones I, II and III, the potential consequences will be evaluated prior to a final decision on whether to allow or disallow specific activities at the site. In any case, denial of resource extraction from Zones I, II and III would cause only a small percentage of the natural resources at the site to be lost. As reported in the FEIS, more than half the hydrocarbon resources and more than two-thirds of potash resources are located in Zone IV. Additionally, it is believed that deviated drilling from Zone IV would allow extraction of all hydrocarbon resources at the WIPP Site.

3. DOE plans to maintain its resource recovery policy at the WIPP Site for the duration of its administrative control over the site lands. In the FEIS, it was assumed to be reasonable that administrative control would exist for a minimum of 100 years.

4. At the time of publication of the FEIS, studies necessary to evaluate the effects of primary production stimulation and secondary recovery of hydrocarbons had not been conducted. Thus, to maintain the consistently conservative posture of the WIPP Project, DOE elected to preclude these hydrocarbon recovery methods until further study could be undertaken. As noted in the second paragraph of this letter, the Interim Policy was intended to provide direction relative to the types of breach scenarios that should be considered and analyzed. In development of the statement, it was felt unreasonable to allow an extraction company to complete an exploration well (at great cost) and to then not allow the operator to perform whatever techniques he deemed useful to regain his investment. Thus, it was felt essential that the potential consequences of all types of production enhancement be evaluated before general distribution of a policy on resource extraction.

5. Presently, the potential dose consequences of resource extraction at the WIPP Site are deemed unacceptable if the potential hazards to public health and safety exceed those of the breach events considered in the FEIS and SAR.

We are currently on schedule in the preparation of the report on the potential consequences of resource recovery at the WIPP Site and plan to submit a draft to the State in December. If you have further questions or comments on this matter, please contact me.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 81-5135/5190

cc:
D. T. Schueler, AMPEP, ALO
R. H. Neill, Director, EEG, Santa Fe, NM
W. Weart, Org. 4510, SNLA
J. F. McNett, OCC, ALO
G. L. Hohmann, TSC
C. C. Little, TSC
C&C File, IEA, TSC
L. H. Harmon, NE-30, USDOE, HQ
W. F. Jebb, WIPP, Carlsbad Site Office

ENVIRONMENT department

"Equal Opportunity Employer"

STATE OF NEW MEXICO

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(505) 827-5481

February 23, 1982

Mr. Joseph McGough
Project Manager on WIPP
WIPP Project Office
U. S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, NM 87115

Dear Mr. McGough:

The Environmental Evaluation Group has reviewed D'Appolonia's Draft Report, "Natural Resources Study" which you transmitted to us on January 29, 1982. There is attached a summary of our comments. We would appreciate your response to these comments and will be pleased to discuss them if you have any questions.

Sincerely,

Robert H. Neill
Director

RHN:MSL:lgr

cc: George S. Goldstein, Ph.D., Secretary, Health & Environment Department
Larry Kehoe, Secretary, Energy and Minerals Department
Joe Hewett, Secretary, Highway Department
Thomas E. Baca, Director, Environmental Improvement Division
Joe Canepa, Attorney at Law
Wendell Weart, Manager, Sandia Laboratories
Chuck Little, Westinghouse Electric Corporation
TSC, IEA

REVIEW COMMENTS

CONCERNING

Draft Report on Natural Resources Study.

Waste Isolation Pilot Plat (WIPP) Project

Southeastern New Mexico

Comments by

Environmental Evaluation Group

Environmental Improvement Division

Health and Environment Department

P. O. box 968

Santa Fe, New Mexico

87503

February 22, 1982

General Comments

1. The report fails to comprehensively address the question of new exploration. Neither the DOE Interim Policy statement (Section 1.4) nor the balance of the report indicate that any restrictions will be imposed on new exploration for natural resources, only extraction. Since certain exploratory techniques may seriously affect the integrity of the repository, the Interim Policy Statement should impose restrictions similar to those for removal.

2. It is recognized that the construction of solution cavities for storage of hydrocarbons does not constitute exploration or mining for natural resources; however, it is an extraction technology; it is very relevant to gas and oil resources; it is becoming an increasingly popular practice; and it has not previously been examined by DOE. Therefore, EEG recommends that it be included and the impact analyzed in the Final Policy Statement and Report on Natural Resouces.

3. It is noted that this report addresses the extraction in Zone IV only, which is consistent with the present Interim Policy. It should be noted that if at some future date, DOE proposes to modify that Policy to allow extractions from Zones II or III, it would be necessary to make a new analysis of the impact of such change.

Specific Comments

1. <u>Section 1.4, DOE Interim, Policy Statement</u> -- In a letter dated November 17, 1981, Dr. George Goldstein, Secretary for Health and Environment of New

Mexico, submitted several comments with respect to the DOE Interim Policy Statement. Although a letter from J. M. McGough of the DOE Albuquerque Operations Office responded to Dr. Goldstein's comments, the Interim Policy Statement was not modified and the report failed to either clarify or amend the ambiguous passages of the Policy Statement. For example, the phrases "unacceptable effects" (p. 1-6) and "allowable effects" (p. 1-8) remain undefined. EEG recommends that the statement be revised to reflect Dr. Goldstein's previous comments and the comments contained herein.

2. Section 2.1.1. Page 2-2, second paragraph -- The report is inconsistent in statements about the depth at which potash may be found. This section states that it is not within 400 feet of the repository horizon. Table 1 indicates langbeinite as low as 1800 feet (350 feet above the repository horizon). However, Table 5 indicates depths as low as 2300 feet (150 feet below the horizon). It would be helpful if the report indicated where the potash mines listed in Table 5 are located, and what are the actual depths to potash within the site.

3. Section 3.1.1.1, Page 3-1, last paragraph -- It is emphasized that empirical data for the pressure arch theory is based on coal mining experience. The appropriateness and applicability for mines in salt needs to be addressed.

4. Section 3.1.1.2, Page 3-3, last paragraph -- The author should also include data from studies performed by Sandia using elaborate rock mechanics codes, as contained in the following reference:

Morgan, H. S., Krieg, R. D., Matalucci, R. V., "Comparative Analyses of Nine Structural Codes Used in the Second WIPP Benchmark Problem," Sand-81-1839, Sandia National Laboratories, Albuquerque, N.M.

5. Section 3.1.1.2, Page 3-5, first line -- This sentence assumes that the stress-relaxation process which occurs prior to establishing steady-state conditions, cannot be studied. This assumption seems to be incorrect since the problem of transient creep is treated in great detail in report ECN-89. (See reference provided in comment 4 above.) The report also contains a program for the HP-41C pocket calculator.

6. Section 3.1.1.2, Page 3-5 3rd paragraph -- This paragraph addresses the zone of influence of a potential potash mine when superimposed by the influence of the WIPP repository and concludes that a separation of 2,100 feet assures that interaction will not occur. This conclusion seems to be based on the assumption that the existing rock between the WIPP and the potential potash mine is reasonably stable. However, in Zone III, north of the repository, there is a zone of "anomalous seismic reflection" where the structure is presently unknown. Also the presence of brine at WIPP-12 suggests that fracturing within the Castile may be extensive. Further information is needed on this anomalous zone before it can be concluded that 2,100 feet is sufficient.

7. Section 3.1.1.2, Page 3-5, 3rd paragraph -- The conclusion that the effects of mining the WIPP repository will only extend to 200 feet beyond the perimeter of the repository, the effect of a single panel, is not convincing. A potash mining activity approaching the WIPP repository from the north faces

a 2560' x 33' room running east-west and crossed by 18 rooms running north-south. It may be better to model the WIPP facility by some effective cavity. Also, since potash mining may extend to depths from the McNutt zone to 2300 feet (see comment 2 above), it may be preferable to approximate the extent of WIPP influence on the potash mine by the extent of possible subsidence area over the WIPP.

8. Section 4.1, page 4-2, 3rd paragraph -- The assumption that plutonium would dissolve at the same rate as the Salado formation is undoubtedly conservative if the salt is actually all dissolved (this would give a concentration of ≈ 1.6 mg/ℓ Pu in the brine). However, leaching of Pu from the waste can occur in the absence of net salt dissolution. Studies at PNL* have shown that about 10^{-4} per year of plutonium oxide fuel pellets would leach into "WIPP-B" brine. At this leach rate it would take 500 years to get a concentration of 1.6 mg/ℓ and solubility limits would probably prevent this high a concentration from ever occurring. It is recommended that the final report recognize that some waste leaching will occur if brine is in contact with the waste. Also, leaching by brine is more plausible than scenarios that require large volumes of the Salado formation to be dissolved.

---

*Bradley, D.J., Harvey, C.O., and Turcotte, R.P. Leaching of Actinides and Technetium from Simulated High-Level Glass (PNL-3152), August 1979.

RESPONSES TO NATURAL RESOURCES STUDY COMMENTS

GENERAL COMMENTS

1. Comment:

"The report fails to comprehensively address the question of new exploration. Neither the DOE Interim Policy Statement (Section 1.4) nor the balance of the report indicate that any restrictions will be imposed on new exploration for natural resources, only extraction. Since certain exploratory techniques may seriously affect the integrity of the repository, the Interim Policy Statement should impose restrictions similar to those for removal."

Response:

The report indicates that exploration activities are an integral part of resource development for both potash and hydrocarbons. As exploration is an essential portion of resource development, it is implied that restrictions placed on extraction activities would also apply to new exploration. Additionally, it is highly unlikely that resource companies would spend money to explore areas that are closed to resource extraction; however, a phrase will be added to the introduction to address exploration activities.

2. Comment:

"It is recognized that the construction of solution cavities for storage of hydrocarbons does not constitute exploration or mining for natural resources; however, it is an extraction technology; it is very relevant to gas and oil resources; it is becoming an increasingly popular practice; and it has not previously been examined by DOE. Therefore, EEG recommends that it be included and the impact analyzed in the Final Policy Statement and Report on Natural Resources."

Response:

A statement will be added to the report prohibiting any extraction activities at the WIPP site other than those discussed in the report, without prior approval of the DOE. It is unlikely, however, that DOE would allow construction of storage cavities at the site because there are many other suitable locations in the Delaware Basin for construction of these cavities.

3. Comment:

"It is noted that this report addresses the extraction in Zone IV only, which is consistent with the present Interim Policy. It should be noted that if at some future date, DOE proposes to modify the Policy to allow extractions from Zones II and III, it would be necessary to make a new analysis of the impact of such change."

Response:

Substantial modification of portions of the report would likely be necessary should DOE choose to examine the impacts of resource recovery from Zone II or Zone III.

SPECIFIC COMMENTS

1. Comment:

"Section 1.4, DOE Interim, Policy Statement -- In a letter dated November 17, 1981, Dr. George Goldstein, Secretary for Health and Environment of New Mexico, submitted several comments with respect to the DOE Interim Policy Statement. Although a letter from J. M. McGough of the DOE Albuquerque Operations Office responded to Dr. Goldstein's comments, the Interim Policy Statement was not modified and the report failed to either clarify or amend the ambiguous passages of the Policy Statement. For example, the phrases "unacceptable effects" (p. 1-6) and "allowable effects" (p. 1-8) remain undefined. EEG recommends that the Statement be revised to reflect Dr. Goldstein's previous comments and the comments contained herein."

Response:

The DOE Interim Policy Statement was included in the report for historical perspective and to indicate that certain extraction activities would not be allowed at the site and thus would not be evaluated relative to their impact. The precise definitions of "unacceptable effects" and "allowable effects" are not germane to the technical content of the report, because no effects are expected to result from resource recovery in Zone IV.

It should be realized that the Interim Policy Statement was developed not as a legal document but to provide a basis with which the potential effects of resource recovery could be studied.

2. Comment:

"Section 2.1.1 Page 2-2, second paragraph -- The report is inconsistent in statements about the depth at which potash may be found. This section states that it is not within 400 feet of the repository horizon. Table 1 indicates langebinite as low as 1800 feet (350 feet above the repository horizon). However, Table 5 indicates depths as low as 2300 feet (150 feet below the horizon). It would be helpful if the report indicated where the potash mines listed in Table 5 are located, and what are the actual depths to potash within the site."

Response:

The depth to the base of the McNutt potash member of the Salado Formation is about 1740 feet at ERDA-9, or approximately 400 feet above the storage horizon. The depth at which potash is found in the basin varies as the depth to the McNutt potash member varies, which is dependent on the occurrence of strata dip, structural features and changes in topography. The base of the McNutt is at a depth of aproximately 1600 feet in the northern part of Zone IV; at a depth of about 1500 feet in the western part of Zone IV; at a depth of about 1550 feet in the southern part and at a depth of about 2000 feet in the eastern part. The depths to potash mineralization were included in the report primarily to indicate the depths at which potash mining experience exists. The location of the drillholes or mines from which depth measurements were obtained are available from the reference given in the tables or from maps prepared for WIPP or for other purposes and included in published project documents.

3. Comment:

"Section 3.1.1.1, Page 3-1, last paragraph -- It is emphasized that empirical data for the pressure arch theory is based on coal mining experience. The appropriateness and applicability for mines in salt needs to be addressed."

Response:

The pressure arch theory is a sound, proven concept and should be applicable to nearly any underground opening. As noted in the report, limited data exist for mines in salt compared to the extensive data base developed from coal mining experience. Further attempts, however, are underway to obtain more data on potash mining to strengthen the conclusions reached relative to mining effects. In any case, the report will be modified to demonstrate the appropriateness of the methodology used relative to the pressure arch theory.

4. Comment:

"Section 3.1.1.2, Page 3-3, last paragraph -- The author should also include data from studies performed by Sandia using elaborate rock mechanics codes, as contained in the following reference:

Morgan, H. S., Krieg, R. D., Matalucci, R. V., "Comparative Analyses of Nine Structural Codes Used in the Second WIPP Benchmark Problem." SAND-81-1839, Sandia National Laboratories, Albuquerque, N.M."

Response:

The Benchmark studies were directed at determining predicted stress-strain behavior of the WIPP underground workings in the near field. The effects that potash mining in Zone IV might produce on the WIPP facility are certainly not near-field. Thus, the applicability of the Benchmark analyses relative to this problem is not apparent.

In any case, more sophisticated techniques, such as geomechanical modeling using finite element techniques are not necessary. This is primarily because the results of first approximations as described in the report, using very conservative assumptions, demonstrate the integrity of a significant buffer zone between potash mines developed in Zone IV and the WIPP facility.

5. Comment:

"Section 3.1.1.2, Page 3-5, first line -- This sentence assumes that the stress-relaxation process which occurs prior to establishing steady-state conditions, cannot be studied. This assumption seems to be incorrect since the problem of transient creep is treated in great detail in report ECN-89. (See reference provided in comment 4 above.) The report also contains a program for the HP-41C pocket calculator."

Response:

The sentence referenced in the comment will be modified to indicate that the model used to determine zone of influence around underground openings cannot be used to address transient creep phenomena. The determination of the transient creep characteristics are unimportant in this instance because the cummulative effects of stress-relaxation on the surrounding strata, produced by a potash mine or the WIPP facility, are of primary concern.

6. Comment:

"Section 3.1.1.2, Page 3-5 3rd paragraph -- This paragraph addresses the zone of influence of a potential potash mine when superimposed by the influence of the WIPP repository and concludes that a separation of 2,100 feet assures that interaction will not occur. This conclusion seems to be based on the assumption that the existing rock between the WIPP and the potential potash mine is reasonably stable. However, in Zone III, north of the repository, there is a zone of "anomalous seismic reflection" where the structure is presently unknown. Also the presence of brine at WIPP-12 suggests that fracturing within the Castile may be extensive. Further information is needed on this anomalous zone before it can be concluded that 2,100 feet is sufficient."

Response:

The "zone of anomalous seismic reflection data" extends less than half a mile into Zone III at the Cowden Anhydrite horizon. No disturbance has been noted at WIPP storage horizon; in fact, there is very little steepening of strata at the storage horizon. At the McNutt potash zone horizon, the strata in the northern part of Zone IV are nearly horizontal and unaffected by the steepening of the

Castile Formation. Additionally, core obtained from boreholes located in the Salado Formation in the northern part of the Zones III and IV has not shown evidence of fracturing or deformation. Further, it is highly unlikely that any fracture created in the Salado Formation would remain open and permeable, due to the geomechnical properties of salt rock. It should be remembered that the fracture networks that are brine-containing in the Castile Formation are confined to thick anhydrite layers. Even in areas where fractures in Castile anhydrites are present, these fractures generally terminate at anhydrite-halite contacts. Thus, it is highly improbable that the "zone of anomalous seismic reflection data" represents any geologic condition that would impact the determination of the zones of influence of a potash mine or the WIPP underground workings.

7. Comment:

"Section 3.1.1.2, Page 3-5, 3rd paragraph -- The conclusion that the effects of mining the WIPP repository will only extend to 200 feet beyond the perimeter of the repository, the effect of a single panel, is not convincing. A potash mining activity approaching the WIPP repository from the north faces a 2560' x 33' room running east-west and crossed by 18 rooms running north-south. It may be better to model the WIPP facility by some effective cavity. Also, since potash mining may extend to depths from the McNutt zone to 2300 feet (see Comment 2 above), it may be preferable to approximate the extent of WIPP influence on the potash mine by the extent of possible subsidence area over the WIPP."

Response:

The statements that describe the independence of individual rooms within the WIPP underground facility will be better substantiated in the final report. It should be noted, however, that the length of the cavity is irrelevant as a cylinder of infinite length was assumed in the analysis. Relative to the expected depths of potash mining in Zone IV, see the Response to Comment 2 of the Specific Comments.

8. Comment:

"Section 4.1, page 4-2, 3rd paragraph -- The assumption that plutonium would dissolve at the same rate as the Salado Formation is undoubtedly conservative if the salt is actually all dissolved (this would give a concentration of 1.6 mg/l Pu in the brine). However, leaching of Pu from the waste can occur in the absence of net salt dissolution. Studies at PNL* have shown that about 10^{-4} per year of plutonium oxide fuel pellets would leach into "WIPP-B" brine. At this leach rate it would take 500 years to get a concentration of 1.6 mg/l and solubility limits would probably prevent this high a concentration from ever occurring. It is recommended that the final report recognize that some waste leaching will occur if brine is in

*Bradley, D. J., Harvey, C. O., and Turcotte, R. P. Leaching of Actinides and Technetium from Simulated High-Level Glass (PNL-3152), August 1979.

contact with the waste. Also, leaching by brine is more plausible than scenarios that require large volumes of the Salado formation to be dissolved."

Response:

The report simply restates the assumptions that were used in development of the WIPP long-term waste isolation assessment. The assumption that the waste is as soluble as the encapsulating salt is basic to the scenario analyses performed for this assessment. Although some leaching of plutonium oxide might occur under flowing conditions, some driving force must be present to cause brine to enter and leave the facility and pathways for brine to enter and leave must be established. The analyses and discussion in the report indicate that resource extraction activities in Zone IV would not significantly contribute to the creation of necessary pathways or driving forces.

9. Comment:

"Section 4.2, page 4-2 -- As previously discussed, the zone of influence in the northern sector of Zone III as a result of potash mining cannot be determined with reliability because the structure over the disturbed zone is unknown. It may contain significant fractures and be in direct communications with Zone II. See Comment 17 for recommended action."

Response:

See Response to Comment 6 of Specific Comments.

10. Comment:

"Section 4.2, page 4.2 -- It would seem that fresh water would not be required to move through a more permeable formation around the repository. Brine with some driving force should be able to flow through a permeable salt formation."

Response:

The permeability of undisturbed Salado salt is quite low and would allow very little fluid flow through the formation. The areal extent of mining-caused elevated permeability is very limited around both a hypothetical potash mine and the WIPP facility. No overlap of the zones of increased permeability would be expected, thus, a preferential flowpath for fluid travel would not be created.

If brine were to saturate the zone of increased permeability, no additional dissolution could occur. Additionally, the fracture network representing the zone would not be expected to remain open for any significant time interval based on the creep-closure properties of salt.

11. Comment:

"Section 4.2.1, page 4-3 -- The Interim Policy Statement does not appear to impose any restrictions on exploratory drilling in Zones II or III. If such restrictions were intended, it should be stated more clearly."

Response:

See Response to Comment 1 of General Comments

12. Comment:

"Section 4.2.1.1, page 4-3, first paragraph -- See Comment 2 above concerning the separation between the potash ore and the repository horizon. Also see Comment 11 above."

Response:

See Response to Comment 2 of Specific Comments and Comment 1 of General Comments.

13. Comment:

"Section 4.2.1.1. -- Why is it necessary to dissolve the (entire) one-mile-wide buffer strip to get to the repository? Could not fresh water follows fractures, (dissolving salt along the way) between potash mine and repository? The probability of dissolving in a straight line between the repository and mine may be low but subsidence (page 3-8) and zone of influence (page 3-3) effects could provide a preferential pathway for part of the distance between Zone II and III."

Response:

This section will be modified to clarify its intended meaning. It was not meant to imply that the entire one-mile-wide buffer must be dissolved for fluids to reach the WIPP facility. It is understood that fluids would seek preferential pathways (if such pathways exist). The primary purpose of Chapter 3 is to describe the expected extent of any preferential pathways created by resource extraction activities or by WIPP facility construction. As shown in this chapter, the effects on surrounding strata created by mining for potash in Zone IV and by construction of the WIPP facility do not overlap. Given the expected extent of effects from construction of these underground openings, millions of years would be required for fluids to dissolve a sufficient amount of halite to create a pathway from a mine in Zone IV to the WIPP storage facility.

14. Comment:

"Section 4.2.2., page 4-4 -- As previously indicated, mining of potash in the northern sector of Zone IV indeed may establish communications with Zone II at the repository horizon. The zone of anomalous seismic reflections encompasses virtually all of Zone III and portions of Zone II; there is a large brine reservoir at WIPP-12; thus there is considerable disturbance in Zone III which may extend to the repository horizon. Additional information is needed on this disturbed area before it can be known with confidence that potash mining in Zone IV can be allowed. See also Comment 13 above."

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Response:

The analyses performed to evalute the effects of potash mining indicate that mining in Zone IV will not establish communications with Zone II.

Also, see Response to Comment 6 and Comment 13 of Specific Comments.

15. Comment:

"Section 4.3.1 -- There is a question concerning deviated drilling into the Ramsey sand. Since this formation is less than 6,000 feet deep zones I, II, III, it could not be developed under the policy stated on page 1-9. The question is whether this formation would not be developed under the inner zones or whether a variance would be permitted."

Response:

Deviated drilling into the Ramsey sand under Zones I, II and III will not be allowed. Disallowing this action will maintain the conservative approach taken by DOE on WIPP development. Additionally, denial of drilling into the Ramsey sand under the inner three Control Zones should not cause a substantial volume of hydrocarbons to remain untapped because the Ramsey sand is not an attractive exploration target in the site area.

16. Comment:

"Section 4.3.2, Page 4-8, paragraph 2 -- What is the basis for the statement (on page 4-8) that the Capitan aquifer potentiometric gradient is high enough to reach the surface at the WIPP site? Hiss' data show the potentiometric surface to the north of the site as 2900-3200 feet (fresh water equivalent), compared to a surface elevation of 3400 feet at the site."

Response:

The sentence should have stated that the potentiometric gradient of the Capitan and the ground surface in the WIPP site area is insufficient to drive fresh water to the surface.

17. Comment:

"Section 5.0, page 5.1, last paragraph -- It is the conclusion of EEG that the mining of potash in Zone IV should not be allowed until after the completion of the analysis of the zone of anomalous seismic reflection in Zone III and of WIPP-12. Therefore, the decision on allowing extraction of natural resources within Zone IV should be delayed until after the State has commented on the DOE reports on Brine Reservoirs and the Disturbed Zone."

Response:

See Response to Comment 6 of Specific Comments

EDITORIAL COMMENTS

The report is in final editing and these as well as other editorial items will be corrected in the final report.

"Equal Opportunity Employer"

STATE OF NEW MEXICO

ENVIRONMENTAL EVALUATION GROUP
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HEALTH ENVIRONMENT department

October 26, 1982

M

Joseph M. McGough
WIPP Project Manager
U. S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, NM 87115

Dear Mr. McGough:

Pursuant to our conversations over the past several weeks, I wanted to confirm the EEG's concern relative to DOE's issuance of a "Policy on Resource Recovery" without giving the State ample opportunity for review. We have a number of questions about the relinquishment of Zone IV control, a few of which are contained below. I request that you involve us at the earliest practical stage in the review process to assure that we can work together constructively on the resource recovery issues.

A few of our questions about the DOE policy follow:

1. Will solution mining be allowed in Zone IV?
2. If so, how will it be controlled?
3. Will storage cavities be allowed?
4. Will there be any restrictions on extraction or storage cavities in any of the evaporite formations in Zone IV?
5. Will directional drilling be allowed in Zone III?
6. Will extraction of brine reservoirs in the Castile from Zone IV permit drainage of brine from underneath the inner zones?
7. What will the Interim Policy Statement say regarding restrictons in zones?
8. Will the MOW between BLM and/or MMS allw DOE to have any input concerning future requests for activities in Zone IV? Or will it be completely out of DOE's hands?
9. What has become of the interim DOE policy to permit no exploration or extraction before 1993?
10. How will Zone IV be controlled if it is not under direct DOE control?
11. Will extraction of brine be authorized? Who will decide?

Please advise how we may best work together on resolution of not just these questions but others as well.

Sincerely,

Robert H. Neill
Director

2-081AG2-19-1

RHN:JM:eg

cc: TSC, IEA

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

RECEIVED

NOV 29 1982

ENVIRONMENTAL
EVALUATION GROUP

NOV 24 1982

Mr. Robert H. Neill
Director
State of New Mexico
Environmental Evaluation Group
320 Mary Street
P. O. Box 968
Santa Fe, NM 87504

Dear Mr. Neill:

DOE Policy on Resource Recovery at the WIPP Site

As you know, the DOE Interim Policy Statement on Resource Recovery at the WIPP Site, which was transmitted to the State of New Mexico on November 3, 1981, was developed to serve as the basis for performing the Natural Resources Study. And, as you also are aware, the study concludes that activities related to potash and hydrocarbon resource extraction and solution mining outside the Control Zone III boundary, using currently available and applicable technology, will not compromise the integrity of the WIPP waste emplacement facility.

It was my understanding that your concerns regarding the draft and final Natural Resources Study reports were discussed with representatives of our Technical Support Contractor and resolved to your satisfaction. The DOE is now considering the issuance of a revised interim policy statement on resource recovery which would reflect the conclusions of the Natural Resources Study and, possibly, permit access to potash and hydrocarbons that many believe are critical resources.

Although the revised interim policy statement is still undergoing DOE review, responses to your questions have been developed based on our current position and are included in the enclosure. The revised interim policy statement will be based on the results of the Natural Resources Study and will be transmitted to the State of New Mexico as soon as our internal review is completed.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 82-0801/6252A

Enclosure

cc w/o enclosure:
R. K. Brown, TSC
G. L. Hohmann, TSC
C. C. Little, TSC

cc w/enclosure:
C&C File, IEA, TSC

Question -- Will solution mining be allowed in Zone IV?

Response -- Unsuccessful experiences in solution mining of potash by the Potash Company of America and Continental Potash and the lack of suitable water supplies in the Carlsbad area suggest that the potential for application of currently available solution mining technology for the extraction of sylvite is remote; however, solution mining will be allowed in Control Zone IV.

Question -- If so, how will it be controlled?

Response -- The DOE will impose no controls over solution mining in Control Zone IV. The U.S. Department of the Interior Minerals Management Service and the New Mexico Energy and Minerals Department are responsible for reviewing proposed mining operations to assure compliance with regulations and prevent violation of adjacent leases.

Question -- Will storage cavities be allowed?

Response -- Although the development of storage cavities in the WIPP site area is considered unlikely, the DOE will exercise no controls over the development of such cavities outside Control Zone III provided that the WIPP site boundary is not violated.

Question -- Will there be any restrictions on extraction or storage cavities in any of the evaporite formations in Zone IV?

Response -- No, provided that the WIPP site boundary is not violated.

Question -- Will directional drilling be allowed in Zone III?

Response -- No drilling will be allowed from Control Zone III. However, drilling from outside Control Zone III to gain access to hydrocarbons beneath Control Zones I, II and III at depths greater than 6000 feet will be allowed if the planes formed by the downward vertical projections of the Control Zone III boundaries are not penetrated above a depth of 6000 feet.

Question -- Will extraction of brine reservoirs in the Castile from Zone IV permit drainage of brine from underneath the inner zones?

Response -- In general, the geographical extent of brine reservoirs in the Castile Formation has not been determined; however, it is possible that a brine reservoir encountered in Control Zone IV could extend beneath the inner zones. Consequently, extraction of brine from a reservoir beneath Control Zone IV could result in removal of brine from beneath the inner zones. Because of the characteristics of brine reservoirs found in the Castile Formation, extraction of brine will not result in subsidence of sufficient magnitude to fracture overlying strata. Thus, no effect on the underground facility is expected.

Question -- What will the Interim Policy Statement say regarding restrictions in zones?

Response -- The revised interim policy statement is expected to indicate the following:

- No potash or other commercial mining will be allowed in Control Zones I, II and III.

- No commercial drilling (hydrocarbon or other) will be allowed from Control Zones I, II and III.

- Drilling from outside Control Zone III to access locations beneath Control Zones I, II and III at depths greater than 6000 feet will be allowed.

Question -- Will the MOU between BLM and/or MMS allow DOE to have any input concerning future requests for activities in Zone IV? Or will it be completely out of DOE's hands?

Response -- The DOE does not expect to exercise any control over activities in Control Zone IV except that no permanent residences will be allowed by BLM in Zone IV. The DOE will, however, arrange with BLM and MMS to be kept apprised of all such activities in Zone 4 and provide recommendation or other assistance to Federal and State regulatory agencies upon request.

Question -- What has become of the interim DOE policy to permit no exploration or extraction before 1993?

Response -- The interim DOE policy which was transmitted to the State of New Mexico in November 1981, was developed to serve as the basis for performance of the Natural Resource Study. The results of this study demonstrate that activities related to potash and hydrocarbon resource extraction and solution mining from within (and outside of) Control Zone IV, using currently available technology, would not compromise the integrity of the WIPP waste emplacement facility. Because of these findings, the DOE is evaluating the desirability of revising the interim policy statement as indicated above.

Question -- How will Zone IV be controlled if it is not under direct DOE control?

Response -- The lands in Control Zone IV will be managed by the Bureau of Land Management in the same manner as other public lands. Commercial mining and hydrocarbon extraction activities will be controlled by the Minerals Management Service and the New Mexico Energy and Minerals Department in accordance with Federal and State regulations governing such activities.

Question -- Will extraction of brine be authorized? Who will decide?

Response -- As indicated above, no commercial mining or drilling (hydrocarbon or other) will be allowed in Control Zones I, II and III, however, no controls will be imposed on such activities outside the Zone III boundary. Although requests for approval of brine extraction activities in the WIPP site area are considered unlikely, such requests will be reviewed by the Minerals Management Service, New Mexico Energy and Minerals Department (for State lands) and the Bureau of Land Management to assure compliance with Federal and State regulations. The DOE will provide assistance to these agencies if requested.

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STATE OF NEW MEXICO

ENVIRONMENT department

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December 6, 1982

Mr. Joseph M. McGough
Project Manager of WIPP
WIPP Project Office
U.S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. McGough:

Thank you for your letter of November 24, 1982 (WIPP:JMM82-C801/6252A) enclosing a response to our questions concerning the DOE plans for the "Policy on Resource Recovery."

There is attached a summary of EEG's comments concerning the recent draft of the DOE "Revised Interim Policy Statement on Natural Resource Recovery at the WIPP Site."

Sincerely,

-for-

Robert H. Neill
Director

RHN:MSL:eg

2-92-AG2-19-1-1

cc: TSC, IEA

Providing an independent analysis for the New Mexico Health and Environment Department of the proposed Waste Isolation Pilot Plant (WIPP), a federal nuclear waste repository.

REVIEW COMMENTS
on
DOE REVISED INTERIM POLICY
STATEMENT ON NATURAL RESOURCES
RECOVERY AT WIPP SITE

by

Environmental Evaluation Group
Environmental Improvement Division
N. M. Health and Environment Department
P. O. Box 968
Santa Fe, NM 87503

December, 1982

A. GENERAL COMMENTS

1. The Statement implies that DOE plans to relinquish all control over Zone IV of the present WIPP site, and that DOE plans to rely on the New Mexico Energy and Minerals Department and the Minerals Management Service of the U. S. Dept. of Interior for reviewing plans in this zone in the future. Because of the remote possibility that activities in this zone may have an adverse impact on the long-term stability of the repository horizon, it is recommended that DOE maintain, in a memorandum of understanding with DOI, a provision for DOI to notify DOE of any proposal for solution mining, solution storage cavities, and mining of Castile brine in Zone IV prior to a decision on that proposal, and that DOE in cooperation with the appropriate State agencies will review these plans and submit comments to DOI for their consideration.

2. The Policy Statement applies only during facility construction and operation of the WIPP facility. The Policy should be expanded to reflect the post-operation controls, since the integrity of the repository and the consequence analyses are dependent upon some controls being maintained.

B. SPECIFIC COMMENTS

1. Page 1, line 6:

The phrase "commercial drilling" should be defined so that it clearly excludes any drilling as well as mining not related to WIPP in Zones I, II, and III.

2. Page 1, line 14:

As reflected in the preceding "General Comments," EEG recommends that the MOU between DOE and DOI request that DOE (and the appropriate State agencies) be notified of any proposal in Zone IV envolving solution mining, construction of solution storage cavities or mining of brine from brine reservoirs in the Castile.

3. Page 1, line 25:

As recommended in the "General Comments," we believe that the controls which are to be maintained after decommissioning should be addressed. This would necessitate deletion of the sentence at line 25.

4. Page 2, line 6:

The phrase "measurable effects" is ambiguous and may lead to misunderstandings. It should be deleted or more precisely defined.

5. Page 2, paragraph 2:

This paragraph does not adequately state the potential for resources at the site. It should recognize that technology and market conditions are not predictable and some materials, such as may be found in Castile brine, or Salado salt could become of economic value if technology and market conditions are substantially modified.

6. Page 3, paragraph 4, line 7:

The D'Appolonia draft report "Natural Resources Study" indicates that "resource grade oil" is under the site.

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

DEC 2 3 1982

Dr. George S. Goldstein
Chairman, Radioactive Task Force
Health and Environment Department
P.O. Box 968
Santa Fe, NM 87503

Dear Dr. Goldstein:

DOE Revised Interim Policy Statement on Natural Resource Recovery at the WIPP Site

Enclosed for your use and information is the DOE Revised Interim Policy Statement on Natural Resource Recovery at the WIPP Site. Under the terms of this policy statement no potash or other commercial mining in, or commercial drilling from, Control Zones I, II and III will be allowed; however, the DOE will exercise no control over mining or drilling outside Control Zone III. (Control Zone III is being redefined as the area withdrawn for SPDV which is a square containing 16 sections (10,240 acres) surrounding the center of the site.) Additionally, BLM will prohibit permanent inhabitation of Zone IV while the facility is in operation. Hydrocarbon resources below 6000 ft. beneath Control Zones I, II and III can be accessed by deviated drilling from outside the Control Zone III boundary. The DOE will rely on the review of State and Federal regulatory agencies, including the New Mexico Energy and Minerals Department and the U.S. Department of the Interior, Minerals Management Service, to protect the integrity of the WIPP Site boundaries from commercial exploration, mining or other extractive activities. So that the DOE can maintain information on resource recovery near the WIPP Site, the Bureau of Land Management will notify the DOE of any requests for resource recovery permits within one mile of the WIPP Site boundary.

The final DOE policy will be issued when the decision is made regarding retrieval of the waste. Should the DOE decide to retrieve all the radioactive waste, the WIPP Site will become available for complete resource recovery after retrieval and decommissioning are complete.

The initial Interim Policy Statement, which was transmitted to the State of New Mexico on November 3, 1981, was developed to serve as the basis for the performance of the Natural Resources Study. The initial DOE

Interim Policy, as indicated therein, was "temporary denial of all resource extraction within the four control zones of the WIPP Site until the decision is made relative to which, if any, of the emplaced waste will be retrieved." Based on the conclusions of the Natural Resources Study, which was transmitted to the State of New Mexico on October 5, 1982, we have determined that the initial Interim Policy can be revised as indicated above.

Not only does the DOE Revised Policy Statement reflect the conclusions of the Natural Resources Study but it also addresses comments provided by the New Mexico Environmental Evaluation Group on the Policy Statement.

If you require additional information or have questions on this matter, please contact me.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

Enclosure

WIPP:JMM 82-0885/6366A

cc: w/encl:
J. K. Otts, Chairman, Radioactive Waste Consultation Committee, Santa Fe, NM
J. Bingaman, Attorney General, Santa Fe, NM
D. T. Schueler, AMPEP, AL
R. G. Romatowski, Manager, AL
L. H. Harmon, DP-12.1, DOE, HQ
W. F. Jebb, OSM, Carlsbad, NM
J. Stout, OCC, AL
R. H. Neill, Director, EEG, Santa Fe, NM
C. W. Luscher, State Director, BLM, Santa Fe, NM
M. Wilson, OCC, AL

M

DOE REVISED INTERIM POLICY STATEMENT ON RESOURCE RECOVERY AT THE WIPP SITE

The policy of the Department of Energy (DOE) concerning resource recovery at the Waste Isolation Pilot Plant (WIPP) site during facility construction and operation is as follows:

- No potash or other mining excluding that conducted for the WIPP Project will be allowed in WIPP Control Zones I, II, and III.

- No drilling excluding that conducted for the WIPP Project will be allowed from Control Zones I, II, and III.

- Drilling from outside Control Zone III to access locations beneath Control Zones I, II, and III at depths greater than 6,000 feet will be allowed if the planes formed by the downward vertical projections of the Control Zone III boundaries are not penetrated above a depth of 6,000 feet.

- DOE will rely on the review of State and Federal regulatory agencies, including the New Mexico Energy and Minerals Department and the Minerals Management Service, U.S. Department of the Interior, to protect the integrity of the WIPP site boundaries from commercial exploration, mining, and other extractive activities.

- If the DOE decides that all radioactive waste is to be retrieved, the WIPP site will become available for complete resource recovery once retrieval and facility decommissioning is accomplished.

M

This policy may be re-evaluated after facility decommissioning. The following paragraphs provide a measure of clarification of the rationale used to develop the resource recovery policy.

It is the policy of the DOE to maximize the opportunity for resource recovery at the WIPP site, consistent with the requirements to isolate the emplaced radioactive wastes from the biosphere. Within five years after the first emplacement of each type of TRU waste (i.e., contact and remotely handled), separate decisions will be made about the retrieval of each kind of waste. If the DOE decides that all waste is to be retrieved, the WIPP site will become available for complete resource recovery once retrieval and facility decommissioning are accomplished.

The criterion for the DOE policy is that permanent denial of resources should be limited to those areas in which extraction activities could potentially lead to measurable effects[1] on the WIPP facilities or whose protection is needed to satisfy institutional considerations, all extraction activities that would not lead to measurable effects on the WIPP site are defined as "allowable" under the DOE policy.

Potash (sylvite and langbeinite) and hydrocarbons (natural gas and distillate) comprise the resources present at the WIPP site that are of interest considering the technology and market conditions in the foreseeable future. These resources and the methods available to recover them are described in detail in the FEIS (U.S. Department of Energy, 1980).

---

1 Measureable effects are those influences from extraction activities that could cause the assumptions made in the breach scenario consequence analyses (U.S. Department of Energy, 1980) to be unconservative.

Due primarily to institutional considerations, no potash mining in or commercial exploratory drilling (hydrocarbon or other) from Control Zones I, II, and III will be permitted. A study was conducted to investigate the possible effects of resource recovery within Control Zone IV on the WIPP facility (Natural Resources Study, Brausch et al., 1982). The following paragraphs provide a brief summary of the results and conclusions of that study.

The extraction of potash outside Control Zone III is allowable. Potential methods of mining potash include drill-and-blast, continuous mining, solution mining, shortwall, and longwall techniques. Since mining of potash is allowable, it is not reasonable to prohibit those mining techniques that make such an activity economically viable. To prohibit such activities is, in effect, to preclude mining. Accordingly, extraction ratios can be maximized in any mines developed outside Control Zone III of the WIPP site, consistent with mine safety considerations and other state and federal requirements. Solution mining will be allowable outside Control Zone III. Resource extraction by solution mining may be applied to recovery of sylvite. Solution mining for recovery of langbeinite would be ineffective because langbeinite is less soluble than the surrounding minerals (e.g., halite, sylvite). However, the lack of existing solution mining for sylvite in the Carlsbad potash mining district suggests that solution mining for potash within Control Zone IV may not be feasible.

The recovery of hydrocarbon resources outside Control Zone III is allowable. This activity includes drilling, production stimulation, and, possibly, secondary recovery. Resources located outside Control Zone III may be accessed by vertical drilling; resources located beneath the inner three control zones at depths greater than 6,000 feet may be accessed by drilling vertically outside Control Zone III to a depth of 6,000 feet and then deviating from vertical at the angle required to reach the target resource zone.

If oil or gas is found, it is not reasonable to prohibit those techniques available to the producer that maximize recovery. Enhancing the production from drilled wells by hydraulically fracturing the reservoir rock, acidizing the formation, or other applicable techniques would not be expected to affect the WIPP facility.

These types of production stimulation are used primarily to increase the permeability of the rock that contains the hydrocarbons. Secondary recovery methods (techniques used to enhance or replace the natural driving force that "pushes" the oil to the production well) and tertiary methods (techniques used primarily to decrease the viscosity of heavy crude oils) may also be employed but, because the crude oil resources at the site are not reasonably or economically extractable, these techniques are not expected to be useful unless significant technological advances and adaptations are made.

State and federal regulatory agencies, including the New Mexico Energy and Minerals Department and the Minerals Management Service of the U.S. Department of Interior, are responsible for reviewing proposed mining and hydrocarbon exploration plans to prevent injury to adjacent leases or properties. The DOE will rely on this regulatory review process to protect the integrity of the WIPP site boundary from potash mining and hydrocarbon exploration on adjacent properties. The DOE will provide assistance to these agencies during the review process upon request. In addition, the BLM will notify the DOE of any requests for permits for resource recovery activities within one mile of the WIPP site boundary.

This policy will be modified if changes in institutional requirements occur or if significant new data relevant to the policy are obtained during development and operation of the WIPP facility.

References Cited

Brausch, L. M., Kuhn, A. K., Register, J. K., 1982, Natural Resources Study, Waste Isolation Pilot Plant (WIPP) Project, Southeastern New Mexico, TME 3156, Prepared for U.S. Department of Energy.

U.S. Department of Energy, 1980, Final Environmental Impact Statement, Waste Isolation Pilot Plant, DOE/EIS-0026, Assistant Secretary for Defense Programs, Washington, D.C.

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

RECEIVED

JAN 12 1983

ENVIRON.
EVALUATION GROUP

JAN 6 1983

Mr. Robert H. Neill
Director
State of New Mexico
Environmental Evaluation Group
P. O. Box 968
Santa Fe, NM 87503

Dear Mr. Neill:

DOE Responses to EEG Comments on DOE Revised Interim Policy Statement on Natural Resource Recovery at the WIPP Site (Letter, Neill/McGough, dated December 6, 1982)

This is a response to your review comments on our Revised Interim Policy Statement on Natural Resource Recovery at the WIPP Site. Enclosed is our response to your comments and a revised Interim Policy Statement which incorporates changes resulting from your comments.

Based on the conclusions of the Natural Resource Study and the DOE's desire to mitigate any adverse effect of the WIPP Project, we believe that this policy provides the maximum opportunity for resource recovery without any degradation of public health and safety or facility integrity.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 82-0899/6363A

2 Enclosures

cc w/o enclosures:
G. L. Hohmann, TSC, AL
C. C. Little, TSC, AL

cc w/enclosures:
C&C File, IEA, TSC, AL

M

General Comment No. 1

"The Statement implies that DOE plans to relinquish all control over Zone IV of the present WIPP Site, and that DOE plans to rely on the New Mexico Energy and Minerals Department and the Minerals Management Service of the U.S. Department of Interior for reviewing plans in this zone in the future. Because of the remote possibility that activities in this zone may have an adverse impact on the long-term stability of the repository horizon, it is recommended that DOE maintain, in a Memorandum of Understanding with DOI, a provision for DOI to notify DOE of any proposal for solution mining, solution storage cavities, and mining of Castile brine in Zone IV prior to a decision on that proposal, and that DOE in cooperation with the appropriate State agencies will review these plans and submit comments to DOI for their consideration."

Response:

The WIPP Site is now defined as the lands withdrawn by Public Land Order 6232, March 30, 1982, for the purpose of performing the Site and Preliminary Design Validation (SPDV) Program and protecting the integrity of the Site. The administrative land withdrawal application for full WIPP facility construction and the legislation land withdrawal, which is being requested by DOE, will encompass these same lands, i.e., 8960 acres of public lands and 1280 acres of State land which will be subject to the withdrawal if they pass to Federal ownership.

The lands withdrawn will be managed in accordance with a DOE/BLM Memorandum of Understanding which will, among other things, withdraw DOE objection to leasing, drilling and mining outside this withdrawal area; require BLM to notify DOE of any requests for resource recovery permits within one mile of the site boundary; and prohibit habitation within one mile of the site boundary. While the DOE does not plan to exercise any control over resource extraction activities outside the WIPP Site boundary, if required, the DOE will take any actions necessary based upon our review of resource recovery permits which may include State involvement if adverse impacts could result from the proposed resource recovery permits.

This position is consistent with the conclusions of the Natural Resources Study (Brausch, et al., 1982) which indicates that resource exploration and extraction activities more than one mile from the limits of the underground facility will not compromise the integrity of the facility.

General Comment No. 2

The Policy Statement applies only during facility construction and operation of the WIPP facility. The Policy Statement should be expanded to reflect the post-operation controls, since the integrity of the repository and the consequence analyses are dependent upon some controls being maintained.

Response:

The Policy Statement does apply only during WIPP construction and initial operation, a period of about 10 to 15 years. During that period, advances in drilling and mining technology and other pertinent information can be evaluated to determine whether more or less stringent resource recovery restrictions are required to protect the facility. Early (5-10 years) in the operating life of the facility, DOE will decide whether to retrieve all emplaced waste and return the land to BLM for releasing or to finalize the present interim policy. At this time, no revisions to the interim policy are planned if WIPP becomes a permanent disposal facility.

Specific Comment No. 1

The phrase "commercial drilling" should be defined so that it clearly excludes any drilling as well as mining not related to WIPP in Zones I, II, and III.

Response

The sentence has been changed to read: "No drilling excluding that conducted for the WIPP Project will be allowed from Control Zones I, II and II."

Specific Comment No. 2

As reflected in the preceding "General Comments," EEG recommends that the MOU between DOE and DOI request that DOE (and the appropriate State agencies) be notified of any proposal in Zone IV involving solution mining, construction of solution storage cavities or mining of brine from brine reservoirs in the Castile.

Response

As indicated in our response to your first general comment above, the DOE/BLM Memorandum of Understanding, under which the lands will be managed, will require the BLM to notify the DOE of any requests for permits for resource recovery activities within one mile of the site boundary. The following sentence has been added to the third paragraph on page 4: "In addition, the BLM will notify the DOE of any requests for permits for resource recovery activities within one mile of the WIPP Site boundary."

Specific Comment No. 3

As recommended in the "General Comments" we believe that the controls which are to be maintained after decommissioning should be addressed. This would necessitate deletion of the sentence at line 25.

Response

As indicated in our response to your second general comment, the 10 to 15 year duration of remaining construction and initial operation allows adequate time to review and assess changes in technology and develop detailed plans for controls following decommissioning.

Specific Comment No. 4

The phrase "measurable effects" is ambiguous and may lead to misunderstandings. It should be deleted or more precisely defined.

Response

A footnote has been added to clarify the phrase. The footnote reads as follows: "Measurable effects are those influences from extraction activities that could cause the assumptions made in the breach scenario consequence analyses (U.S. Department of Energy, 1980) to be unconservative."

Specific Comment No. 5

This paragraph does not adequately state the potential for resources at the site. It should recognize that technology and market conditions are not predictable and some materials, such as may be found in Castile brine, or Salado salt could become of economic value if technology and market conditions are substantially modified.

Response

The brief paragraph on resources present at the site is not intended to describe all possible resources which could become of economic value. It does indicate the two resources that are of current interest and whose recovery could potentially affect the underground facility. In the event that other resources at the WIPP Site become of economic value in the future, exploration and extraction technology for such resources will be evaluated and, if required, appropriate changes will be made in the Policy Statement.

Specific Comment No. 6

The D'Appolonia draft report "Natural Resource Study" indicates that "resource grade oil" is under the site.

Response

The hydrocarbon resource evaluations of the WIPP Site are based on known resources of natural gas and crude oil in the region and the probability of discovering new reservoirs. The fundamental assumption is, therefore, that the WIPP Site has the same potential for containing hydrocarbons as the much larger area for which exploration data are available. Although the New Mexico Bureau of Mines and Mineral Resources (NMBM & MR) study shows that minor deposits of crude oil are statistically probable at the WIPP Site, later studies have discounted the existence of economically attractive quantities of crude oil at the site.

HEALTH ENVIRONMENT department

"Equal Opportunity Employer"

STATE OF NEW MEXICO

ENVIRONMENTAL EVALUATION GROUP
320 Marcy Street
P.O. Box 968
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(505) 827-5481

January 21, 1983

Mr. Joseph M. McGough
Project Manager on WIPP
WIPP Project Office
U.S. Department of Energy
P.O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. McGough:

This is in reply to your letter (WIPP:JMM 82-0899/6363A) and enclosures of January 6, 1983 concerning the DOE Revised Interim Policy Statement on Natural Resource Recovery at the WIPP Site. While we are generally satisfied with the revised Policy Statement, as provided in your recent letter, there remains one concern which needs to be resolved.

The Policy Statement and the DOE/BLM Memorandum of Understanding include the requirement that BLM notify DOE of any requests for resource recovery permits within one mile of the new site boundary. While the DOE does not plan to exercise control over resource extraction activities outside the new WIPP site boundary, we note that, "if required, the DOE will take actions necessary... which may include State involvement if adverse impacts could result from the resource recovery permits." So that the State may continue to make its own independent analysis of potential adverse impacts, we would like DOE's assurance that EEG will be notified of any request for resource recovery permits within one mile outside of the site boundary. And further, we would like to be advised of the planned Federal action on such requests prior to the initiation of the resource recovery.

The statements accompanying the Policy Statement implying no possibility of objection to solution mining of potash and secondary recovery for hydrocarbons outside the Control Zone III should be revised to indicate that any proposals for fluid injection underground within one mile of the WIPP site will be evaluated by DOE and EEG to determine if such proposals will adversely affect the integrity of the repository.

Sincerely,

Robert H. Neill
Director

RHN:jdc

2-100AG2-19-1-2

cc: TSC,IEA

M

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

RECEIVED

FEB 28 1983

ENVIRONMENTAL
EVALUATION GROUP

FEB 24 1983

Mr. Robert H. Neill
Director
State of New Mexico
Environmental Evaluation Group
P. O. Box 968
Santa Fe, NM 87503

Dear Mr. Neill:

As you know, the DOE Revised Interim Policy Statement on Resource Recovery at the WIPP Site is based on the Natural Resources Study which concludes that resource recovery outside the Site boundary (Zone III) using current technology, will not compromise the integrity of the WIPP underground facility. Accordingly, the DOE does not plan to exercise any control over resource recovery activities outside the Site boundary and will rely, primarily, on other Federal and State regulatory agencies to assure that the WIPP boundaries are not violated. As an additional protection measure, the BLM will notify the DOE of any requests for resource recovery permits within one mile of the WIPP Site boundary so that the DOE will be aware of resource recovery activities near the Site.

We do not expect to perform a comprehensive review of resource recovery plans utilizing conventional technology; however, any plans which employ unusual methods or advanced technology will be evaluated to determine possible effects on the underground facility. Upon receipt of notification of unusual or advanced technology planned resource recovery activities from the BLM, we will forward the information to the EEG.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 83-0171

cc:
G. L. Hohmann, TSC, AL
C. C. Little, TSC, AL
C&C File, IEA, TSC, AL
M. Wilson, OCC, AL

DEEP DISSOLUTION

SAND 82-0461

HEALTH & ENVIRONMENT department

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STATE OF NEW MEXICO

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August 13, 1982

M

Joseph M. McGough
WIPP Project Manager
U. S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, NM 87115

Dear Mr. McGough:

Enclosed is a summary of our comments on the Draft "Interim Report: Dissolution of Evaporites in and Around the Delaware Basin, Southeastern New Mexico and West Texas," by Stephen J. Lambert.

We would appreciate your consideration of these comments in the preparation of the final report. As with the other formal reports required by the Stipulated Agreement, we would like to have our staff and yours meet to discuss the final version of the document before its publication.

Sincerely,

[signature] -for-

Robert H. Neill
Director

RHN:eg
2-047AG2-15-1-1
Enclosure

cc with attachment:
George S. Goldstein, Ph.D., Secretary, Health & Environment Department
Joe Hewitt, Secretary, Highway Department
Charles Turpen, Secretary, Energy and Minerals
Jeff Bingaman, District Attorney
Russell F. Rhoades, Director, Environmental Improvement Division
Joe Canepa, Attorney at Law
James K. Otts, Chairman, Rad-Waste Consultation Committee
D. T. Schueler, Assistant Manager for Project of Energy Programs
Wendell Weart, Sandia Laboratories
TSC, IEA

REVIEW COMMENTS

CONCERNING

Interim Report: Dissolution of
Evaporites in and Around the Delaware
Basin, Southeastern New Mexico
and West Texas, by Stephen J. Lambert
Sandia National Laboratories
Printed February, 1982

Comments by

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
P. O. Box 968
Santa Fe, New Mexico 87504-0968

August 12, 1982

INTRODUCTION

These comments are based upon a critical reading of the report and many of the references cited in the report. A meeting with the author of the report, Steven Lambert, was held on July 21, 1982 to clarify the important points discussed in the report. Since a major part of the report deals with the ideas of salt dissolution at depth as postulated by Roger Anderson, he was also invited to attend this meeting. Some of the following comments resulted from this and subsequent discussions with Lambert and Anderson.

The report is a major effort to include in one document the various components of the theory, experimental and field work bearing on the partial removal of evaporite beds in the Delaware Basin. The work and scholarship displayed in the report is most commendable.

GENERAL COMMENTS

The purpose of the State's request for this document was to get DOE's most current thinking on the matter of the dissolution of evaporites in the Delaware Basin. The main area of concern in this matter is the possibility of removal of salt from the repository horizon in lower Salado by circulating waters, in the recent geologic past and the possibility of such dissolution being ongoing. Roger Anderson has published several papers during the past 10 years developing this hypothesis. This report was expected to provide DOE's views on the feasibility of such dissolution having taken place and the consequences and threat, if any, to the integrity of the proposed waste repository.

Although the report has presented data on the geologic, geomorphic, geohydrologic and geochemical aspects of the question of dissolution and removal of salt and has presented a review of various models of dissolution, it has not addressed the possibility of "deep dissolution" in sufficient depth. It is hoped that the document in its final form will either accept or reject the idea of active dissolution of salt beds in the lower Salado formation in the vicinity of WIPP site. Of course, detailed reinterpretation of the existing data and argumentation will have to be provided for a conclusion.

To help the author accomplish the objective of a more definitive conclusion of the deep dissolution controversy, the following is a discussion of the important aspects of this question, with reference to their treatment in the draft report.

Non-existence of Lower Salado Salt

Anderson has shown that a large amount of salt from the lower part of Salado formation is missing from the Delaware Basin and has attributed this to the removal by dissolution at depth in geologically recent times. A number of acoustic logs from oil and gas wells have been used by Anderson as hard data to advance his hypothesis. The report has acknowledged that the salt is missing from the Lower Salado, but does not acknowledge that it is missing due to dissolution. Other ideas advanced are non-deposition or erosion shortly after deposition (p. 98). No arguments are advanced, however, for statements such as, "...removal of some halite (if originally deposited) near the basin margin must have occurred during Castile time (not Pleistoene)" -p. 90.

The argument of non-deposition could easily be settled with a statistical study of regional thickness trends in acoustic logs. However, according to Anderson, (written communication) there is no reason to do this because lateral changes into depressions are dramatic and associated with collapse and therefore not the result of original deposition (or non-deposition). Also, according to Anderson, the argument of dissolution at some earlier than late Cenozoic time is not tenable because of the age of the fill in the collapse.

According to Lambert, "A complete review of raw geophysical log data, and possible interpretations of them, will be undertaken, together with an independent determination of thickness variations in the Castile and Salado formations" (p. 98). EEG looks forward to the results of such a review. In fact, this should have been completed before issuing the draft report.

An important point raised in the report with regard to the use of acoustic logs for dissolution studies is that "the sections of anhydrite which are postulated to be dissolution residue by virtue of no interlayered halite, show no log signature of chaotic dissolution residue, but are nearly pure anhydrite" (p. 97). Also such zones "bear the signatures of anhydrite, not gypsum as would be present in abundance if large quantities of fresh water were circulating in subsurface open space" (p. 98). It appears that the best way to resolve whether there is a distinct signature for the dissolution residue would be to run an acoustic log in one of the WIPP holes in Nash Draw (WIPP-25 to WIPP-30) where dissolution residue is known to occur and compare the signatures thus obtained with those used by Anderson where salt sections have changed to Anhydrite.

Other specific instances of "errors" (p. 91) in Anderson's data and interpretations are addressed under Specific Comments (for pages 88-100).

<u>Connection of Evaporite Beds and the Basin Aquifer</u>

In his deep-dissolution model, Anderson (1978, 80, 81) invoked the Delaware Mountain Group aquifer as a pathway for supply (i.e., source) of unsaturated water to the evaporite beds for salt dissolution as well as for removal (i.e., sink) of saturated brines. Contrary to the findings of Hiss (1975) and Anderson, the report rules out the DMG aquifer as a potential supplier of water for dissolution in the evaporite beds, for the following reasons.

a. "The entire Delaware Mountain Group is probably not a single, vertically interconnected hydrostratigraphic unit" (p. 37).
b. In the Bell Canyon formation, as encountered in AEC No. 8 "Static water levels were 615 and 560 feet below land surface as supported by the lower and upper sands, respectively. This conspicuous difference (in levels of water of similar density) attests to the strata-bound, vertically-isolated nature of water occurrences in the Bell Canyon formation." (p. 38)
c. "The deposition-controlled porosity containing natural gas in isolated lens-shaped sandstone reservoirs is also an indication of but small degrees of vertical and horizontal connected porosity in the Bell Canyon formation. Thus, in the upper 700 feet of the Bell Canyon formation, the total saturated thickness is less than 30 feet."
d. "Much of the Bell Canyon water is highly saline, but not completely saturated with sodium chloride under the evaporites" (p. 39).
e. "The salinity does not abruptly rise from west to east as evaporites appear in the overlying section" (p. 39).

f. "The water contains solutes in combinations not found in the evaporites" (p. 39). "Bell Canyon waters from AEC-7, AEC-8 and ERDA-10 have Na/Cl ratios of 0.50, 0.46 and 0.56 respectively" (p. 150). "Na/Cl (weight) ratio of brines formed by dissolution of salt in western Oklahoma is remarkably close to 0.64, regardless of whether the water is a low-salinity or a saturated brine" (p. 150). "Oil-field brines consistently have Na/Cl ratios of 0.55 or less, and the ratio decreases well below 0.50 as the salinity increases" (p. 150). "Thus we see that the Bell Canyon waters clearly have closer affinity with oil-field brines than with dissolution brines (and therefore) it has not been a sink for dissolution brines" (p. 150).

The reasons cited above can be disputed individually, but together they do present a formidable challenge to the idea of an active interconnection of the DMG aquifer with Castile and Salado beds.

In addition, the report also rules out any interconnection of the Bell Canyon aquifer with the Capitan aquifer on the basis of the Bell Canyon potentiometric heads being higher than the juxtaposed Capitan, "at all locations along the Basin margin....even after corrections are made for salinities" (p. 44). This, by itself, does not eliminate the possibility of the Bell Canyon water moving into the Capitan aquifer in the eastern part of the basin.

Replacement Limestone as Basis for Past DMG-Evaporite Bed Connection

Anderson (1980) has cited replacement limestone masses - "Castiles" and "limestone dikes" as evidence for past movement of water from the DMG aquifer to the evaporite beds. Konrad B. Krauskopf (EEG-7, p. 85) commented on these features as follows:

> "The fact that Bell Canyon water has invaded the overlying evaporite sequence at places other than the immediate vicinity of the Capitan reef seems clearly demonstrated by the replacement of Castile Anhydrite by biogenic limestone, locally accompanied by sulfur, in the western part of the Delaware Basin. The reduction of sulfate and its replacement by porous carbonate with a high carbon 12/13 ratio is clearly the work of bacteria, and the organic matter needed for bacteria to flourish could have come only from the Bell Canyon."

Lambert (in the report under review) suggests that "A more likely source for the water to supply the formational process for Castiles is in the nearby solution-subsidence troughs of the type described by Olive (1957), which are both near-surface and recently have contained water" (p. 74). There are two serious errors in this suggestion. Firstly, it does not take into account the brecciation seen in the Castiles, and more importantly, it is contrary to conclusions reached by all the serious investigators (Kirkland and Evans, 1976; Smith, 1978) of these features, without presenting any analysis or reasons.

Castile Formation Brine and Bell Canyon Aquifer

The report rules out the possibility of interconnection between the Bell Canyon waters and the brine encountered at several locations in the Castile Formation. "The (ERDA-6) water's unique stable isotope relationships isolate it from any active source in the Capitan or Bell Canyon. The solutes in the Castile water also make it incompatible with the Bell Canyon; a high sulfate (Castile) water and a high calcium water (Bell Canyon) cannot be in connection lest gypsum precipitate (p. 120)." The proposed deepening of ERDA-6 through the upper Bell Canyon formation should help in answering this question.

Continuity of Strata in Castile

The report (pp. 91-92) criticizes Anderson (1978) for implying that thickening and thinning of Halite Units in Castile are related to deep dissolution and, by comparing the Halite-I "sinks" of Anderson with the isopach map of Anhydrite-I (Snider, 1966) (Fig. VII-2), concludes that "several of these thinings actually represent non-deposition, due to a local elevation of substrate above base level" (p. 92). According to Anderson (personal communication, 1982), the mounds shown on Snider's (1966) map (Fig. VII-2 of Lambert's report) probably resulted from salt tectonics and are not due to non-deposition.

Clearly, there are possible errors in Anderson's estimate of the amount of salt removal through dissolution at depth, due to the apparent assumptions (p. 89) made by him in calculating the percentage of removal. On the other hand, non-deposition or pre-Cenozoic subaerial erosion does not satisfactorily explain the amount and pattern of salt missing.

Geomorphic Evidence against Deep Dissolution

The report cites (p. 82) Bachman's interpretation of the Gatuna stream deposits as evidence of the westward migration of the Pecos river; and also that this is "contrary to a monotonically-eastward progression of postulated evaporite dissolution, if the river is said to keep pace with the dissolution front". Possibly this argument is in reference to the possibility of eastward migration of the Pecos which was suggested in an early EEG report (EEG-2 pp. 16-17). However that possibility was based upon the subsidence which has occurred east of the Pecos, and such subsidence may continue to move eastward if dissolution is occurring at depth. In spite of the assertion made in the report that, "Scarp formation appears to be insensitive to depth of halite removal and appears to keep pace with halite removal" (p. 139), slow removal of salt at depths of approximately 2000 ft. below the surface may not result in the formation of a scarp prominent enough for the river to follow. Erosion by water or by wind would most likely "keep pace to obliterate scarps as they form" (p. 140), if they are formed by lateral sapping of salt at depth.

The Timing of Deep Dissolution

Chapter IX of the report presents the evidence for dissolution in Triassic, Jurassic and Tertiary times. Anderson (1981) presented detailed arguments against Bachman's (1980) interpretation of the Cretaceous outcrops resting on the Castile formation as signifying a profound episode of dissolution down into the Castile during the Jurassic period. Anderson (1981) has referred to several published instances of Cretaceous rocks resting ("implaced by collapse") on rocks of various other ages. The main evidence cited by Anderson (1981) in favor of the more recent age of much of the deep dissolution is the age of the fill in Maley and Huffington's (1953) depressions; the depressions and the fill are clearly post-tilting and the Salado salt is absent in the center of these depressions.

The report acknowledges that, "San Simon Sink, at least, is a collapse feature" (p. 75) but has not commented on Anderson's postulation that the collapse has resulted from the dissolution of lower Salado Salt by waters derived from the Capitan reef aquifer (Anderson, 1981). The question has been left open with remarks such as, "Subsidence in San Simon Sink might (also) be attributable to collapse into a phreatic cavity in the Capitan" (p. 148), "It is likely that these depressions (as well as such features as San Simon Swale) are in part erosional features" (p. 152-153), "The Cenozoic-filled depressions could simply be pre-Gatuna deeply-developed equivalents of Nash Draw" (p. 154) and "The ultimate nature of San Simon Sink, however, remains unresolved." (p. 76).

Stratabound Dissolution

A model of deep-dissolution called "Stratabound Dissolution" has been presented in the report as an alternate hypothesis to that of Anderson's. The essential features of this model are outlined on pages 153-154 and in Figure X-2.

According to the report, "The fatal weakness of the Anderson (1981) model of dissolution is the identification of the Bell Canyon formation as a sink" (p. 150). On the other hand, "One limiting factor in the stratabound dissolution model is as yet the inability to identify an efficient sink for the disposal of saturated brine of dissolution origin" (p. 161). One might say that this is a fatal weakness of thé stratabound model also. The other weakness of this model is its ambiguity with respect to the geologic horizons involved and the time of occurrence.

SPECIFIC COMMENTS

Page 24, paragraph 1 - Jones et al. (1960) refers to drill hole logging in potash deposits which are in the Salado formation. This comment is therefore applicable to the Salado marker beds, which at any rate, "are traceable in the subsurface over horizontal distances of several kilometers to tens of kilometers" (p. 26, 4-6 lines). Anderson et al. (1978) have shown that Castile units can be correlated in wells as much as 113 km. apart.

Page 44 (last 2 lines) - The water from Bell Canyon could flow into Capitan?

Page 83 (First 2 lines) - But the line of cross-section in Figure x-1 does not pass through San Simon Swale!

Page 90 (Bottom) - "... removal of some halite (if originally deposited) near the basin margin must have occurred during Castile time (not Pleistocene)." What is the basis for this statement?

Page 100 - With regard to the quotation from Bachman (1980), Anderson points out that the correct interpretation is that of Castile-Salado unconformity and not "pan" deposition. At any rate, it does not address dissolution and collapse in lower Salado. With respect to the quotation from Jones (1972), Anderson points out that there are lateral variations in Salado, but not enough to explain the correlatable salt zones and missing salt as seen in logs.

Page 103, Fig. VII - 1-B - According to Anderson (personal communication), his interpretation of these logs was wrong. Cowden Anhydrite should be at the top of UNM Phillips No. 1 and higher in all other logs. The discussion of this figure on p. 97 is therefore irrelevant.

Page 144 - There should be detailed discussion of Maley and Huffington's depressions and Pleistocene dissolution and fill exhibited by them in this section.

Page 160 (3rd para) - Anderson's (1980) Brine Density Flow works laterally as well as vertically, driven by density gradient.

Page 161 (Mid Para) - Maley and Huffington's Cenozoic filled depressions provides the evidence that much of the salt removal at depth occurred in late Cenozoic, according to Anderson (1981).

SUMMARY AND RECOMMENDATIONS

Looking at Figure X-2 and the discussion of the Stratabound Dissolution concept, one gets the impression that the author of this report accepts the central basis for the idea of deep dissolution i.e., the preferential removal of salt at depth in the lower Salado beneath the Maley and Huffington depressions. The stratabound explanation is a fairly strong commitment to the idea of removal of salt by dissolution. The admission to the lack of a "sink" for the brine makes the concept difficult to accept. Not completing a thorough review of the geophysical logs and cores from wells to examine the causes for the absence of salt in the lower Salado horizon is a serious omission on the part of DOE which should be corrected as soon as possible.

It appears that one could skirt the issue of deep dissolution in the Delaware Basin altogether Vis-a-Vis the safety and integrity of the WIPP site, if an area of stable platform into which dissolution at depth has not made a dent, could be established around the WIPP site. This would, of course, require a fairly accurate estimate of the rate of advance of the "dissolution front", which could then be used to estimate a minimum period of safety. However, such an effort cannot be undertaken unless the mechanism for salt removal at depth is fairly clearly understood. The lower Salado salt is seen to be missing on accoustic log of Perry Federal #1 well, which is less than 2 miles east of the Zone IV boundary of WIPP. And of course, the encounter of brine at WIPP-12 has opened the entire question of the relationship of brine in Castile and the mechanism of salt removal in lower Salado formation. These questions must be answered in the best possible manner if confidence is to be placed on the geological integrity of the WIPP site.

EDITORIAL COMMENTS

1. Page 3, line 4 - delete "as."
2. Page 5, line 7 - "dendritic" is misspelled.
3. Page 9, equation in middle of page - The formula for polyhalite is incorrect. It should be

   $$Ca_2K_2Mg\ (So_4)_4.H_2O$$

4. Page 22, line 2 - The word "with" or "to" should be inserted between "proximity" and "the Ochoan."
5. Page 36, line 5 - The word "water" should be "salt" or "evaporites."
6. Page 49, 2nd paragraph, line 1 - The word "Rustler" is misspelled.
7. Page 72, line 1 - The word "completion" should be "completeness."
8. Page 94 - The first sentence on this page needs rewording....something like, "Anderson (1978) did not entertain the possibility that infra-Cowden thinning over the reef was due to reef-controlled non-deposition rather than reef related dissolution from below."
9. Page 163, 3rd line - "Origin" should be "original".
10. Page 164, para 4, line 4 - "features" is misspelled.

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

NOV 0 5 1982

Mr. Robert H. Neill
Director
State of New Mexico
Environmental Evaluation Group
P. O. Box 968
Santa Fe, NM 87503

Dear Mr. Neill:

Reply to Review Comments by EEG on Deep Dissolution Report (Neill to McGough, August 13, 1982)

Your comments on the draft Deep Dissolution Report have been taken into consideration, and the enclosed response has been prepared by the authoring organization.

It is necessary to keep in mind that it was the intent of this work to show that:

(1) there is no direct evidence of present or past preferential removal of lower Salado halite;

(2) previous (Anderson's) hypotheses have been tested and found wanting;

(3) a potentially efficient mechanism for stratabound dissolution (more efficient than "brine density flow" involving Bell Canyon, Capitan or Castile) had been identified;

(4) there is little evidence for stratabound dissolution anywhere save in the Rustler;

(5) if an efficient sink for brine disposal cannot be identified, there is no active dissolution, regardless of the postulated mechanism, and;

(6) if greater confidence in these conclusions is required, specific tests of the stratabound hypothesis could be made, for it is a testable hypothesis.

If after reviewing these responses you feel that further discussion of your comments is warranted, please contact my office to arrange for a meeting with the authors prior to printing of the final report.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 82-0759/6217

Enclosure

cc w/o enclosure:
R. K. Brown, TSC
G. L. Hohmann, TSC
C. C. Little, TSC
W. Weart, Sandia
C&C File, TC

M

ATTACHMENT TO MCGOUGH LETTER
NUMBER 0759/6217 DATED 11/5/82

Non-existence of Lower Salado Salt

Anderson's "hard data" for absence of salt are really his interpretations of acoustic logs, not the logs themselves. We disagree in numerous instances with his stratigraphic picks. A rereading of p. 90 will reveal that the page is replete with arguments for the statement about some halite removal (if any) being Permian and not Pleistocene.

Use of the word "missing" forces specific conclusions not appropriate with a sense of healthy skepticism toward any hypothesis. Non-deposition, for example, means "not missing." The whole discussion on p. 92 says the thickness of anhydrite near the basin margin is strong evidence that no halite was deposited, or if originally deposited, "removal . . . must have occurred during Castile time."

Despite your assurance from Prof. Anderson that thickness trends are not worth reanalyzing, we shall continue our re-interpretation as we have proposed and you have urged. As to the age of fill, Maley and Huffington called it Cenozoic. There is no evidence that we are aware of that assures us that broad definition (Cenozoic) has any precision greater than 65 my to present. No faunal or radiometric data are known on which to base any maximum age. Gatuna age deposits are known as part of the fill, but that does not demonstrate anything other than a minimum age. The age of the fill in the collapse areas is not well documented as all Pleistocene; therefore, Anderson's speculation of constraint of all dissolution to the Pleistocene on this basis alone is not tenable.

SNL proposed log correlations early in this process, but the preparation of the dissolution and deformation reports is what convinced us of the necessity. Activity was deferred until the specific goals of such a reinterpretation could be defined, and additional resources could be allocated, since the activity will serve many endeavors (structure, deformation, dissolution, etc.).

The acoustic logs have been run in Nash Draw holes (WIPP 25 through 30) and compared with Anderson's logs. That comparison was the basis for saying that the Anderson logs showed no signature of either gypsum or dissolution residue. Specific examples will be included to demonstrate the point.

Connection of Evaporite Beds and the Basin Aquifer

The potentiometric (static) differences between Bell Canyon and Capitan do not eliminate the possibility of interconnection. A re-reading of p. 45 will uncover a further, more powerful, argument against interconnection in the immense difference in osmotic potentials. The report says "there is no tendency" for water movement across the Capitan/Bell Canyon interface, and also explains the basis for this statement. Page 45 explains the high osmotic gradient between Capitan and Bell Canyon waters, which must be taken into account as well as the static potentiometric gradient in predicting degree of water movement. The discussion will be augmented to clarify that in view of these opposing conditions, flow in either direction is considered unlikely.

Replacement Limestone as Basis for Past DMG-Evaporite Bed Connection

It was stated that the hypothesis of Kirkland and Evans was not the primary point of review; perhaps a more orderly discussion in the text is necessary so that the point about castiles not necessarily indicating deep dissolution will be considered "serious."

There are several serious flaws in the Kirkland and Evans suggestions and the Anderson speculation; chief among these is the innate (thermodynamic) incompatibility between (oxygenated) meteoric water (postulated to have moved freely in the Bell Canyon) and highly reduced hydrocarbons in the Bell Canyon.

By "errors," it is assumed that you mean the discussion is incomplete. It isn't what might normally be considered an "error" to suggest explanations, no matter how "serious" the investigation. We fail to comprehend how brecciation in the castiles is inconsistent with a deeper development of Olive's solution - subsidence troughs in the Gypsum Plain.

Castile Formation Brine and Bell Canyon Aquifer

There remains no "question" in our minds of Castile/Bell Canyon isolation in view of fundamental thermodynamics. Deepening ERDA-6 just to "answer" the "question" (which we consider non-existent) is not expected to help much. We feel that this comment recommends no useful change to the original text.

Continuity of Strata in Castile

It is Lambert's opinion expressed in the report that thinned halite overlying thickened anhydrite represents a syndepositional phenomenon. Apparently, Anderson considers it deformation. It is difficult to imagine how salt tectonics can give rise to anhydrite mounds, long after sedimentary consolidation. Anhydrite does not flow. The deformation report (Barrows et al., in preparation) considers that compensating variations in thicknesses of Castile anhydrite and halite beds are due to deformation (rather than late Cenozoic dissolution), despite cursory geological reasoning for such a situation.

It can be agreed that non-deposition or pre-Cenozoic subaerial erosion does not explain all things concerning the amount and pattern of salt "missing." The professional opinion is expressed that these are very important factors which can explain the basic amount and pattern. Certainly a very strong case is made that a pronouncement of "deep dissolution" through the last few million years has very serious shortcomings whether the Anderson or Lambert models are applied. We are unable to make specific revisions based on the comment.

Geomophic Evidence Against Deep Dissolution (sic)

The results of serious investigations of dissolution in the Permian Basin of west (and northern) Texas shows the presence of scarps and dissolution as a front (Gustavson et al., 1980). If erosion destroys such a scarp or prevents it from forming, the dissolution rate is reasonably slow. If scarp formation due to "deep dissolution" is so slow that erosion obliterates scarps, (and the river keeps pace), the dissolution is so slow as to be inconsequential on the time scale appropriate to WIPP. Simultaneous blanket dissolution to prevent scarp formation is a difficult process to envision as "fresh" water has to be distributed over large areas before dissolving salt. There is no revision apparent for responding to the comment.

The Timing of Deep Dissolution

Rereading of p. 142 will reveal that Bachman's Cretaceous occurrences were not used as timers, and the report considers some of Anderson's objections to them valid. The absence of Jurassic rocks (Bachman, 1980) still stands as evidence of Jurassic or post-Jurassic exposure, since no Jurassic has been found associated with the Cretaceous collapsed rock.

The comment has been made (p. 141) that not all of these times when the area was above (and below) sea level are separable. However, there is consistent evidence for dissolution during earlier times, no matter how the Cretaceous rocks are interpreted. We have to disagree over the precision of the age of fill in the troughs -- see comment above, same subject.

No comment was intended to be made on Anderson's postulation of lower Salado dissolution by Capitan water under San Simon Sink. Overnight collapse occurs, however, only in brittle rock, and that is strong evidence for collapse into a phreatic cavity in the Capitan. A large natural open cavity in halite at 2000 ft depth has not been found: such cavities are not preserved so as to collapse catastrophically. See p. 147 (quote from Brokaw, et al, 1972). It was intended that the question of San Simon Sink be left open. The origins of Capitan-associated features (such as San Simon Sink, Carlsbad Caverns, and "breccia pipes") were not intended to be ultimately resolved by this report, unless they are shown by consequence analysis to be worthy of consideration as direct threats to the integrity of the WIPP horizon. This will be made explicit in the revision.

Stratabound Dissolution

The identification of the Bell Canyon Formation as a sink in Anderson's (1981) model is a fatal flaw. The lack of a demonstrated sink for stratabound dissolution is a problem, but not fatal in the same sense. This lack of a good candidate is a major reason why all schemes for dissolution at depth that are postulated to be very active now must be considered suspect. The parenthetical remark on p. 152 will be made more explicit in this regard.

Discussion of the stratabound model will be clarified to indicate that the only evidence of its occurrence is in the lower Rustler/upper Salado of Nash Draw.

Specific Comments

p. 24, para. 1: It is recognized that C. L. Jones can correlate the Salado marker beds as well and as far as R. Y. Anderson can correlate the Castile anhydrites.

p. 44 (last 2 lines): Yes. No tendency for Capitan water to flow into the Bell Canyon. See p. 45, middle. No tendency is indicated for flow in the other direction, either.

p. 83 (first 2 lines): Indeed the cross-section does not pass through San Simone Swale. A transition phrase will be added to make the reasoning smoother. The discussion concerns a general category of depressions to which San Simon Swale may belong. It is not necessary that Figure X-1 show San Simone Swale, since the relationship is clear along the line of Section A-A.

p. 90 (bottom): The basis for the statement is that the total thickness of Castile halite/anhydrite paired units remains the same. The only time that anhydrite could have formed "mounds" over which halite was thinned was the Permian, not the Pleistocene. Words will be added to that effect.

p. 100: The quotation is accurate and it does concern the evolution of evaporites within the basin. An unconformity at the Castile/Salado boundary would be an acceptable way of having Castile halite beds in the western part of the basin disappear, but we doubt this is the inference Anderson means to have drawn. The known Salado variations are evidence that beds may have disappeared during Salado times. No claim is made that it accounts for all "missing" halite.

Anderson has totally ignored the greatly thickened anhydrite sections that occur in the same boreholes with the thinned halite sections. This neglect makes his interpretations suspect. Thus, variations in the Salado can be explained by processes other than Pleistocene dissolution. This statement will be made explicit.

p. 103: The discussion is not irrelevant just because Anderson found an error in his interpretation. The interval nomenclature will need to be annotated or clarified. Final revision will probably await reinterpretation of the log data. This is an example of why the interpretation should be redone.

p. 144: It is not the intent of this work to reproduce all the source works within it. It will be clarified that the "Cenozoic" age of all the fill is not well established, and therefore cannot be used as a strong argument in favor of dominantly Pleistocene dissolution.

The basis of ages (e.g., lack thereof) for fill in the depressions will be more explicitly stated. The chapters on recommendations will be more explicit concerning some followup investigations of information on the fill.

p. 160 (3rd para.): There is geological evidence that Brine Density Flow does not work at all in this geologic setting. There is no salinity stratification observed in any subevaporite aquifer in the basin (excluding the Capitan). See p. 161, 1st para.

p. 161 (mid-para.): There is no evidence that all the Maley and Huffington fill is "late Cenozoic." Anderson's speculation is unwarranted solely on this basis. Again, it will be re-emphasized that the age of the fill is largely unknown.

SUMMARY AND RECOMMENDATIONS

The comments do not recognize that the Figure X-2 is diagrammatic and hypothetical. Looking at the text, we find it difficult to get the impression that the report accepts "deep dissolution." In addition, to our knowledge this report is the first instance of the detailed examination of the immense difficulty of brine disposal in any proposed dissolution mechanism, given the geohydrologic conditions of the Delaware Basin. If the concept of dissolution is made difficult to accept for want of a sink, there can be no active dissolution.

Stratabound dissolution is a hypothesis to explain how dissolution is occurring (Nash Draw); the lack of sink makes any hypothesis regarding active dissolution at great depths suspect. See similar earlier comment.

The review of geophysical logs had been previously done by Anderson under contract. The drafting of dissolution and deformation reports demonstrated the necessity of re-examining and updating the interpretation.

The problems with an operating, active method of "deep dissolution" will have to be more explicitly summarized. No estimate of rate of advance is germane without an operating mechanism. A revision to express the threat from stratabound dissolution (vis a vis Nash Draw) will be included.

There is no relationship apparent between brine reservoirs and salt removal.

The example of Perry Federal #1-31 cannot be used to illustrate preferential (active?) dissolution in the lower Salado. Note the greatly thickened section of Castile Anydrite III underlying the "thinned" halite between "Cowden"(?) and MB136. The total thickness of this section does not differ markedly from regional thickness, thus supporting depositional thinning of halite over an anhydrite "mound."

At the risk of repetition, we say that it has been scientifically established that WIPP-12 brine is not active dissolution brine. We do not consider the "relationship of brine in Castile and the mechanism of salt removal in the lower Salado Formation" an "open question." Such an issue has been addressed in detail on pages 114 through 121.

HEALTH
ENVIRONMENT
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January 3, 1983

Mr. Joseph M. McGough
Project Manager on WIPP
WIPP Project Office
U. S. Department of Energy
P. O. Box 5400
Albuquerque, NM 87115

Dear Mr. McGough:

RE: Deep Dissolution Report (SAND 82-0461)

Your reply to EEG's comments on the subject report (McGough to Neill, 11/5/82) and the attachment to your letter, indicate that the author of this report has accepted a number of EEG suggestions for improvement of the report. We understand that the final version of the report will include the following major changes.

a. A reinterpretation of geophysical logs of Salado and Castile strata in the northern part of the Delaware Basin will be completed and the results clearly presented to prove your assertion that the absence of halite in Salado is due to non-deposition or erosion shortly after deposition.

b. Specific examples of accoustic logs from WIPP 25 through 30 will be used to show that the zones of missing salt in Salado, as interpreted from accoustic logs of deeper boreholes do not show signature of either gypsum or dissolution residue.

c. Clear examples and explanations will be provided to justify the contention that the total thickness of Castile halite/anhydrite paired units remain essentially the same in the basin. Figure VII-2 (p. 105) and the discussion on page 92 show some examples of errors in Anderson's argument but do not bring out the point being made convincingly.

M

There are other points in your reply to our comments which could be argued from an academic point of view. However, the changes listed above will satisfy our major concerns in this area.

Sincerely,

Robert H. Neill
Director

RHN:eg

2-096-AG2-15-1-1

cc: TSC, IEA

DMG HYDROLOGY

TME-3166

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STATE OF NEW MEXICO

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August 25, 1982

Mr. Joseph McGough
Project Manager of WIPP
U.S. Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, NM 87115

Dear Mr. McGough:

Enclosed are our review comments regarding the draft of "Delaware Mountain Group (DMG) Hydrology - Salt Removal Potential NM78-648-813B. April 1982" by D'Appolonia Consulting Engineers. We shall be looking forward to hearing your response.

Sincerely,

Robert H. Neill
Director
2-050AG2-18-3
RHN:du:lgr

cc: TSC, IEA

M

Comments on Draft DMG Hydrology Report

INTRODUCTION

These comments are based upon a critical reading of the report and many of the references cited in the report. The calculations, assumptions and data in the report were checked for accuracy and reasonableness. Most of the calculations are correct - a few specific errors or discrepancies are noted under Specific Comments. Construction of some of the graphs presented in Chapter 5 is unclear - these are also discussed under Specific Comments. The section on General Comments contain our suggestions for improvement of the report on a thematic basis.

EXPECTATIONS FROM THE REPORT

The "Cost and Merits Evaluation for Stipulated Agreement Activities" attached to the 8.31.81 letter from Schueler to Goldstein contained details of the proposed work and expected results. In our judgement, the following two items have not been included in the draft report.

a. "Possible communication (of DMG) with other aquifers e.g. reef aquifer, San Andres limestone aquifer and shallow aquifers" has not been treated in this report. Although the details on this theme are expected in the regional hydrology report, a brief treatment of this subject will be desirable in this report for completeness. We recommend adding a subsection under section 2.2 of the report for such discussion.

b. The "Expected Results" section of the Costs and Merits document for DMG Hydrology states, "Additionally, the relative merits of various dissolution theories will be discussed." We understand that the primary document for such a discussion is the Deep Dissolution report, but the DMG Hydrology report should at least discuss the possibility of proposed mechanisms, other than Anderson's deep dissolution, explaining the observed features of DMG and Reef hydrology and hydrogeochemistry. A discussion of Bachman's "Solution and fill," subaerial erosion during Jurassic time and Lambert's "Stratabound Dissolution" in this context would be very appropriate and useful.

GENERAL COMMENTS

Acceptance of Deep Dissolution

On the basis of geological and geochemical evidence and observed rates of mass transport, the report has accepted the possibility of deep-seated dissolution at the margins of the Capitan reef and above it. The following quotations from the report indicate such acceptance.

> "Based on observed mass transport rates in the Capitan Reef and existing deep-seated dissolution features (breccia pipes), convective mechanisms such as brine density flow may be occurring at the reef margin." (p. 4-16, para 3)
>
> "...there is evidence to suggest that active convective dissolution of the overlying Salado Formation together with the diffusion from halite zones can result in the observed mass transport rate in the Capitan Reef aquifer". (p. 4-9, para 2)
>
> "....dissolution at the Capitan Reef margin in the Castile and Salado may be associated with the convective mechanism and is consistent with observed deep dissolution features which suggest a more vigorous dissolution process than diffusion." (p. 5-4, 3rd para)

In addition, the report has accepted the possibility of some deep-seated dissolution throughout the basin.

"Additionally, the presence of saline waters to the Bell Canyon and Capitan Reef aquifers which underlie or are adjacent halite units suggests that some form of deep-seated dissolution may be present throughout the basin." (p. 3-3, 4th para).

Omission of Salado Salt Removal

Having accepted the possibility of the mechanism of salt removal through convective flow at depth, the report has not addressed a major contention of Anderson (1981), i.e., the removal of salt from the Salado formation. All the analytical models considered in the report deal with the "salt dissolution in the Castile Formation and mass transfer to the Bell Canyon Aquifer" (p. 6-1, para 2).

The reasons for this omission are not clear, since according to the report, "it seems likely that the groundwaters have dissolved some salt from the Salado and Castile formations" (p. 3-2, 2nd line). In fact, task no. 3 (p. 1-4) for the study is to, "Assess the potential for dissolution in the Castile and Salado formations." It is hoped that the final version of this report will correct this omission.

DMG Aquifer Parameters

The conclusion that the rate of dissolution of salt is so slow that, "this would have an insignificant effect on the integrity of the facility" (p. 1-7) is based upon the salt transporting capacity of the DMG aquifer. The report accepts that, "Removal rates from the Castile Formation based on convective transport mechanisms are estimated to be significantly greater than the salt transport capacity of the Bell Canyon aquifer" (p 4-11, line 3 to 6). Therefore, it becomes critically important to examine the raw data which has been used to estimate the salt transporting capacity of the DMG aquifer.

The input parameters for numerical computations are listed in Table 4-1 of the report. These parameters are identified from the hydrogeological characteristics of the Bell Canyon formation listed in Table 2-1. The data for Bell Canyon hydrogeology are taken from Hiss (1975a). The only other source of data is Lynes Inc. (1979) which reports on a drill-stem test in AEC-7 drillhole.

The most important input parameter is the hydraulic conductivity of Bell Canyon aquifer. Hiss (1975a) compiled laboratory determinations of permeability and porosity, made by oil companies on cores collected from the lower Bell Canyon and Upper Cherry Canyon formations. The cores were collected from sections most promising for hydrocarbon production. On the basis of these compiled values, Hiss (1975a) computed an "average" permeability for the DMG formation as 6.70 millidarcies which is equal to about 0.005 m/day of hydraulic conductivity. The hydraulic conductivity of 1.8 m/yr. listed in Table 4-1 is simply this value computed by Hiss (1975) from reported laboratory values (0.005 m/day x 365 = 1.8 m/yr.). Similarly, the effective porosity value of 0.16 is also the "average" porosity value reported by Hiss (1975a) from his compilation of oil companies data. Hiss (1975a) did not report any aquifer performance tests for Bell Canyon. In fact, the only aquifer data are that collected from a drill stem test in AEC-7 (Lynes, Inc. 1979).

While the report treats several mechanisms for flow in the Castile formation, it only treats porous media flow in the DMG aquifer. The hydrologic data available for porous media flow in the DMG indicates that the DMG is not capable of transmitting significant amounts of salt. This in turn keeps dissolution of salt to a minimum even when considering the "implausible worst case scenarios" described in the report (Sec. 5.2).

In view of a possible fault connecting Bell Canyon with Castile formation (U.S. DOE, 1980b, Figs. 2.7-20 and 2.7-21) and the existence of a joint system (p. 2-7, para. 2), it is surprising that no consideration is given to salt transport through fractures which may exist in DMG aquifer. It is recommended that the final version of the report includes calculations based on assumptions of joints in DMG and at least one fault connecting DMG and Castile formations.

Capitan Aquifer as a Deep Dissolution Sink

The report states that the, "Geochemical evidence of salt dissolution is provided by the composition of groundwater from the Bell Canyon and Capitan aquifers" (p. 3-1, 3rd para) and that "it seems likely that the groundwaters have dissolved some salt from the Salado and Castile formations" (p. 3-2, first para). While the report rules out DMG as a carrier of the dissolved salt, it suggests that the Capitan aquifer may directly participate in the salt dissolution at depth. The Chapter on "Conclusions" (Chapter 6) states,

> "As is evident from this study, brine density flow or convective dissolution is a potential mechanism for removal of halite and its occurrence in the Delaware Basin is possible in areas overlying and at the Capitan Reef aquifer margin." (p. 6-3)

This is an important statement and raises several questions concerning the mechanism of salt removal without DMG aquifer participation, directly to the Capitan aquifer. The existence of decreasing chloride concentration down gradient in the Capitan Reef aquifer is one example of the problems to be resolved and understood. The report, in its final form, should try to present a mechanism of salt removal from Castile and Salado into the Capitan Reef aquifer without involving the DMG aquifer.

Brine in Castile

The report has disregarded the importance of pressurized brine in the Castile formation vis-a-vis the question of salt removal from Castile and Salado (p. 2-12). Even though these brine occurrences do not seem to be connected to the DMG aquifer, they may not be completely isolated. Also, the brine is found in large volumes. The most recent estimate of the volume of the brine reservoir encountered by WIPP-12 is 30 million barrels (Popielak, NAS-WIPP panel presentation, Aug. 1982) which would occupy 170 million cu. ft of space. The significance of such large volumes of pressurized brine to the question of removal of salt through dissolution in the same formation should be discussed more thoroughly in the report.

Use of Mathematical Models and Equations

The report has quantified the rates of dissolution for mechanisms of diffusion and density induced convection by using the equations for density induced flow effects, Rayleigh numbers and Nusselt numbers; use of a steady state analytical mass balance model; and the use of a numerical mass transport model.

Many of these approaches and assumptions appear to have possibilities of errors. Thus, for example it seems possible that brine density flow could occur in fractures much smaller than the 0.5 and 1.5 mm calculated in the report; the value of Rs used for the equation $N_s = 0.1\ R_s^{1/3}$ may not exceed 5×10^{10} whereas the report uses $R_s = 1.2 \times 10^{21}$; and the comparison of the dispersion coefficients calculated from the Knapp and Podio (1979) experiments to the diffusion coefficient could be erroneous. All these points are discussed in detail under Specific Comments.

SPECIFIC COMMENTS

page 1-3, 8th and 9th line from top and page 2-7, 2nd paragraph:
The WIPP Safety Analysis Report (page 2.7-33, Figures 2.7-20 and 2.7-21) indicates that a northwest-southeast trending fault may exist on the interface between the Delaware Mountain Group and the Castile Formation. The fault is located approximately 9 km northeast of ERDA-9 and would be within 1 km of the repository as presently planned. The potential existence of a fault and its consequent hydrologic effects on the repository should be addressed in this report.

page 1-4, 1st paragraph:
The statement, "When placed in salt beds which have remained generally stable since deposition in the Permian time (more than 230 million years ago), the waste buried in the WIPP facility may reasonably be expected to remain isolated from the biosphere for thousands of years" ignores everything that has happened to the salt beds since their deposition, viz. uplift, tilting, folding, salt tectonics, intrusion by a dike, collapse along breccia chimneys, dissolution, formation of cavities filled with huge reservoirs of brine, erosion, etc. It is clearly misleading, detracts from a satisfactory resolution of the question of future stability and isolation of the WIPP repository, and should therefore be removed from this report.

Similarly the sentence following the above mentioned one states that radioactive decay will reduce the hazard to "negligible levels" in a few thousand years. The Pu-239 inventory will be essentially the same as at closure and the statement as incorrect.

page 1-7 3rd, and 4th bulletted conclusions:
The terms "insignificant", "no significance," and "not greatly increase" are qualitative. They should be either replaced by or appear with the respective quantifiable number from Chapter 5 or Appendix B.

page 2-7, section on "Fracturing":
In which formations are the two sets of joints located?

Does the joint set extend into or is it located within the transmitting sandstones of the DMG? These joints may be capable of transmitting water and thus have a high dissolution potential. The dissolution effects of convection along a joint or fracture in the DMG should be addressed in the report.

page 2-8, 19th through 29th line from top:
The values of permeability presented here appear to be taken from Table 6 of Hiss's (1975a) report and are average permeabilities on a county by county basis. Figure 21 of Hiss's (1975a) report indicates that permeabilities near the WIPP site range from less than 1 md to 59 md (<0.3 m/year to 18 m/year for pure water at 20°C).

page 2-11, last paragraph
The report should indicate that the hydraulic conductivity of the Castile anhydrites is not limited to porous flow. At WIPP-12 a fracture in Anhydrite III-IV of the Castile is capable of producing over 300 gallons per minute of brine (D'Appolonia Consulting Engineers, Inc., "Data File Report, ERDA-6 and WIPP-12 Testing," Volume IV A, Activity WIPP-12.2, Feb., 1982). At ERDA-6 a fractured zone in Anhydrite II of the Castile is capable of producing over 20 gallons per minute of brine (D'Appolonia Consulting Engineers, Inc., "Data File Report, ERDA-6 and WIPP-12 Testing, Volume II A, Activity ERDA-6.7, Feb., 1982) Preliminary calculations by EEG staff members indicate hydraulic conductivities of 2000 m/day for the fractured zone at WIPP-12 and 5 m/day for the fractured zone at ERDA-6. These values of hydraulic conductivity are at least six orders of magnitude greater than the values presented here.

page 2-12, 2nd paragraph:
Does the source of salt in the Castile brines come from dissolution of halite overlying or underlying the anhydrite layers?

page 2-12, 2nd paragraph:
The statement is made that Castile brine "pockets exhibit different (mostly higher) potentiometric surfaces than the Bell Canyon". It appears that all the potentiometric surfaces for the brine pockets are higher than those for the Bell Canyon.

page 2-13, 2nd paragraph:
Are the contours on Figure 2-7 "averaged" over the various water bearing units of the Rustler Formation or are they the contours for the Culebra only? They look like they represent water levels in the Culebra. A recent draft report (Gonzalez, D.D., "Fracture Flow in the rustler Formation: Waste Isolation Pilot Plant (WIPP) Southeast New Mexico (Draft Interim Report)," SAND 82-1012, May, 1982) has changed the Culebra contours from those presented in previous reference works (Mercer, J. W., and B. W. Orr, 1977; Mercer, J. W. and B.R. Orr, 1979; Mercer, J. W. and D. D. Gonzalez, 1981). Figure 1 through Figure 4 indicate how conceptions of the head in the Rustler Formation and the Culebra Dolomite have changed with time.

page 3-4, section 3.2.1
This section deals with possible mechanisms for salt dissolution. This section appears to put forth only the ideas developed by Anderson (1978) and Anderson and Kirtland (1980). If any other ideas exist, they are not presented. No additional ideas for potential deep dissolution mechanisms are put forth. The possibility of dissolution from flow in joints or fractures in the Delaware Mountain Group and Castile anhydrite rocks should be addressed.

page 3-5, section 3.2.2
This section quantifies the amount of salt that can be diffused through the lower anhydrite of the Castile Formation by means of either a fracture or a porous medium. The results indicate that the fracture will propagate upward at a rate of 3×10^{-5} meters per year and that, in the porous medium case, a dissolution front would propagate upward at a rate of 3×10^{-6} meter per year.

The analysis is based on the assumption that steady state is reached. This approach is probably correct for the porous medium approach because the porous medium has been in place for more than 200,000,000 years. On the other hand, fractures can form at any time. In a fracture the initial unsteady state rates of dissolution and diffusion of salt should be very large compared to those of the steady state because of the steep concentration gradient which forms at the top of the fracture. The amount of salt that can be dissolved at unsteady state by a fracture should be quantified here.

Both the fracture and porous medium rate of diffusion calculations should include the range of Delaware Mountain Group NaCl concentrations because the amount and rate of dissolution are dependent on this. These calculations should show that dissolution of halite will occur faster at the up gradient parts of the Delaware Mountain Group than at the down-gradient parts.

page 3-8 to 3-10, "Threshold of Convection in Fractures and Porous Media"

This section is used to estimate the width of a fracture required to initiate brine density flow. This is done by approximating the width of a fracture with the radius of a tube. A study performed by Wooding (Wooding, R. A., "Instability of a Viscous Fluid of Variable Density in a Vertical Hele-Shaw Cell," Journal of Fluid Mechanics, vol. 7, Jan. - Apr., 1960, pp. 501-515) tends to indicate that this is not the correct approach. Using a mathematical model of water and mass transport between two parallel plates, he found that the width required to initiate density flow was dependent on the length of the parallel plates. Wooding (1960) verified his results with a Hele-Shaw analog model. The results of his study indicated that brine density flow could occur in fractures much smaller than the 0.5 and 1.5 millimeters indicated in this report. If a fracture is assumed to have smooth parallel sides, then a fracture with a width of 1 mm has a high hydraulic conductivity (0.7 m/s) and is capable of transmitting significant amounts of salt.

page 3-10, 2nd paragraph:
A basis or reference for the statement "It is doubtful whether single fractures of one millimeter or more in aperture could remain open and continuous in Anhydrite I" should be provided. While the drilling in the Castile Formation has not indicated any significant fluid producing fractures in Anhydrite I, they have been observed in the higher anhydrites of the Castile. The most notable example of a fracture occurs at WIPP-12 about 3010

feet below land surface. This fracture is capable of producing several hundred gallons per minute of flow and it could be classed as open and continuous.

page 3-10, last line:
The validity of the equation $Ns=0.1\ R_s{}^{1/3}$ should be examined. It appears that this relationship was originally derived by Elder (1967) although this report attributes it to Golitsyn (1979). Elder (1967) presented data which indicates that the above equation is valid for $\approx 5\times10^{8} < R_s < \approx 5\times10^{10}$. Elder (1967) has other relationships for $R_s < \approx 5\times10^{8}$, but none for $R_s > \approx 5\times10^{10}$. The value of R_s used in the calculation involving the above equation is 1.2×10^{21}, which is many orders of magnitude higher than the known range of valid R_s values for that equation ($\approx 5\times10^{8} < R_s < \approx 5\times10^{10}$).

page 3-11, 2nd paragraph:
The comparison of the dispersion coefficients calculated from the Knapp and Podio (1979) experiments to the diffusion coefficient could be erroneous. This comparison is made on page 3-11 of the report as support for the contention that convective mass flux is 10^{6} times higher than diffusive mass flux. Knapp and Podio (1979) treated the salt transport as a purely dispersive process. Wooding (1959), who studied the same phenomenon, included both a convection term and a diffusive term in his analysis. The large value of the Knapp and Podio (1979) dispersivity estimates tend to indicate that convection is occurring. Essentially the dispersion coefficient determined by Knapp and Podio (1979) approximates the convection of brine as a dispersive process.

Knapp and Podio (1979) performed four experiments in their study of salt transport in boreholes. Three tests were run in a bore tube with a diameter of four inches. Two of these tests were run with an induced velocity in the borehole; one was run with no induced velocity. The fourth test was run in a two inch diameter borehole and had no induced velocity. The calculated dispersivities ranged from 45 cm^2/sec to 48 cm^2/sec for experiments run in the four inch bore tube and was 12 cm^2/sec in the two inch bore tube. Knapp and Podio (1979) concluded that the dispersivity depends on the cross-sectional area of the bore tubes. If these dispersivities are corrected for the "radius of a fracture" of 0.001 meter, the dispersivity would be very small, say on the order of 10^{-6} m^2/sec. This would yield a Nusselt number of about 10^3 instead of 10^6 and would dispute the contention that convective mass transport is 10^6 times higher than diffusive mass transport.

page 3-12, 5th line from top:
The reason for believing that fracture of 1mm or more are unlikely to exist should be given. Wooding's (1960) results indicate that convection in a fracture of less than 1mm width can exist.

page 3-14, 3rd paragraph:
If a fracture were to propogate itself, (i.e. dissolve only the salt directly above it) it would reach the repository in less than 20 years at a rate of 28 cubic meters per square meter per year.

It seems very unlikely for a front to propogate as a square tunnel. Does any literature exist or has any been reviewed to indicate what shape forms when salt dissolves?

page 3-15, 1st line to 6th line from top:
This calculation assumes that there is no flow or dispersive flux through the DMG. What is the effect of flow and dispersion through the DMG on the time for salinity buildup to saturation? It is possible that a fracture extending into the DMG could transport the salt away toward the reef at a high rate and saturation would never be reached. It is highly probable that, due to the sparse drilling activity in the DMG, vertical fractures were missed during drilling.

page 4-4, "Hydraulic Conductivity" section:
The range of hydraulic conductivity should be extended from 1 md to 59 md (0.3 m/year to 18 m/year). See comment regarding page 2-8.

page 4-5, "Chloride Concentrations" section
The chloride data on Hiss's (1975a) Figure 26 tends to confirm the existence of the 100 kg/m^3 contour on the upgradient end of the Bell Canyon aquifer.

page 4-6, section 4.3.1

This is a good approach to use as a first approximation because the method is insensitive to whether the source of salt is by diffusion from above, convection from above or from some other source. In essence, the amount of calculated salt input by this method can be assumed to be from dissolution of overlying halite. Thus the amount of halite dissolved is probably overestimated. However the basic assumption in this model as applied to the DMG is porous media flow in the DMG aquifer. In addition the model presented here does not include longitudinal dispersion, which would tend to increase the amount of salt dissolved. Is dispersion insignificant in this case?

page 4-7, 8th line from top:

The mass of salt dissolved per year or 10,000 years should be presented here. Also the mass flux and rate of salt being dissolved from underneath the WIPP site should be presented for comparison purposes. An EEG calculation indicates these values are $4.1x10^{-4}$ kg/yr/m^2 and 0.31 cm/10,000 years, respectively.

page 4-9, 2nd paragraph:

It would be interesting to see the amount of salt that can be dissolved by the mechanism described in this paragraph. Would it be large enough to dissolve Salado salt laterally from the reef to the repository? Would it also be large enough to account for the amount of salt being transported by the Capitan Reef aquifer? However, the decreasing concentration of chloride downgradient along the eastern side of the Capitan Reef (see page 4-5) tends to indicate that convective dissolution of the overlying Salado is not occurring in this part of the aquifer. Active convective dissolution would tend to increase the chloride.

Could salt transport through fractures in either the DMG or Castile be enough to account for the estimated salt transport in the Capitan Reef aquifer?

page 4-10, 2nd and 3rd paragraphs:

The mass balance model described here should have a longitudinal dispersive term included.

page 4-13, 8th line from bottom:
The average value of vertical removal of 0.34 cm per 10,000 years obtained from the numerical approach agrees very well with the 0.31 cm per 10,000 years obtained from the analytical approach. What is the range of vertical salt removal over the 16,500 m long line underneath the repository?

page 4-14, section 4.4.3
The sensitivity analysis with respect to hydraulic conductivity should be extended to 18 m/yr. See comment regarding page 2-8.

page 4-16, 3rd to 6th line from top:
One of the reasons the numerical approach concluded diffusion as the source of salt to the DMG is that the model assumed diffusion as the source to start with. The model was then calibrated to determine the diffusion coefficient, which happened to be in the range of acceptable values. It can only be concluded that diffusion is a possible explanation but by no means the only one.

page 4-16, last paragraph:
Has an estimate of the rate of salt dissolution from the reef toward the repository been obtained? Page 4-9 indicates that the reef transports 20×10^6 to 440×10^6 kg/year of chloride, of which only about 3×10^6 kg/year is accounted for. If the remainder of the chloride transported by the reef comes from the brine density flow indicated here, how large a cavity would form in the Salado? What is the structural integrity of such a cavity? How fast would a cavity advance toward the repository? No sound basis is provided for the argument that the salt removal potential of the reef will not affect the repository.

page 5-2, 6th line from bottom:
"0.34 centimeter" should read "0.31 centimeter".
It appears that this paragraph is discussing the rates of dissolution determined from the analytical model. Page 4-7, third paragraph, indicates that the amount of salt dissolved is 0.3 centimeters in 10,000 years.

page 5-3, 1st line:
"0.7" should be "0.6". The dissolution process described on page 5-2 has a linear relationship between flow thickness and dissolution height. If the aquifer thickness is doubled, the dissolution height should double.

page 5-4, 5th line from top, ref. Figure 5-2:
The "dissolution controlled by diffusion" curve on Figure 5-2 does not pass through the point defined by flow rate= .135 $m^3/yr/m$ and height = 0.34 cm. The results of the numerical modelling as presented on page 4-13 indicate that flow rate= .135 $m^3/yr/m$ and height = 0.34 cm is the solution to the numerical modelling problem. Is the "dissolution" curve on Figure 5-2 correct?

page 5-6:
Going back to the analytical model; for an aquifer flow rate of .135 $m^3/yr/m$ and a chloride concentration change of 50 kg/m^3 in 16,500m, underneath the repository, the amount of salt dissolved over the 16,500 m line is $4.1x10^{-4}$ kg/yr/m.^{2} If this amount of chloride all dissolved from one fracture, the amount of chloride passing through this fracture is 6.8 kg/yr/m, which is slightly less than the 10 kg/yr/m being used here. Therefore the results presented in Figure 5-2 may be slightly higher than what can actually occur,subject to any sensitivity analysis and the assumption of porous flow in the DMG. An approach to maximize salt dissolution would be to use a chloride concentration change of 150 kg/m^3, which is the change from one end of the DMG to the other. Using this approach, one gets about 20 kg/yr/m of slat dissolution through a fracture.

page 5-6 5th line from bottom:
As mentioned earlier, work by Wooding (1960) indicates that convection can occur in fractures smaller than 1.5 mm.

page 5-6, 2nd para.:
The calculation of fracture width is not quite clear. If a fracture is capable of transporting $6x10^4$ $kg/m^2/yr$ (page 3-11) of salt, it is capable of transporting $3.64x10^4$ $kg/m^2/yr$ of chloride. If fracture width is calculated by $Q\Delta C/3.64x10^4$ $kg/m^2/year$, then the fracture width curve on Figure 5-4B

should be lowered. Again, Wooding (1960) indicates convection can occur in fractures with an aperture smaller than 1.5 mm.

page 5.12, bottom paragraph:
The simple statement that 400 m thickness over a 1 m cavity with a 94 m diameter should be enough structural support is weak and not convincing. Some more justification of this idea should be provided.

Table 4-1
What is the basis for the dispersivity of 3.048 meters shown on Table 4-1?

TYPOGRAPHIC ERRORS

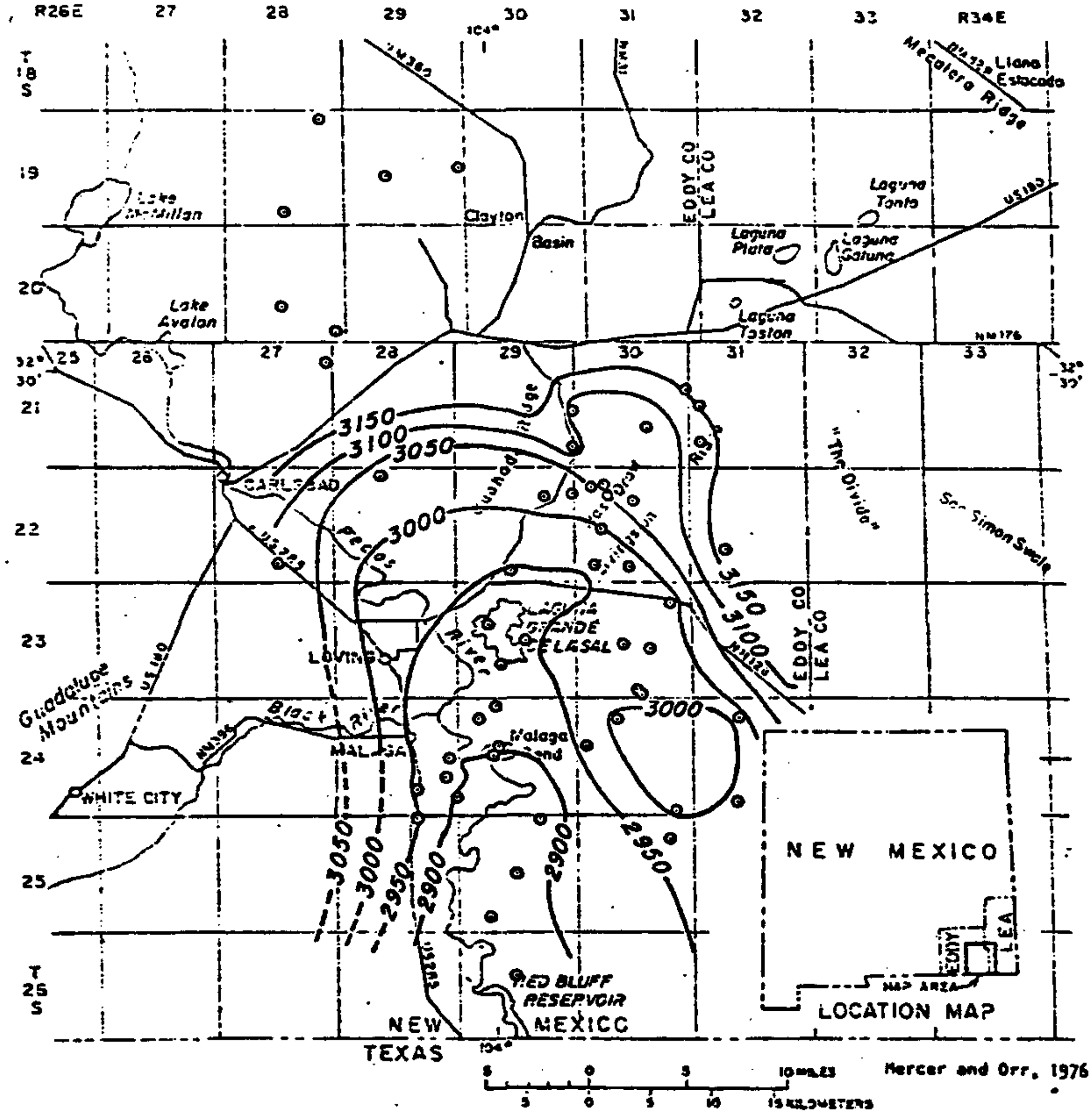
page 2-2, 6th line from bottom, page 2-12, bottom line and "Bibliography," page 6:
"Gonzales" should be "Gonzalez"

page 3-6, bottom line and "Bibliography," page 3:
"Bear, (1975)" should be "Bear (1972)." This typographic error occurs several places in the report.

Table 3-1, footnote 5:
"Figure 3-8" should be "Figure 3-7"

Figure 3-7:
An "H" should be placed after "Dissolution Cavity Width" at the top of the figure.

Figure 5-1:
"Cayon" should be "Canyon" in footnote 2.



EXPLANATION

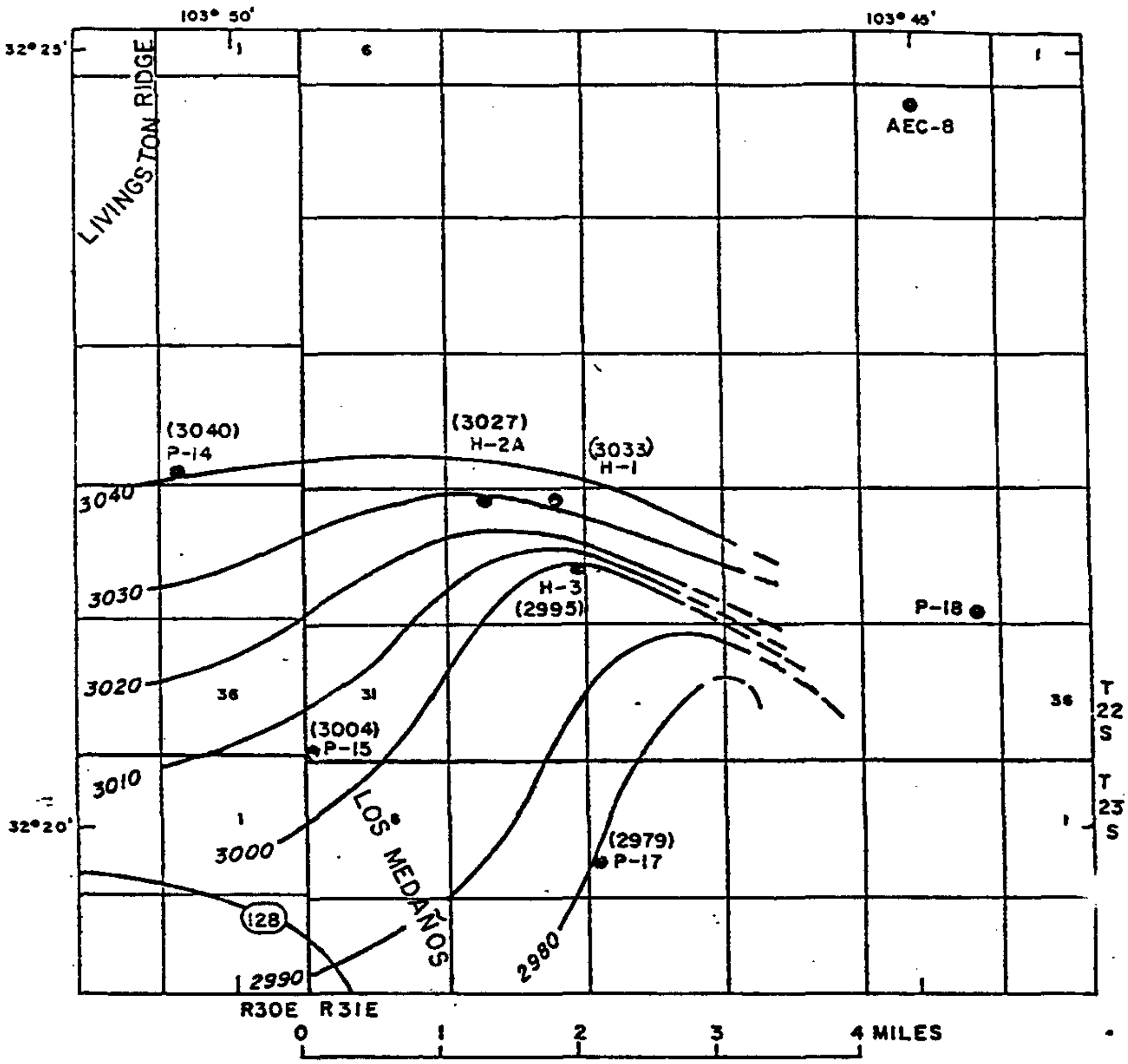
⊙ Well producing water from Rustler Formation

3000 — Potentiometric contour showing altitude at which water level would have stood in tightly cased wells. Dashed where approximately located. Contour interval 50 feet. Datum is mean sea level.

Sources of data:
Hendrickson and Jones, 1952; Hale and others, 1954; Cooper, J. B., 1962; Jones and others, 1973

Figure 1.--Potentiometric surface of the Rustler Formation, 1952 through 1973.

From: Mercer, J. W. and B. R. Orr, 1977



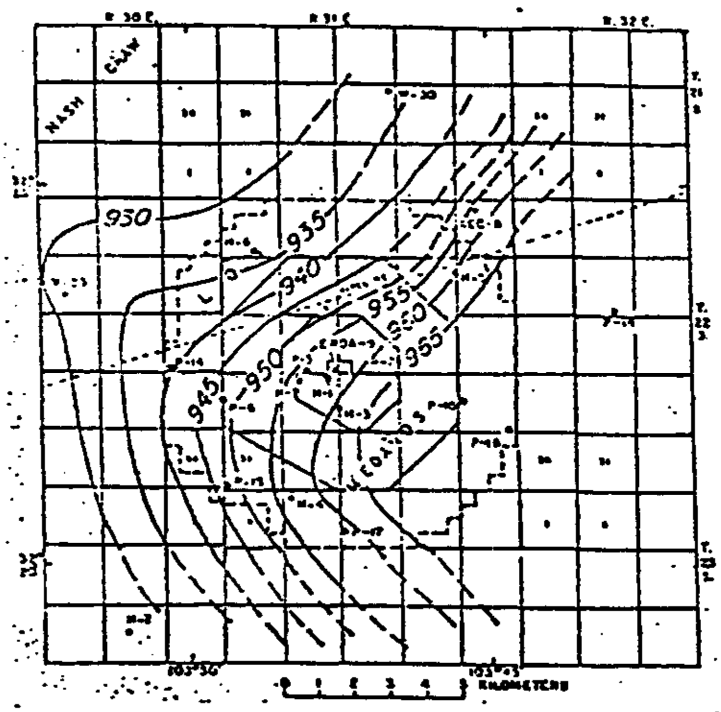
EXPLANATION

● P-17 (2979) WELL--P-17 is well identification. (2979) is altitude of water level, in feet (expressed as freshwater with a density of 1.00 gram per centimeter). Datum is mean sea level

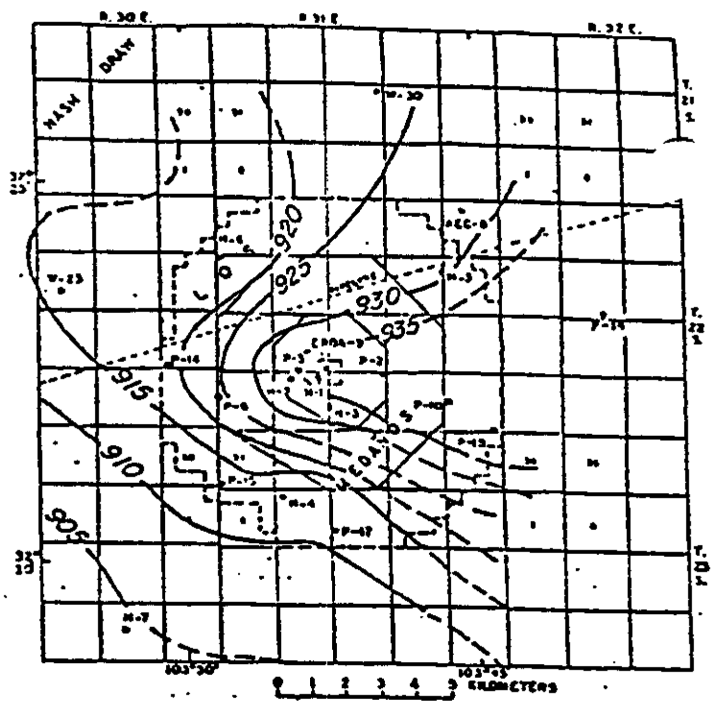
—— 2990 — — POTENTIOMETRIC CONTOUR--Shows altitude at which fresh water having a density of 1.00 gram per centimeter would have stood in a tightly cased well, October 1977. Dashed where approximately located. Contour interval 10 feet. Datum is mean sea level

Figure 2. --Potentiometric surface of the Culebra Dolomite Member of Rustler Formation.

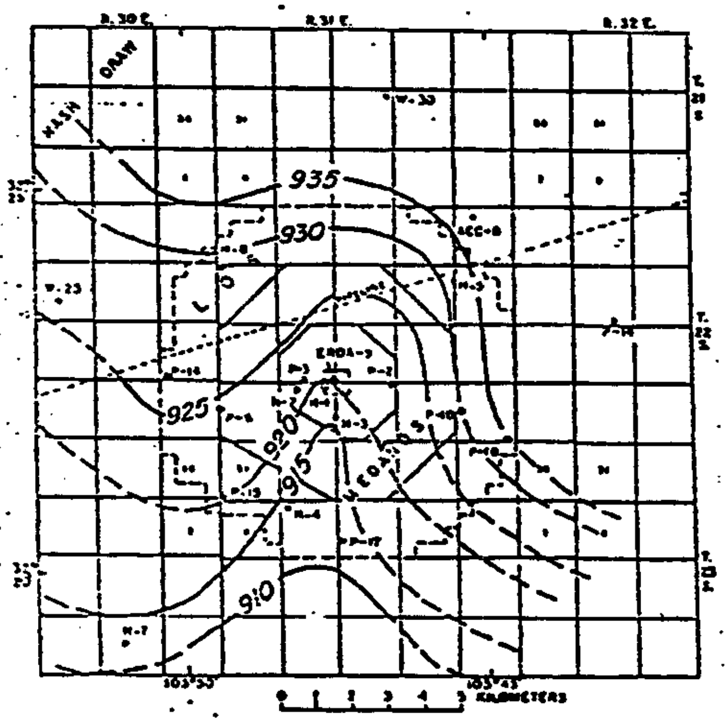
From: Mercer J. W. and B. R. Orr, 1979



MAGENTA DOLOMITE MEMBER
OF THE RUSTLER FORMATION



RUSTLER SALADO CONTACT



CULEBRA DOLOMITE MEMBER
OF THE RUSTLER FORMATION

EXPLANATION

—925-- POTENTIOMETRIC CONTOUR--Shows altitude at which freshwater having a density of 1.00 gram per cubic centimetr would stand in a tightly cased well. Dashed where approximately located. Contour interval 5 meters. National Geodetic Vertical Datum of 1929

P-17 • WELL AND NUMBER

Figure 3.--Preliminary potentiometric surface maps of water-bearing zones at WIPP in fresh-water equivalent head.

From: Mercer, J. W. and D. D. Gonzalez, 1981

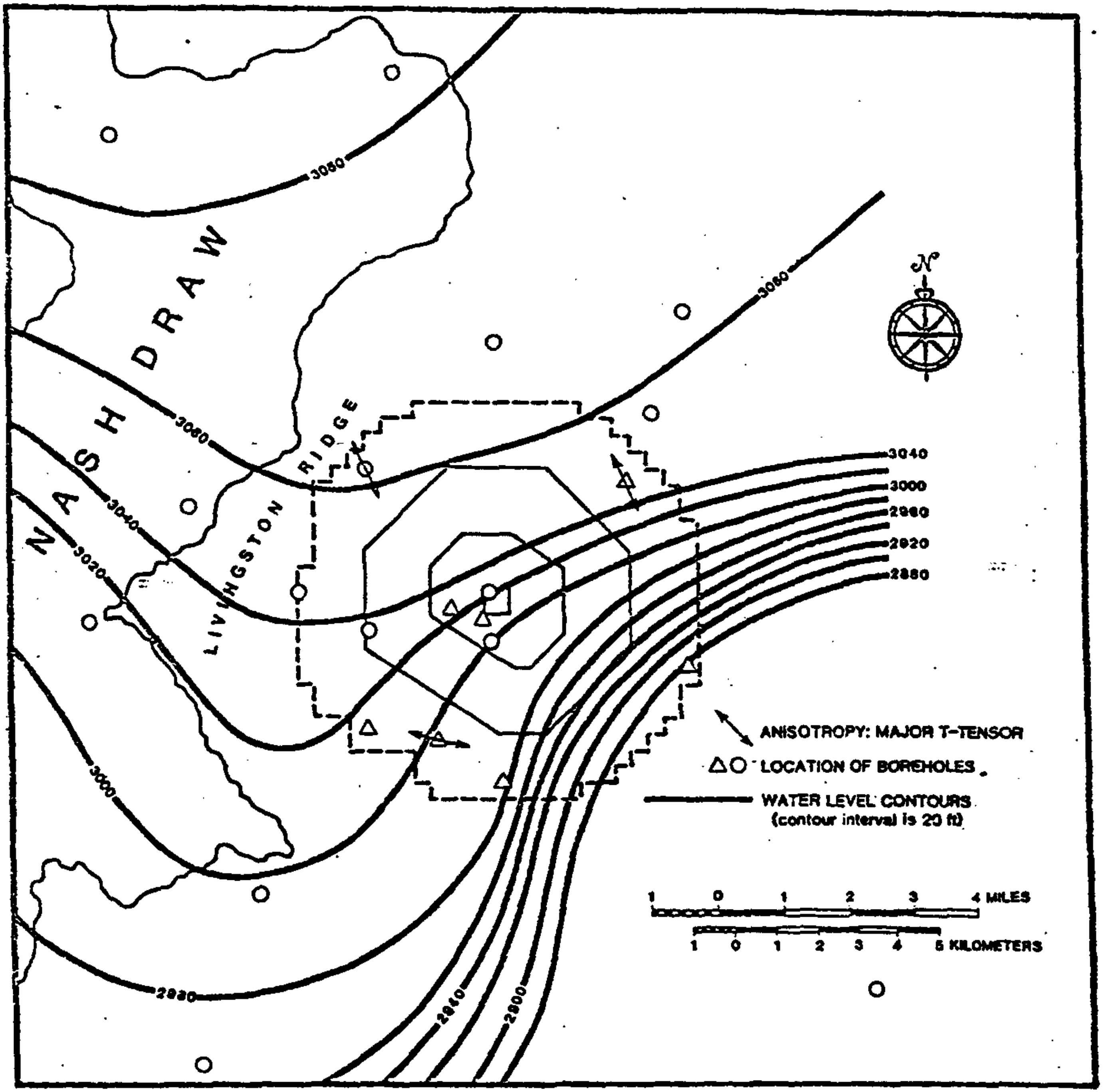


Figure 4. Water Level Contour Map of the Culebra Dolomite in Fresh Water Head

From: Gonzalez, 1982

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

NOV 2 4 1982

Mr. Robert H. Neill
Director
State of New Mexico
Environmental Evaluation Group
P. O. Box 968
Santa Fe, NM 87504

Dear Mr. Neill:

Reply to EEG Comments on Draft Report, "Delaware Mountain Group (DMG) Hydrology - Salt Removal Potential"

Responses to your comments on the subject document have been prepared by the authoring organization. Your comments have led the authors to propose changes in the report which are given with the enclosed responses. It should be noted that the primary purpose of the report is to determine the solute-transport capacity of the Delaware Mountain Group (DMG), specifically, the Bell Canyon Formation. An understanding of the solute-transport capacity of the DMG is essential to any proposed model for dissolution that invokes the DMG as a source of unsaturated fluids or a sink for saturated fluids. Regardless of the specific model proposed for dissolution, transport in the Bell Canyon is the rate-determining mechanism.

After you have had an opportunity to review the responses to your comments, if you feel that a meeting with the authors of the report is necessary, please contact us as soon as possible so that arrangements can be made.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 82-0829

Enclosure

cc w/o enclosure:
G. L. Hohmann, TSC
C. C. Little, TSC
C&C File, IEA, TSC

General Comment No. I

"a. Possible communication (of DMG) with other aquifers e.g. reef aquifer, San Andres limestone aquifer and shallow aquifers" has not been treated in this report. Although the details on this theme are expected in the regional hydrology report, a brief treatment of this subject will be desirable in this report for completeness. We recommend adding a subsection under section 2.2 of the report for such discussion."

Response:

The USGS regional hydrology report currently in preparation includes an assessment of the aquifers of the Delaware Basin and surrounding areas and possible communication between aquifers. As part of the subject study for the draft report, "DMG Hydrology-Salt Removal Potential," the regional hydrogeology, and specifically communication of aquifers, has been reviewed. Chapter 2.0 provides the necessary hydrogeologic background for the study and indicates the communication of ground water between the Bell Canyon and Capitan Reef. To elaborate further on the communication of the DMG with other aquifers, the following discussion summarizing hydraulic communication characteristics of the DMG with the Capitan, San Andres, and shallow aquifers will be added in Section 2.2 after the third paragraph on Page 2-10:

> "Communication between the DMG and the Capitan, San Andres, and shallow aquifers is determined by hydrogeologic parameters. Hiss (1975a) has compiled stratigraphic cross sections, potentiometric surface maps, and hydraulic characteristics of the DMG and Guadalupian age rocks in the Delaware Basin. Hiss' work indicates that the Capitan is immediately underlain by members of the DMG and that the potentiometric surface in the DMG is greater than the Capitan Reef aquifer and some discharge from the DMG to the Capitan is expected.
>
> Stratigraphic cross sections in Hiss' work show that sandstone tongues of the Cherry Canyon Formation interfinger the San Andres limestone. Thus, hydraulic communication between the two units is likely. Hiss, however, reports that the average hydraulic conductivity of the shelf aquifers, including the San Andres, is about 4.8 meters per year compared with the DMG average hydraulic conductivity of 1.8 meters per year. The low conductivity of both units restricts the transfer of large quantities of ground water. The head differential between the DMG and San Andres is difficult to determine from literature sources, but it appears to be similar or less than the differential at the Capitan-DMG interface.

> A relatively small amount of literature information is available on the degree of hydraulic communication between shallow aquifers and the DMG. Major dissolution or fracture zones are the most probable areas where hydraulic communication between shallow aquifers and the DMG could occur."

General Comment No. II

"b. The "Expected Results" section of the Costs and Merits document for DMG Hydrology states, "Additionally, the relative merits of various dissolution theories will be discussed." We understand that the primary document for such a discussion is the Deep Dissolution report, but the DMG Hydrology report should at least discuss the possibility of proposed mechanisms, other than Anderson's deep dissolution, explaining the observed features of DMG and Reef hydrology and hydrogeochemistry. A discussion of Bachman's "Solution and fill," subaerial erosion during Jurassic time and Lambert's "Stratabound Dissolution" in this context would be very appropriate and useful."

Response:

This subject report focuses on the DMG and addresses dissolution data and hypotheses only as far as they relate to salt removal associated with the DMG aquifer. Sandia National Laboratories is preparing a report on deep dissolution which sufficiently addresses the dissolution hypotheses which have been referenced with respect to the DMG. The major hypothesis which involves the DMG is Anderson and Kirkland's (1980) brine density flow model which uses the Bell Canyon Formation as the source of unsaturated ground water and as the sink for saturated brine. Section 3.2 of the report addresses the Anderson and Kirkland hypothesis as the primary model for salt removal associated with the DMG aquifer and discusses the mechanisms (diffusion and convection) for salt removal by ground water. Additional hypotheses which could involve the Bell Canyon as a sink for dissolved halite include downward percolation of meteoric water and Lambert's "stratabound dissolution" hypothesis. Both of these hypotheses employ the mechanisms of diffusion and/or convection for salt removal by ground water which have been studied in the report. Additionally, the results of such dissolution hypotheses have already been implicitly discussed in the report for it was shown that under most circumstances the maximum amount of salt which can be removed is controlled by the mass transport rate of the Bell Canyon aquifer. Further discussion of alternative dissolution hypotheses is given in the response to Comment No. 11.

General Comment No. III

"Omission of Salado Salt Removal

Having accepted the possibility of the mechanism of salt removal through convective flow at depth, the report has not addressed a major contention of Anderson (1981), i.e., the removal of salt from the Salado formation. All the analytical models considered in the report deal with the "salt dissolution in the Castile Formation and mass transfer to the Bell Canyon Aquifer." (page 6-1, paragraph two)

The reasons for this omission are not clear, since according to the report, "it seems likely that the groundwaters have dissolved some salt from the Salado and Castile formations" (page 3-2, second line). In fact, Task No. 3 (page 1-4) for the study is to "assess the potential for dissolution in the Castile and Salado formations." It is hoped that the final version of this report will correct this omission."

Response:

The analytical and numerical modeling which was performed focused on the potential of dissolution of halite immediately overlying the DMG because the mechanisms for salt removal are dependent on the distance of the dissolving media from the aquifer. As a result, dissolution of the lowest halite unit in the Castile Formation was specifically addressed in the report. The potential for dissolution by ground water from the DMG would be less for the upper halite zone and Salado Formation. This is a conservative approach for determining potential dissolution in both Castile and Salado halite deposits because it maximizes the concentration gradient between saturated brine at the dissolution front and unsaturated Bell Canyon ground water. The calculation overestimates the rate of salt removal from the Salado Formation, which is located approximately 300 meters above the lowermost halite unit of the Castile. Thus, the dissolution rates calculated for the lowermost Castile are conservative estimates of salt removal from the Salado Formation.

The report will be clarified at several locations to emphasize that the calculated dissolution rates can be applied to both the Castile and Salado formations.

The last sentence of the first paragraph on Page 1-4 will be reworded as follows:

> "Review of the geologic and hydrogeologic evidence and potential salt dissolution mechanisms has been undertaken to assess the possible extent of the dissolution in the Castile and Salado formations and evaluate the potential impact of such processes on the facility integrity."

The fourth bullet on Page 1-4 will be revised to read:

- "Establish hydrogeologic models for evaluation of the potential for salt removal from the Castile and Salado formations by fluids in the underlying DMG units."

The first sentence on Page 1-6 will be reworded:

> "In addition, their application for salt removal from the Castile and Salado formations by the DMG for site hydrogeologic and geologic conditions was investigated."

The last sentence of the second paragraph on Page 3-4 will be changed to:

> "It is the purpose of this section to review the physical and chemical mechanisms by which salt may be removed from the Castile and Salado formations by solution from below and to estimate the relative efficiency of these processes in removing salt from halite units within the Delaware Basin. In order to simplify the discussion in the remainder of this chapter, salt dissolution only in the Castile Formation will be used to illustrate the mechanisms. Salt dissolution in the Salado Formation could occur due to similar mechanisms but, as will be shown, the dissolution rates would be smaller because of the larger distance between a dissolution front and the Bell Canyon aquifer."

The following sentence will be added at the end of the first paragraph on Page 4-1:

> "As discussed in Section 3.2.1, calculated dissolution rates in the Castile Formation provide conservative estimates of Salado salt removal."

The second sentence on Page 5-1 will be revised to read:

> "An assessment of the impact of salt dissolution on the site integrity must include consideration of the potential solution cavity that may form in the Castile or Salado formations due to the anticipated dissolution rates."

The last sentence on Page 6-3 will be reworded as follows:

> "Furthermore, the very low flow rate of the Bell Canyon aquifer and the associated salt transport rate indicate that significant convective dissolu-

tion of halite in the overlying Castile and Salado formations would be prevented due to the inability of the aquifer to maintain the density gradient for any significant time period."

General Comment No. IV

"In view of a possible fault connecting Bell Canyon with Castile formation (U.S. DOE, 1980b, Figs. 2.7-20 and 2.7-21) and the existence of a joint system (p. 2-7, para. 2), it is surprising that no consideration is given to salt transport through fractures which may exist in DMG aquifer. It is recommended that the final version of the report includes calculations based on assumptions of joints in DMG and at least one fault connecting DMG and Castile formations."

Response:

As discussed in the response to Comment No. 1 (Specific Comments), the existence of the fault cited above, which was based on seismic reflection data, has been recently reevaluated. The existence of a joint system has been identified by Anderson (1978) although no other investigations have identified fracturing and jointing in the central basin area. The joint system identified by Anderson (1978) is exposed near Carlsbad Caverns and has reportedly fractured the lower anhydrite of the Castile Formation along the western basin margin, more than 40 kilometers from the WIPP facility. Available permeability measurements and drill stem tests throughout the site area indicate very low permeabilities and the potentiometric surface in the DMG dips gently northeastward with no apparent discontinuities or steep gradients. These data all strongly suggest that large-scale fracture flow is absent in the DMG aquifer. If localized fracturing of the aquifer was present, the net ground water flow and salt transport rates upgradient and downgradient of the fracture zone would control the flow. As a result, the report calculations have been based on measured permeabilities of the aquifer with the assumption of porous media flow. Because of the importance of the parameters governing flow in the Bell Canyon aquifer, a sensitivity analysis was performed to determine the potential dissolution for a range of aquifer flow rates varying over more than one order of magnitude.

General Comment No. V

"*Brine Aquifer as a Deep Dissolution Sink*

The report states that the, "Geochemical evidence of salt dissolution is provided by the composition of groundwater from the Bell Canyon and Capitan aquifers" (p. 3-1, 3rd para) and that "it seems likely that the groundwaters have dissolved some salt from the Salado and Castile formations" (p. 3-2, first para). While the report rules out a DMG as a carrier of the dissolved salt, it suggests that the Capitan aquifer may directly participate in the salt dissolution at depth. The Chapter on

"Conclusions" (Chapter 6) states, "As is evident from this study, brine density flow or convective dissolution is a potential mechanism for removal of halite and its occurrence in the Delaware Basin is possible in areas overlying and at the Capitan reef aquifer margin." (p. 6-3)

This is an important statement and raises questions concerning the mechanism of salt removal without DMG aquifer participation, directly to the Capitan aquifer. The existence of decreasing chloride concentration down gradient in the Capitan reef aquifer is one example of the problems to be resolved and understood. The report, in its final form, should try to present a mechanism of salt removal from Castile and Salado into the Capitan reef aquifer without involving the DMG aquifer."

Response:

The purpose of the study on salt dissolution was to evaluate the salt removal potential of the DMG and the associated effects on the WIPP facility. The Capitan reef is not a part of the DMG and is located more than 16 kilometers from the WIPP facility. Nevertheless, a preliminary analysis is presented herein to assess the possible rates and hypothetical cavity sizes associated with dissolution from the Capitan reef. Based on the relative isolation of the WIPP facility from the reef aquifer and the brief analysis presented herein, it is believed that dissolution associated with the Capitan reef will not affect the structural integrity of the WIPP facility in 10,000 years and that the last paragraph on Page 4-16 of the report sufficiently addresses this concern.

Section 4.3.2 addressed potential chloride transport rates in the Capitan aquifer and the possible origins of the dissolved salt. A general decrease in chloride concentration is identified downgradient based on recent data (Hiss, 1975a). Evidence of flow reversal in the Capitan due to pumping associated with the petroleum industry has also been reported by Hiss (1975a).

Based on the observed range of chloride concentrations in the Capitan aquifer and the estimated flow rate, the mass transport capacity of the reef has been estimated (Page 4-8 of the report). If dissolution is assumed uniform over the interface of the Castile-Capitan contact throughout the basin (a distance of approximately 110 kilometers), the average dissolution rate is approximately one millimeter per year, or an estimated 4 to 30 meters in 10,000 years, based on the range of aquifer parameters and chloride concentrations. This estimate conservatively assumes that the observed chloride concentration in the reef is due only to dissolution at the Castile-Capitan interface and that the dissolution rate remains constant for the 10,000-year period.

The location of the reef with respect to the WIPP site, more than 16 kilometers away, suggests that the dissolution mechanism as discussed in the report would not impact the facility in 10,000 years. As discussed in the report, the mass transport capacity of the reef is much greater than that of the Bell Canyon aquifer such that convective dissolution may be responsible for some of the observed chloride concentration in the reef. Convective dissolution can be generated by a circulation cell in which lower density (lower concentration) fluid ascends pores or fractures, becomes higher in density (and concentration) due to dissolving of halite, and subsequently descends due to its higher density. A density convection cell resulting in fluid movement can develop in a horizontal direction in addition to a vertical direction. However, development of a horizontal convection cell is hindered as the width of the cell increases (the distance between the discharge point of saturated brine water and the dissolution front). Since the length to width ratio of a fracture extending from the reef toward the WIPP facility would be very large, the horizontal advance of dissolution from the Capitan aquifer into the Castile is not anticipated to be very aggressive.

As a very conservative estimate of the mass flux through a fracture capable of supporting convective dissolution in a horizontal direction, studies by Warner and Arpaci (1968) and Cheesewright (1968) concerning natural convection at a vertical face were reviewed. These investigations did not consider the full circulation effect with reversal of flow. The circulation pattern in a fracture extending from the Capitan into the Castile Formation would involve horizontal flow of unsaturated brine from the reef toward the dissolution front, downward flow during salt dissolution at the front, and flow of saturated brine back toward the reef (flow reversal). Applying the results reported in the above reference is believed to be conservative because the reversal of flow would tend to reduce the horizontal density gradient which drives the circulation cell.

Warner and Arpaci (1968) and Cheesewright (1968) identified the following relationship for the Nusselt number (N_s) for natural convection at a vertical face for Rayleigh numbers (R_s) up to 10^{12}:

$$N_s = 0.1\ R_s^{1/3}$$

This is identical to Equation (3-6) of the report which was utilized in the assessment of potential convective dissolution through a vertical fracture. Based on this relationship and the relationship for the Rayleigh number [Equation (3-5)], an estimate of the total mass flux associated with convective flow in a horizontally propagating fracture can be determined. Substitution of Equation (3-5) for the Rayleigh number into the previous expression for the Nusselt number results in an equation for the convective mass transport through the fracture.

The potential dissolution cavity resulting from convective mass flux through a horizontal fracture was assumed to take the form of either a cylinder with a vertical axis or a rectangular tunnel with equal depth and width. For an assumed one-millimeter fracture, the hypothetical mass flux is 93 kg/yr per meter of fracture height. The hypothetical dissolution cylinder would have a diameter of 24 meters in 10,000 years, or a hypothetical rectangular tunnel would have a depth and width of 21 meters.

Considering a one-centimeter fracture and convective mass transport from the Capitan aquifer, the hypothetical mass flux is 930 kg/yr per meter of fracture height. The dissolution diameter for a cylindrical cavity would be about 100 meters in 10,000 years. The dissolution depth and width of a rectangular tunnel would be 66 meters in 10,000 years.

This analysis is conservative in that there is no consideration of return of saturated brine through the fracture to the Capitan and the associated reduction of the density gradient which drives the circulation cell. Due to the difficulty in sustaining a convection cell over a distance of several kilometers, it is reasonable to assume that the location of a hypothetical cavity would be near the reef where halite units are adjacent the aquifer. While it is clear that the potential convective dissolution rate from a hypothetical fracture could be transported by the Capitan aquifer, it is believed that development of a cavity over the period of study will not impact the WIPP facility, which is more than 16 kilometers from the reef.

General Comment No. VI

"Brine in Castile

The report has disregarded the importance of pressurized brine in the Castile formation vis-a-vis the question of salt removal from Castile and Salado (p. 2-12). Even though these brine occurrences do not seem to be connected to the DMG aquifer, they may not be completely isolated. Also, the brine is found in large volumes. The most recent estimate of the volume of the brine reservoir encountered by WIPP-12 is 30 million barrels (Popielak, NAS-WIPP panel presentation, Aug. 1982) which would occupy 170 million cu. ft of space. The significance of such large volumes of pressurized brine to the question of removal of salt through dissolution in the same formation should be discussed more thoroughly in the report."

Response:

Observations made in the WIPP-12 and ERDA-6 boreholes indicate storage of brine in fractures and flow through fractures of up to five millimeters aperture, with the majority of storage appearing to be in microcracks as discussed further in the brine reservoir report (in preparation). The brine pressures are well above that of the Bell Canyon aquifer, which indicates that they are not hydraulically connected. The brine reservoirs have formed in response to deformation and are isolated from one another by zones of Castile anhydrite of very low permeability. In addition, the brine pockets and wide (up to five millimeters) fractures are typically associated with the uppermost anhydrite unit in the sequence rather than with the lowermost unit overlying the Bell Canyon aquifer. Therefore, although the presence of fractures cannot be ruled out, it is believed that the low Castile Formation permeabilities discussed in Section 2.2 are representative of most of the lower anhydrite unit overlying the DMG.

These observations indicate that the presence of pressurized brine in the Castile Formation does not affect the salt dissolution calculations and discussions given in the report. However, a discussion of this subject will be added to the report as indicated in the response to Comment No. 7.

Comment No. 1

"Page 1-3, 8th and 9th line from top and Page 2-7, 2nd paragraph: The WIPP Safety Analysis Report (Page 2.7-33, Figures 2.7-20 and 2.7-21) indicates that a northwest-southeast trending fault may exist on the interface between the Delaware Mountain Group and the Castile Formation. The fault is located approximately 9 km northeast of ERDA-9 and would be within 1 km of the repository as presently planned. The potential existence of a fault and its consequent hydrologic effects on the repository should be addressed in this report."

Response:

The WIPP Safety Analysis Report (SAR) states that "on the Delaware sandstone, roughly 9,500 feet above the Morrow horizon, a possible fault (interpreted from seismic reflection data,[31]) trends in a northwest direction for about nine miles (Figure 2.7-20), with about 200 feet of indicated displacement." Figures 2.7-20 and 2.7-21 of the WIPP SAR suggest that this potential fault is located within one kilometer of the site and at the Bell Canyon-Castile interface. The existence of this fault was based on connecting a series of "features" seen on the seismic reflection processed sections. A subsequent interpretation of the reflection data indicates that the existence of this fault is highly unlikely (Powers, 1982). Amendments to the SAR which are published subsequent to issuance of the Sandia National Laboratories site deformation report (currently in preparation) will no longer indicate a fault. Available permeability measurements and drill stem test data indicate very low values of permeability and we have incorporated these available measurements into our investigation. Even if localized fracturing of the Bell Canyon aquifer was present, the net ground water flow and salt transport rates would not be affected because aquifer zones without fracturing upgradient and downgradient of the fracture zone would control the flow.

The last sentence of the first paragraph on Page 1-3 will be deleted. The last sentence of the first paragraph on Page 2-7 will be revised to read:

> "Continuous post-Wolfcampian strata indicate that major faulting had ceased before the middle Permian and hence is not believed to affect the Bell Canyon, Castile, or Salado formations."

Comment No. 2

"Page 1-4, 1st paragraph: The statement, "When placed in salt beds which have remained generally stable since deposition in the Permian time (more than 230 million years ago), the waste buried in the WIPP facility may reasonably be expected to remain isolated from the biosphere for thousands of years" ignores everything that has happened to the salt beds since their deposition, viz. uplift, tilting, folding, salt tectonics, intrusion by a dike, collapse along breccia chimneys, dissolution, formation of cavities filled with huge reservoirs of brine, erosion, etc. It is clearly misleading, detracts from a satisfactory resolution of the question of future stability and isolation of the WIPP repository, and should therefore be removed from this report."

Response:

A discussion of the geologic history of the Delaware Basin is presented in Section 2.1.1. The first sentence of Page 1-4 will be revised as follows:

> "It has been proposed to locate the WIPP facility in Permian age salt beds (formed more than 230 million years ago) in order to isolate the radioactive waste from the biosphere for a period of at least several thousand years."

Comment No. 3

"Page 1-4, 1st paragraph: Similarly, the sentence following the above mentioned one states that radioactive decay will reduce the hazard to "negligible levels" in a few thousand years. The Pu-239 inventory will be essentially the same as at closure and the statement is incorrect."

Response:

A time period of a few thousand years is sufficient to allow complete decay of the highest activity fission products, Cs-137 and Sr-90, but not for some of the lower activity species such as Pu-239. However, we agree that the statement might be misleading. The sentence beginning on the fourth line of Page 1-4 will therefore be reworded to read:

> "This period is sufficient to allow virtually complete decay of the short-lived high activity nuclides such as Cs-137 and Sr-90 and thus to substantially reduce the hazard posed by the waste."

Comment No. 4

"Page 1-7, 3rd and 4th bulletted conclusions: The terms "insignificant," "no significance," and "not greatly increase" are qualitative. They should be either replaced by or appear with the respective quantifiable number from Chapter 5 or Appendix B."

Response:

The actual values of potential dissolution and flow rate which are referenced in Section 1.4, "Summary and Conclusions," are presented and discussed in more detail in the appropriate sections of the report. The last two bullets on Page 1-7 will be revised as follows:

- "Based on an analysis of potential changes in the hydrologic characteristics (e.g., hydraulic gradient and associated flow rate) of the Bell Canyon aquifer, an increase in flow rate of even one order of magnitude (from an estimated rate of 0.135 cubic meter per year per meter of width to 1.35 cubic meter per year per meter) would not increase the salt removal from the Castile Formation by more than 17 percent (from a calculated rate of approximately 0.3 centimeter in 10,000 years to less than 0.4 centimeter in 10,000 years). The unlikely occurrence of a change in hydrogeologic characteristics and the associated potential dissolution are not anticipated to have any effect on the facility integrity.

- An analysis of implausible "worst-case" dissolution rates associated with both diffusive and convective dissolution at the Bell Canyon aquifer-Castile Formation interface suggests that the structural integrity of the WIPP facility located more than 400 meters above would not be affected. In this analysis, it was determined that the theoretical maximum cavity radius would be seven meters over a fracture and one meter above a circular porous zone in a period of 10,000 years."

Comment No. 5

"Page 2-7, section on "Fracturing": In which formations are the two sets of joints located? Does the joint set extend into or is it located within the transmitting sandstones of the DMG? These joints may be capable of transmitting water and thus have a high dissolution potential. The dissolution effects of convection along a joint or fracture in the DMG should be addressed in the report."

Response:

The WIPP SAR (Page 2.6-35) indicates that "two sets of joints, striking northwest and northeast" have been identified in the Delaware Basin rocks. The joints, believed to be pre-Cenozoic in age, are exposed near Carlsbad Caverns and filled with early Cretaceous sandstone and conglomerate.

The potentiometric surface for the DMG aquifer in the Carlsbad area implies northerly flow with no evidence of large scale fracturing. For example, there are no indications of the radical changes in flow field which might be expected in an extremely fractured area. Similarly, 40 kilometers to the east of the outcrop of the joint, the potentiometric surface in the DMG dips gently northeastward with no apparent discontinuities or steep gradients (Figure 2-5). These data all strongly suggest that large scale fracture flow is absent from the DMG aquifer. If localized fracturing of the aquifer was present, the net ground water flow and salt transport rates would not be affected because the aquifer zones without fracturing upgradient and downgradient of the fracture zone would control the flow. As a result, the report calculations have been based on the measured permeabilities of the aquifer with the assumption of porous media flow.

The second paragraph of Page 2-7 will be reworded as follows:

> "Although no major faults are known to exist at the WIPP site, data from boreholes drilled at the site indicate that jointing has occurred. Data concerning joint frequency and orientations are extremely sparse. Joint orientations are described as 'two sets of joints striking northwest and northeast' (U.S. Department of Energy, 1980b). The joints are exposed near Carlsbad Caverns, more than 40 kilometers from the WIPP site. These joints have been identified in Delaware Basin rocks and may extend into the water bearing sandstone."

Comment No. 6

"Page 2-8, 19th through 29th line from top: The values of permeability presented here appear to be taken from Table 6 of Hiss's (1975a) report and are average permeabilities on a county by county basis. Figure 21 of Hiss's (1975a) report indicates that permeabilities near the WIPP site range from less than 1 md to 59 md (<0.3 m/year to 18 m/year for pure water at 20°C)."

Response:

The permeabilities of the Bell Canyon aquifer near the WIPP site, as indicated in Figure 21 of Hiss's (1975a) report, are generally in the range of 1 to 25 millidarcys (md) (less than 0.3 to 8 meters per year). The 59 md (18 meters per year) measurement is isolated and does not appear to be representative of the site area permeability. The range of permeabilities used in the salt dissolution sensitivity analysis (Appendix B) was from approximately 1.7 to 15 md (0.5 to 4.5 meters per year), with an average value of 6 md (1.8 meters per year). The average Bell Canyon permeability on a county by county basis ranges from approximately 3 to 10 md (1.1 to 2.9 meters per year). These permeabilities are average values for all areas around the WIPP site and were utilized because the potentiometric surface for the Bell Canyon aquifer is relatively uniform. Specifically, the available data do not indicate a significantly variable flow field which would be observed with large variations in the aquifer permeability. However, the sensitivity analysis presented in Appendix B has been modified to include a permeability of 18 meters per year and this result will be incorporated in the report.

The fourth sentence of the last paragraph on Page 2-8 of the report will be clarified as follows:

> "The hydraulic conductivity of the Bell Canyon aquifer [based on core sample measurements (Hiss, 1975a)] ranges from 1.1 to 2.9 meters per year and averages approximately 1.8 meters per year. One measurement of hydraulic conductivity of 18 meters per year has also been reported; however, it does not appear representative of the basin."

The sentence beginning on the twentieth line of Page B-2 will be reworded as follows:

> "As shown in Figure B-1(A), an increase in Bell Canyon aquifer hydraulic conductivity from 1.8 to 18.0 meters per year would result in a 17 percent increase in dissolution height (H/H_{ref}, dimensionless dissolution rate, increases from 1.0 to 1.17)."

The seventh and eighth lines of Table B-1 will read:

"Hydraulic Conductivity of Bell Canyon Aquifer, K	0.5 to 18.0	Meters per year (m/yr)"

In Table B-2, the seventh, eighth, and ninth lines will read:

"Hydraulic conductivity	0.5	Meters per	-72	0.14	-57
of Bell Canyon aquifer,	1.8*	year (m/yr)	-	0.34*	-
K	18.0		+900	0.40	+17"

In addition, a fourth point will be added to Figure B-1(A) representing K = 18.0 meters per year and H/H_{ref} = 1.17.

The sensitivity of the average dissolution rate when assumed to be controlled only by the Bell Canyon aquifer flow rate is presented in Figure B-2 of the report. As is evident from the figure, an order of magnitude increase in the flow rate of the Bell Canyon aquifer from 0.135 to 1.35 m^3/yr-m (based on a permeability increase from 1.8 to 18.0 meters per year) would result in an average dissolution of less than 4 centimeters in 10,000 years.

Comment No. 7

"Page 2-11, last paragraph: The report should indicate that the hydraulic conductivity of the Castile anhydrites is not limited to porous flow. At WIPP-12 a fracture in Anhydrite III-IV of the Castile is capable of producing over 300 gallons per minute of brine (D'Appolonia Consulting Engineers, Inc., "Data File Report, ERDA-6 and WIPP-12 Testing," Volume IV A, Activity WIPP-12.2, Feb., 1982). At ERDA-6 a fractured zone in Anhydrite II of the Castile is capable of producing over 20 gallons per minute of brine (D'Appolonia Consulting Engineers, Inc., "Data File Report, ERDA-6 and WIPP-12 Testing, Volume II A, Activity ERDA-6.7, Feb., 1982). Preliminary calculations by EEG staff members indicate hydraulic conductivities of 2000 m/day for the fractured zone at WIPP-12 and 5 m/day for the fractured zone at ERDA-6. These values of hydraulic conductivity are at least six orders of magnitude greater than the values presented here."

Response:

Observations made in the WIPP-12 and ERDA-6 boreholes indicate storage and flow of brine in fractures with apertures of up to 5 millimeters. The majority of storage appears to be in microcracks which have formed in response to deformation and which are isolated from one another by zones of Castile anhydrite of very low permeability. In addition, the brine pockets and wide (up to 5 millimeters) fractures are typically associated with the uppermost anhydrite unit in the sequence rather than with the lowermost unit overlying the Bell Canyon aquifer. In general, Anhydrite I of the Castile Formation appears not to be affected by the deformations and associated fractures identified in the upper anhydrites. Thus, it is not likely that the lower anhydrite would be fractured.

It is therefore concluded that the low permeabilities discussed on Page 2-11 are appropriate for most of the lower anhydrite units overlying the DMG. The report will, however, be reworded to include a description of the occurrence of fractures associated with brine pockets and to state that the occurrence of such fractures in Anhydrite I cannot be ruled out.

The last sentence of the first paragraph on Page 2-12 will be deleted and the following will be added at the end of the paragraph:

> "Observations made in the WIPP-12 and ERDA-6 boreholes indicate storage and flow of brine in fractures of up to 5 millimeters aperture, with the majority of storage appearing to be in microcracks. The brine reservoirs have formed in response to deformation and are isolated from one another by zones of Castile anhydrite of very low permeability. In addition, the brine pockets and wide (up to 5 millimeters) fractures are typically

> associated with the uppermost anhydrite unit in the sequence rather than with the lowermost unit overlying the Bell Canyon aquifer. Although the presence of fractures cannot be ruled out, it is believed that the low permeabilities discussed in the previous paragraph are representative of most of the lower anhydrite unit overlying the DMG."

Comment No. 8

"Page 2-12, 2nd paragraph: Does the source of salt in the Castile brines come from dissolution of halite overlying or underlying the anhydrite layers?"

Response:

D'Appolonia has performed an extensive series of hydrologic and geochemical tests on the brine reservoirs occurring in WIPP-12 and ERDA-6 since the draft DMG hydrology report was prepared. The geochemical evidence strongly suggests that the brines were not produced by the dissolution of evaporite units either by ground or meteoric waters. The very high content of bromide (up to 990 milligrams per liter) and the ratios of Na, K, Cl, SO_4, and Ca to bromide all correspond very well to the expected values for evaporated seawater. This evidence suggests that the most likely origin of the brines is original residue from seawater evaporation. They therefore appear to be original evaporated Permian seawaters that may have dissolved very small amounts of evaporite minerals during transport to the anhydrite fracture system.

Comment No. 9

"Page 2-12, 2nd paragraph: The statement is made that Castile brine "pockets exhibit different (mostly higher) potentiometric surfaces than the Bell Canyon". It appears that all the potentiometric surfaces for the brine pockets are higher than those for the Bell Canyon."

Response:

The second sentence of the first paragraph on Page 2-12 will be reworded to read:

> "These 'reservoirs' have higher potentiometric surfaces than the Bell Canyon aquifer and do not appear to be connected with the DMG."

Comment No. 10

"Page 2-13, 2nd paragraph: Are the contours on Figure 2-7 "averaged" over the various water bearing units of the Rustler Formation or are they the contours for the Culebra only? They look like they represent water levels in the Culebra. A recent draft report (Gonzalez, D. D., "Fracture Flow in the Rustler Formation: Waste Isolation Pilot Plant (WIPP) Southeast New Mexico (Draft Interim Report)," SAND 82-1012, May 1982) has changed the Culebra contours from those presented in previous reference works (Mercer, J. W. and B. W. Orr, 1977; Mercer, J. W. and B. R. Orr, 1979; Mercer, J. W. and D. D. Gonzalez, 1981). Figure 1 through Figure 4 indicate how conceptions of the head in the Rustler Formation and the Culebra Dolomite have changed with time."

Response:

The origin of the potentiometric surface and extent of brine aquifer presented in Figure 2-7 for the Rustler Formation are based on the USGS Open-File Report 77-123, 1977 (Mercer and Orr, 1977), as reproduced in the WIPP SAR. These data do not differentiate between Culebra and Magenta dolomites or other zones. Based on the reference cited in the comment, it appears that the potentiometric surface has been redefined although its level when converted to fresh water with a specific gravity of 1.0 is below the observed potentiometric surface for the Bell Canyon aquifer. The second paragraph of Page 2-13 will be revised as follows:

> "The potentiometric surface of the Rustler Formation is generally lower than the potentiometric surface in the DMG. The brine aquifer and the potentiometric surface identified in the Rustler Formation are shown in Figure 2-7. These representations are based on data compiled from wells during the period 1962 through 1973 (Mercer and Orr, 1977). Recently, some revision to the potentiometric surface has been suggested (Gonzalez, in preparation) but the estimated level is below that of the Bell Canyon aquifer."

Comment No. 11

"Page 3-4, Section 3.2.1: This section deals with possible mechanisms for salt dissolution. This section appears to put forth only the ideas developed by Anderson (1978) and Anderson and Kirkland (1980). If any other ideas exist, they are not presented. No additional ideas for potential deep dissolution mechanisms are put forth. The possibility of dissolution from flow in joints or fractures in the Delaware Mountain Group and Castile anhydrite rocks should be addressed."

Response:

Two basic mechanisms or processes for the removal of salt from the halite regions are discussed in the report. These are molecular diffusion and convection associated with ground water flow induced by a density gradient. The major hypothesis for deep dissolution which involves the Bell Canyon Formation as the source of water and the sink for saturated brine is that put forward by Anderson (1978) and Anderson and Kirkland (1980). This hypothesis invokes the mechanisms of diffusion and convection for salt removal and is specifically addressed in Section 3.2.1.

Other hypotheses which involve the DMG as the sink for saturated brines are downward percolation of meteoric water and Lambert's (in preparation) "strata-bound dissolution" mechanism. These may be regarded as subsets of the hypotheses treated in the report since the total mass of salt that can be removed is controlled by the flow and mass transport rate in the underlying aquifer, regardless of the dissolution mechanism believed to occur in the basin. Removal rates calculated in Chapters 3.0, 4.0, and 5.0 which are limited by the Bell Canyon flow rate apply to all possible mechanisms which use the Bell Canyon as a sink.

To clarify the report with respect to these points, the following changes will be made. The last sentence of the first paragraph on Page 3-5 will be deleted. On Page 3-5 after the first paragraph, the following paragraph will be added:

> "Other hypotheses which include the DMG as the sink for saturated brines are downward percolation of meteoric water and Lambert's (in preparation) hypothesis of "strata-bound dissolution." In the latter, water dissolves salt while migrating approximately horizontally along soluble strata. The Bell Canyon aquifer could potentially provide a sink for saturated brines produced by this mechanism. In the context of this report, both these mechanisms may be regarded as subsets of the Anderson (1978) hypothesis since they require flow through Castile anhydrites in order to reach the Bell Canyon Formation. Thus, the calculated maximum rates of salt removal above a fracture or through a porous zone discussed in Chapters 3.0, 4.0, and 5.0 apply approximately to all hypotheses. Since the physical processes described by Anderson (1978) and Anderson and Kirkland (1980) are readily analyzed, their hypothesis is used in subsequent sections to illustrate the mechanisms for salt removal."

Comment No. 12

"Page 3-5, Section 3.2.2: This section quantifies the amount of salt that can be diffused through the lower anhydrite of the Castile Formation by means of either a fracture or a porous medium. The results indicate that the fracture will propagate upward at a rate of 3×10^{-5} meter per year and that, in the porous medium case, a dissolution front would propagate upward at a rate of 3×10^{-6} meter per year.

The analysis is based on the assumption that steady state is reached. This approach is probably correct for the porous medium approach because the porous medium has been in place for more than 200,000,000 years. On the other hand, fractures can form at any time. In a fracture the initial unsteady state rates of dissolution and diffusion of salt should be very large compared to those of the steady state because of the steep concentration gradient which forms at the top of the fracture. The amount of salt that can be dissolved at unsteady state by a fracture should be quantified here.

Both the fracture and porous medium rate of diffusion calculations should include the range of Delaware Mountain Group NaCl concentrations beause the amount and rate of dissolution are dependent on this. These calculations should show that dissolution of halite will occur faster at the upgradient parts of the Delaware Mountain Group than at the downgradient parts."

Response:

In the steady state calculation of diffusion through a fracture, a constant chloride concentration gradient of 1.2 kg/m^3 per meter was assumed based on a 100 meter fracture height above the Bell Canyon aquifer, existing chloride concentration in the aquifer of 70 kg/m^3 (actual range is generally 100 to 150 kg/m^3), and a concentration of 190 kg/m^3 (saturation) at the top of the fracture. Under such conditions, the fracture propagates upward at a rate of 3×10^{-5} meter per year. These calculations were presented as an approximate illustration of the propagation rate of a fracture which originates at a distance of less than 100 meters above the Bell Canyon aquifer. It was assumed that by the time the fracture reaches the 100 meter level, a gradually varying concentration gradient would have developed from 70 to 190 kg/m^3.

For the case of instantaneous formation of a 100 meter fracture, the initial gradient at the top of fracture is very steep, thereby resulting in a high initial propagation rate. The transient propagation rate and the time to reach steady state were calculated for such a fracture and the results will be documented in the final report.

Section 3.2.2 will document the results of the transient analysis of diffusion through a fracture and the calculated fracture propagation rate as a function of time. The following paragraph will be inserted after the second paragraph on Page 3-6:

"In the above discussion of dissolution by diffusion through a fracture, it was assumed that a uniformly varying steady state concentration gradient had developed. For the case of instantaneous formation of a 100 meter fracture, the initial gradient at the top of fracture is very steep, thereby resulting in a high initial propagation rate. As salt dissolution and fracture propagation continue, the variation in salt concentration becomes more gradual due to diffusion in the fracture and the propagation rate declines. To evaluate the rates at which a fracture moves under these conditions, a transient form of the one-dimensional diffusion equation (Crank, 1975) was solved. The parameter values are identical to the ones used in the steady state calculation except that the initial chloride concentration in the fracture is assumed to be constant at 70 kg/m^3 instead of uniformly varying at a 1.2 kg/m^3 per meter gradient. The analytical solution of the diffusion equation gives the chloride concentrations at different locations within the fracture as a function of time. From this information, the concentration gradient at the top of the fracture, which determines the salt dissolution and propagation rates, is determined.

The calculated propagation rates for different times beyond initial fracture formation are as follows:

TIME (years)	PROPAGATION RATE (meters per year)
1	290×10^{-5}
10	230×10^{-5}
100	89×10^{-5}
1,000	29×10^{-5}
10,000	9×10^{-5}
100,000	3×10^{-5}

This analysis indicates that on the order of 100,000 years is required for the upward fracture movement to decline to the assumed steady state rate of 3×10^{-5} meter per year. The initial rate (e.g., time = 1 year) is almost 100 times greater; but after 1,000 years, the rate is less than 10 times the assumed steady state value. Integration of the above results for the first 10,000 years after fracture formation yields a total propagation distance of approximately 2.0 meters. These transient results indicate that fracture propagation due to diffusion is a relatively slow process, even immediately after fracture formation."

The first sentence of the third paragraph on Page 3-7 will be revised as follows:

> "The above discussion demonstrates that diffusion-controlled dissolution is an extremely slow process. The steady state propagation of a single fracture is approximately 3 x 10^{-5} meter per year and the steady state movement of a dissolution front above a porous zone is on the order of 3 x 10^{-6} meter per year. For instantaneous formation of a fracture, the initial propagation rate is approximately 3 x 10^{-3} meter per year, decreasing to 2.9 x 10^{-4} meter per year in 1,000 years, and reaches steady state conditions (3 x 10^{-5} meter per year) in 100,000 years."

Comment No. 13

"Pages 3-8 to 3-10, "Threshold of Convection in Fractures and Porous Media": This section is used to estimate the width of a fracture required to initiate brine density flow. This is done by approximating the width of a fracture with the radius of a tube. A study performed by Wooding (Wooding, R. A., "Instability of a Viscous Fluid of Variable Density in a Vertical Hele-Shaw Cell," Journal of Fluid Mechanics, Vol. 7, Jan. through Apr. 1960, pp. 501-515) tends to indicate that this is not the correct approach. Using a mathematical model of water and mass transport between two parallel plates, he found that the width required to initiate density flow was dependent on the length of the parallel plates. Wooding (1960) verified his results with a Hele-Shaw analog model. The results of his study indicated that brine density flow could occur in fractures much smaller than the 0.5 and 1.5 millimeters indicated in this report. If a fracture is assumed to have smooth parallel sides, then a fracture with a width of 1 mm has a high hydraulic conductivity (0.7 m/s) and is capable of transmitting significant amounts of salt."

Response:

The conditions necessary for the onset of convection in a fracture must depend on the geometry of the aperture as was recognized on Page 3-9 of the draft report. The rationale for using cylindrical geometry is that it gives an approximate order of magnitude of the fracture width required for the onset of convection without the need to specify a hypothetical aspect ratio. The results were shown on Page 3-10 to confirm the approximate magnitude of critical fracture width deduced by Anderson and Kirkland (1980). Wooding's (1960) results may be used to deduce that for an aspect ratio (length/width) of 20, the critical fracture width for solute-driven convection would be about 0.4 millimeter, whereas an aspect ratio of 100 would yield a critical width of about 0.2 millimeter.

The choice of an appropriate aspect ratio is complicated by the general roughness of geologic fracture surfaces which would hinder convection in long, thin fractures but, even with a high aspect ratio (100), the result is not substantially different from that (0.5 to 1.5 millimeter) given in the draft report.

Given the variability in critical width, the important conclusion of Section 3.2 is that, if convection occurs, the Nusselt number is so high that the fracture rapidly saturates with salt. Removal rates therefore are controlled by the properties of the aquifer rather than by the critical width of potential fractures as discussed in Section 5.2.1.

The report will be modified by adding the following comments after the first paragraph on Page 3-10:

> "The above calculations of critical fracture width are based on the simplifying assumption of cylindrical geometry. If the fracture is to be elongated, then the minimum width for convection is reduced, although the results are of similar order to those given above. Wooding's (1960) study may be used to estimate a minimum fracture width of approximately 0.4 millimeter for an aspect ratio (length/width of the fracture) of 20 and approximately 0.2 millimeter for an aspect ratio of 100. As aspect ratio increases, the irregularity of fracture surfaces and occasional fill materials will tend to interfere progressively with the convective process so that modeling as long, thin, parallel-sided fractures is inappropriate. It is likely, therefore, that the cylindrical model gives a reasonable and conservative order of magnitude calculation of the critical fracture width for solute-driven convection."

<u>Comment No. 14</u>

"Page 3-10, 2nd paragraph: A basis or reference for the statement "It is doubtful whether single fractures of one millimeter or more in aperture could remain open and continuous in Anhydrite I" should be provided. While the drilling in the Castile Formation has not indicated any significant fluid producing fractures in Anhydrite I, they have been observed in the higher anhydrites of the Castile. The most notable example of a fracture occurs at WIPP-12 about 3,010 feet below land surface. This fracture is capable of producing several hundred gallons per minute of flow and it could be classed as open and continuous."

Response:

Fluid pressures in the brine reservoir intercepted by WIPP-12 and ERDA-6 are substantially greater than those in the Bell Canyon aquifer, extending up to about 70 percent of the calculated lithostatic value. As a result, fluid pressure may be expected to keep fractures open within a brine reservoir even if there is a general tendency for plastic deformation to close them. In the case of a fracture connecting the lowermost Castile anhydrite to the DMG, however, the fluid pressure would be less able to keep the fracture open because the aquifer cannot be pressurized by deformation in the same way as a small localized reservoir can. Thus, it is to be expected that fractures connected to the Bell Canyon aquifer will be mechanically much less stable than those within limited pressurized reservoirs.

The first sentence of the second paragraph on Page 3-10 will be modified to read:

> "There is some doubt as to the long-term stability of a one millimeter fracture in a deformable medium such as the Anhydrite I unit of the Castile Formation."

Comment No. 15

"Page 3-10, last line: The validity of the equation $Ns \approx 0.1 R_s^{1/3}$ should be examined. It appears that this relationship was originally derived by Elder (1967) although this report attributes it to Golitsyn (1979). Elder (1967) presented data which indicate that the above equation is valid for $\approx 5 \times 10^8 < R_s < \approx 5 \times 10^{10}$. Elder (1967) has other relationships for $R_s < \approx 5 \times 10^8$, but none for $R_s > \approx 5 \times 10^{10}$. The value of R_s used in the calculation involving the above equation is 1.2×10^{21}, which is many orders of magnitude higher than the known range of valid R_s values for that equation ($\approx 5 \times 10^8 < R_s < \approx 5 \times 10^{10}$)."

Response:

From a review of the literature discussed by Golitsyn (1979), Warner and Arpaci (1968), and their references, it appears that the relationship $Ns \approx 0.1 R_s^{1/3}$ is both a theoretically predicted and experimentally observed limit for very high Rayleigh numbers ($R_s \gg 10^6$, Warner and Arpaci, 1968). While experiments only appear to have been performed to Rayleigh numbers on the order of 10^{10} (Golitsyn, 1979), no substantial deviations from this relationship have been observed experimentally. The data of Knapp and Podio (1979) provide a check on the validity of this Nusselt-Rayleigh relationship at a very high Rayleigh number (10^{19}). At this Rayleigh number, the predicted Nusselt number is within an order of magnitude of that obtained from Knapp and Podio's empirical dispersion coefficients. This tends to confirm the general applicability of the above equation in the approximate manner employed by the report.

Comment No. 16

"Page 3-11, 2nd paragraph: The comparison of the dispersion coefficients calculated from the Knapp and Podio (1979) experiments to the diffusion coefficient could be erroneous. This comparison is made on Page 3-11 of the report as support for the contention that convection mass flux is 10^6 times higher than diffusive mass flux. Knapp and Podio (1979) treated the salt transport as a purely dispersive process. Wooding (1959), who studied the same phenomenon, included both a convection term and a diffusive term in his analysis. The large value of the Knapp and Podio (1979) dispersivity estimates tend to indicate that convection is occurring. Essentially, the dispersion coefficient determined by Knapp and Podio (1979) approximates the convection of brine as a dispersive process.

Knapp and Podio (1979) performed four experiments in their study of salt transport in boreholes. Three tests were run in a bore tube with a diameter of four inches. Two of these tests were run with an induced velocity in the borehole; one was run with no induced velocity. The fourth test was run in a two-inch-diameter borehole and had no induced velocity. The calculated dispersivities ranged from 45 cm^2/sec to 48 cm^2/sec for experiments run in the four-inch bore tube and was 12 cm^2/sec in the two-inch bore tube. Knapp and Podio (1979) concluded that the dispersivity depends on the cross-sectional area of the bore tubes. If these dispersivities are corrected for the "radius of a fracture" of 0.001 meter, the dispersivity would be very small, say on the order of 10^{-6} m^2/sec. This would yield a Nusselt number of about 10^3 instead of 10^6 and would dispute the contention that convection mass transport is 10^6 times higher than diffusive mass transport."

Response:

The discussion in the draft report is aimed at deducing the convective mass transport from Knapp and Podio's dispersivity estimate and comparing it with predictions based on the relationship N_s Z $0.1\ R_s^{1/3}$. The fact that Knapp and Podio obtained empirical dispersivities which are six orders of magnitude greater than the diffusion coefficient implies that convective transport in their experiments is six orders of magnitude greater than diffusive transport, i.e., N_s Z 10^6. This observation is in reasonably good agreement with convection theory which predicts an N_s of about 3×10^5 (Page 3-11 of the draft report). Thus, the experiments confirm the general validity of the Nusselt-Rayleigh relationship at a very high Rayleigh number (approximately 10^{19}).

Knapp and Podio observed some dependence of dispersivity on tube diameter. They also found a dependence of dispersivity-salinity relationships on tube diameter. Although such effects are not predicted in the simple convection theory used in the report, they may be quantitatively understood by considering the nature of the experiments and the fitting procedures used. First, Knapp and Podio's experiments started with a concentration discontinuity in their simulated well bore which is expected to lead to short-term transient transport effects. The initiation of rapid convection in such a system could depend on tube diameter although in the long-term, as steady state is approached, tube diameter is expected to be relatively unimportant. Secondly, by forcing actual convective transport data to fit a diffusion (or dispersion) equation, Knapp and Podio introduced empirical parameters which cannot readily be justified. Although their data are of considerable interest, their theoretical treatment is very limited and impossible to extrapolate with confidence. Thus, the complex dispersivity composition and dispersivity tube width relationships they obtained cannot be put into a good theoretical framework because they apply to a physical process different from the one actually observed. In such a case, a relationship between dispersivity and tube diameter may appear to be present but simply be an artifact of the fitting procedures used. There is certainly no justification for a linear extrapolation of Knapp and Podio's apparent dispersivity-width relationship in the manner suggested by the comment.

In conclusion, Knapp and Podio's experiments provide a reasonable test of the Nusselt-Rayleigh number relationship at high values of R_s, but their data cannot be extrapolated using dispersion theory. Paragraph 2 of Page 3-11 will be modified to clarify the discussion. The first sentence will be revised to read:

> "Some recent experiments on salt transport in wide bore tubes (Knapp and Podio, 1979) tend to confirm the approximate convective mass transport relations derived and discussed here."

The third sentence will be reworded as follows:

> "They found that the data, although produced by a vigorous convective process, could be modeled by using a semiempirical equation of the same form as the diffusion equation (Fick's second law):"

Comment No. 17

"Page 3-12, 5th line from top: The reason for believing that fractures of one millimeter or more are unlikely to exist should be given. Wooding's (1960) results indicate that convection in a fracture of less than one millimeter width can exist."

Response:

Discussions of the long-term stability of fractures and critical fracture widths for convection are presented in the responses to Comment

Nos. 13 and 14. In response to this comment, the first two sentences of the second paragraph on Page 3-12 will be changed as follows:

> "Although the long-term stability of large fractures in Anhydrite I is open to doubt, it is conceivable that zones of small fractures, 0.01 millimeter or less in width, could remain stable for extended time periods. Although they would be below the critical radius for convection (approximately 0.2 to 1.5 millimeters), convection could occur in multiple fracture zones where inflow takes place in some fractures and descent in others, similar to the method discussed by Anderson and Kirkland (1980)."

Comment No. 18

"Page 3-14, 3rd paragraph: If a fracture were to propagate itself, (i.e., dissolve only the salt directly above it) it would reach the repository in less than 20 years at a rate of 28 cubic meters per square meter per year.

It seems very unlikely for a front to propagate as a square tunnel. Does any literature exist or has any been reviewed to indicate what shape forms when salt dissolves?"

Response:

D'Appolonia has reviewed the available literature on cavity shapes resulting from salt dissolution. Very little information is applicable to the problem addressed by the DMG report. The most comprehensive work that has been found (Jessen, 1973) is for solution mining where the principal dissolution mechanism is injection of large volumes of fresh water. The principal dissolution mechanism for the Castile halite is natural solute-driven convection due to the vertical density gradient in a fracture or porous zone resulting from the variation in salt concentration.

Salt dissolution within a cavity is a very complex mechanism depending on many variables, including concentration (degree of saturation) and chemical composition of the solute fluid, temperature, viscosity, pressure, size and shape of the dissolution cavity, effects of surface irregularities and insoluble inclusions as well as lamination of layers of different mineralogical composition (solubility), and the angle of contact between the salt and fluid. A discussion of this very complex mechanism in full detail is beyond the scope of the report. The shape of a dissolution cavity formed by this process cannot be analytically predicted in terms of the relative rates of vertical and horizontal spreading as the cavity enlarges. This would be a complex function of the flow patterns within the cavity and the material characteristics of the halite formation. However, certain simplifications and assumptions allow an estimate of the size and shape of the dissolution cavity to be made.

D'Appolonia has evaluated data on solutioning presented by Jessen (1973) and has used it to evaluate the potential dissolution of the Castile halite. The shape of the dissolution cavity would be affected mainly by:

- o Impurity (laminae layers) content in the halite.
- o Chemical and physical properties of these impurities, mainly their solubility ratio (impurity versus pure salt).
- o Effect of the angle of contact between the salt and solution fluid. The maximum rate of salt removal occurs when the contact surface is inclined about 70 degrees from vertical and the fluid is below it.

After applying various simplifications and assumptions, it was determined that the dissolution cavities would resemble a rounded trapezoid with the base slightly shorter than the top and a general width to height ratio of approximately 1:1 for pure halite. WIPP-12 analysis results indicate that the 2 to 5 percent range of anhydrite impurities is representative of the Halite I Formation. Considering the inclusion of anhydrite impurities in the Castile and Salado formations, the theoretical cavity ratio (width to height) could be as large as 10:1 (assuming a dissolution ratio of halite to anhydrite of 157:1). These results show that assuming a rectangular tunnel geometry (1:1 width to height ratio), or a cylindrical shape (2:1 width to height ratio) as for the worst case analysis, is conservative in terms of upward movement of a dissolution cavity.

The first sentence of the last paragraph on Page 3-14 will be modified as follows:

> "The potential dissolution front would probably take the form of a cavity whose shape is governed by a very complex mechanism depending on many variables. Using the available information from the literature (Jessen, 1973) and adapting it for the Castile and Salado halite dissolution problem, it was determined that the cross-section of the cavity may resemble a rounded trapezoid with the base slightly shorter than the top. The width to height ratio is estimated to be about 1:1 for pure halite and, considering the influence of anhydrite impurities, the ratio may be as high as 10:1. To simplify further calculations, a conservative rectangular tunnel shape

(width to height ratio of 1:1) was used. If the dissolution front were to propagate as such (Figure 3-7), then for a 1.5 millimeter wide fracture it would have advanced less than 0.2 meter in one year and less than 20 meters in 10,000 years."

Comment No. 19:

"Page 3-15, 1st line to 6th line from top: This calculation assumes that there is no flow or dispersive flux through the DMG. What is the effect of flow and dispersion through the DMG on the time for salinity buildup to saturation? It is possible that a fracture extending into the DMG could transport the salt away toward the reef at a high rate and saturation would never be reached. It is highly probable that, due to the sparse drilling activity in the DMG, vertical fractures were missed during drilling."

Response:

The calculation on Page 3-15 dealing with time to reach saturation for the case of a large fracture connecting Castile halite and Bell Canyon Formation is not significantly affected by dispersion and ground water flow. The latter parameters are only important if the fracture density becomes extremely small such that the dissolution rate approaches that expected for diffusive flux. Since the calculated salt transport rate of 6×10^4 kg/m^2 is many orders of magnitude greater than the rate at which the Bell Canyon aquifer can remove salt from a fracture, it is reasonable to ignore the effects of flow and dispersion for the purposes of the illustration.

The remainder of Comment No. 19 involves a speculation that transport within fractures in the DMG could be more important than porous media flow. If there were any indication in the current data base that fracture permeability is important over a significant portion of the basin, then it could be addressed. Available permeability measurements and drill stems test data indicate very low values of permeability and we have incorporated these available measurements into our modeling study. Further discussion of the effects of fractures in the DMG is given in the response to Comment No. 5.

Comment No. 20

"Page 4-4, "Hydraulic Conductivity" section: The range of hydraulic conductivity should be extended from 1 md to 59 md (0.3 m/year to 18 m/year). See comment regarding Page 2-8."

Response:

Consistent with the response to Comment No. 6, the fifth sentence of the last paragraph on Page 2-8 will be revised to read:

> "The hydraulic conductivity of the Bell Canyon aquifer [based on core sample measurements (Hiss, 1975a)] ranges from 1.1 to 2.9 meters per year and averages approximately 1.8 meters per year. One measurement of hydraulic conductivity of 18 meters per year has also been reported; however, it does not appear representative of the basin."

The first sentence of the third paragraph on Page 4-4 will be reworded as follows:

> "Based on laboratory measurements of the core samples (Hiss, 1975a) and analysis of drill stem tests in Borehole AEC-7 as discussed in Section 2.2, the representative hydraulic conductivity of the Bell Canyon aquifer ranges from 1.1 to 2.9 meters per year with a weighted average value of 1.8 meters per year.

Comment No. 21

"Page 4-5, "Chloride Concentrations" section: The chloride data in Hiss's (1975a) Figure 26 tend to confirm the existence of the 100 kg/m^3 contour on the upgradient end of the Bell Canyon aquifer."

Response:

The Bell Canyon aquifer flow direction near Whites City is toward the north which is not the direction of flow observed through the section (Figure 4-1) used for the salt dissolution analyses (northeastward). Chloride concentrations in this section generally increase in the direction of flow and no chloride concentration measurements were available at the upgradient end of the section which is approximately 20 kilometers southeast of Whites City. As a result, it is believed that there is little evidence for the existence of the 100 kg/m^3 contour in this particular area.

The potential dissolution associated with the Bell Canyon aquifer mass transport capacity was evaluated through average dissolution calculations and two implausible worst case analyses. These analyses are not sensitive to the existing chloride concentration identified near Whites City. The upgradient chloride concentration of 100 kg/m^3 in the 16,500 meter section (Figure 4-1) used for the average and worst case dissolution analyses is well defined by existing data (Hiss, 1975a).

Comment No. 22

"Page 4-6, Section 4.3.1: This is a good approach to use as a first approximation because the method is insensitive to whether the source of salt is by diffusion from above, convection from above or from some other source. In essence, the amount of calculated salt input by this method can be assumed to be from dissolution of overlying halite. Thus the amount of halite dissolved is probably overestimated. However, the basic assumption in this model as applied to the DMG is porous media flow in the DMG aquifer. In addition, the model presented here does not include longitudinal dispersion, which would tend to increase the amount of salt dissolved. Is dispersion insignificant in this case?"

Response:

The discussion in Section 4.3.1 describes the average rate of salt dissolution from the Castile and Salado formations assuming that the Bell Canyon aquifer controls the rate at which salt can be removed from the dissolution zone. For this approach, the mechanism by which salt dissolves is not important; the aquifer mass transport capacity is the key parameter. The product of aquifer flow rate and salt concentration increase in the direction of flow beneath the dissolution area yields the average dissolution rate. An illustration of this process, including dispersion, is provided in Figure 4-4 which shows the numerical model results.

Consideration of the dissolved salt transport in the Bell Canyon aquifer based on porous media flow theory is justified based on the available data on the DMG. (See response to Comment No. 5 for further discussion of the possibilities and effects of fractures in the DMG.) Section 5.1 of the report presents a discussion of the dissolution rate as computed by this technique with respect to possible parameter variations. Fracture flow would have to be significant and widespread to impact the calculations presented in the report.

As part of the sensitivity analysis described in Appendix B, the effect of longitudinal dispersion in the Bell Canyon aquifer on salt dissolution was investigated. The results of the analysis are presented in Figures B-1(F) and B-1(G) and show that salt dissolution is insensitive to the magnitude of longitudinal, as well as transverse, dispersion. Similarly, the effect of longitudinal dispersion on the hand calculation results in Section 4.3.1 is insignificant.

Comment No. 23

"Page 4-7, 8th line from top: The mass of salt dissolved per year or 10,000 years should be presented here. Also, the mass flux and rate of salt being dissolved from underneath the WIPP site should be presented for comparison purposes. An EEG calculation indicates these values are 4.1×10^{-4} kg/yr/m^2 and 0.31 cm/10,000 years, respectively."

Response:

The variation of salt dissolution along the 16,500 meter section beneath the WIPP facility is shown by the dimensionless mass flux curve in Figure 4-4. The hand calculations presented in Section 4.3.1 are intended only to give approximate ranges of average salt dissolution. More detailed results are given in Section 4.4.2. The mass flux curve shows that the mass flux directly beneath the WIPP facility (Zone II) ranges from 80 to 70 percent of the average mass flux rate (Note 5 in Figure 4-4). Accordingly, the mass dissolution rate of salt varies from 6.6×10^{-4} to 5.8×10^{-4} kg/yr-m^2. For a salt density of 2,160 kg/m^3, the mass rates correspond to vertical movements of 0.31 and 0.27 centimeter per 10,000 years, respectively.The third sentence on Page 4-7 of the report will be clarified as follows:

> "Based on a flow rate of 0.135 m^3/yr-m and the observed chloride concentration profiles, the average thickness of salt removal in the basin was calculated to range between 0.07 and 0.62 centimeter in 10,000 years. This corresponds to a chloride concentration difference (ΔC) between upgradient and downgradient ends of the aquifer varying from 10 to 100 kg/m^3 across the basin, resulting in a salt removal rate ranging from 2.2 to 22.2 kg/yr-m, respectively."

The following statement will be added after the last sentence of the first paragraph on Page 4-7:

> "The calculated variation of salt dissolution along a 16,500 meter section beneath the WIPP facility is presented in Section 4.4.2 which describes numerical model results."

Comment No. 24

"Page 4-9, 2nd paragraph: It would be interesting to see the amount of salt that can be dissolved by the mechanism described in this paragraph. Would it be large enough to dissolve Salado salt laterally from the reef to the repository? Would it also be large enough to account for the amount of salt being transported by the Capitan Reef aquifer? However, the decreasing concentration of chloride downgradient along the eastern side of the Capitan Reef (see Page 4-5) tends to indicate that convective dissolution of the overlying Salado is not occurring in this part of the aquifer. Active convective dissolution would tend to increase the chloride."

Response:

See discussion on General Comment V regarding the potential dissolution associated with the Capitan Reef.

Comment No. 25

"Page 4-10, 2nd and 3rd paragraphs: The mass balance model described here should have a longitudinal dispersive term included."

Response:

The discussion on Page 4-10 refers to the numerical modeling of salt dissolution and subsequent transport in the Bell Canyon aquifer. In the modeling analysis, both longitudinal and transverse dispersion were included. A detailed presentation of the equations of flow and mass transport, which are solved in the numerical model and include longitudinal and transverse dispersion, is presented in Appendix A. The sensitivity analysis, which includes these terms, is discussed in Section 4.4.3 and Appendix B of the report. It demonstrates that the dispersivity of the Bell Canyon aquifer has negligible effect on the salt dissolution rate.

Comment No. 26

"Page 4-13, 8th line from bottom: The average value of vertical removal of 0.34 cm per 10,000 years obtained from the numerical approach agrees very well with the 0.31 cm per 10,000 years obtained from the analytical approach. What is the range of vertical salt removal over the 16,500 m long line underneath the repository?"

Response:

Figure 4-4 shows that along the 16,500 meter length the vertical salt removal varies from approximately 60 percent greater than to 40 percent less than the average salt removal rate for the entire section. Taking the average rate as 0.31 centimeter per 10,000 years, the range of vertical salt removal is 0.50 to 0.19 centimeter per 10,000 years.

Comment No. 27

"Page 4-14, Section 4.4.3: The sensitivity analysis with respect to hydraulic conductivity should be extended to 18 m/yr. See comment regarding page 2-8."

Response:

See response to Comment No. 6.

Comment No. 28

"Page 4-16, 3rd to 6th line from top: One of the reasons the numerical approach concluded diffusion as the source of salt to the DMG is that the model assumed diffusion as the source to start with. The model was then calibrated to determine the diffusion coefficent, which happened to be in the range of acceptable values. It can only be concluded that diffusion is a possible explanation but by no means the only one."

Response:

The purpose of the numerical analysis was to illustrate, using an accurate representation of the geology and transport processes in the DMG, that salt dissolution by continuous diffusion along the 16,500 meter section beneath the WIPP facility could produce the observed chloride concentrations in the Bell Canyon aquifer. Although localized convective dissolution could be present, it is unlikely that convection occurs over a widespread area because the associated large mass dissolution rate would far exceed the capacity of the aquifer to remove the dissolved salt. The potential dissolution cavity sizes and shapes that could result from localized convective mechanisms are discussed in the worst case analyses of Chapter 5.0. For both an average and localized basis, convection and diffusion are presented only as examples of dissolution mechanisms that could exist in the Castile and Salado formations considering the available hydrogeologic data. The Bell Canyon aquifer salt transport capacity, which is independent of the dissolution mechanisms, is concluded to be the primary parameter controlling dissolution rates.

In the final report, the third, fourth, and fifth sentences of the paragraph beginning at the bottom of Page 4-15 will be restated as follows:

> "Both analytical and numerical calculations indicate that salt dissolution by continuous diffusion along the 16,500 meter section beneath the WIPP facility could produce the observed chloride concentrations in the Bell Canyon aquifer. Although localized convective dissolution may be present, it is unlikely that convection occurs over a widespread area because the associated large mass dissolution rate would far exceed the capacity of the aquifer to remove the dissolved salt."

Comment No. 29

"Page 4-16, last paragraph: Has an estimate of the rate of salt dissolution from the reef toward the repository been obtained? Page 4-9 indicates that the reef transports 20×10^6 to 440×10^6 kg/year of chloride, of which only about 3×10^6 kg/year is accounted for. If the remainder of the chloride transported by the reef comes from the brine density flow indicated here, how large a cavity would form in the Salado? What is the structural integrity of such a cavity? How fast would a cavity advance toward the repository? No sound basis is provided for the argument that the salt removal potential of the reef will not affect the repository."

Response:

See discussion on General Comment V concerning potential dissolution associated with the Capitan Reef.

Comment No. 30

"Page 5-2, 6th line from bottom: "0.34 centimeter" should read "0.31 centimeter." It appears that this paragraph is discussing the rates of dissolution determined from the analytical model. Page 4-7, third paragraph, indicates that the amount of salt dissolved is 0.3 centimeter in 10,000 years."

Response:

In the analytical evaluation of salt dissolution, a chloride concentration increase of 50 kg/m^3 (100 to 150 kg/m^3) based on field data was used to represent the salt dissolution along the Bell Canyon aquifer. This increase corresponds to an average dissolution rate of 0.31 centimeter per 10,000 years. The model predicted an increase of approximately 55 kg/m^3 chloride or 0.34 centimeter salt removal per 10,000 years. Due to the relatively small amount of concentration data available and the assumptions required to perform some of the calculations, the difference between 0.31 and 0.34 centimeter per 10,000 years as the average dissolution rate is insignificant. Solely for comparison purposes, the model result of 0.34 centimeter was adopted in Section 5.1.

Comment No. 31

"Page 5-3, 1st line: "0.7" should be "0.6." The dissolution process described on Page 5-2 has a linear relationship between flow thickness and dissolution height. If the aquifer thickness is doubled, the dissolution height should double."

Response:

As discussed in the response to Comment No. 30, the average salt removal rate of 0.34 centimeter per 10,000 years, as determined from the model results, was used for comparative purposes in Section 5.1. Given the same 55 kg/m^3 chloride concentration increase in the Bell Canyon aquifer, doubling the aquifer thickness to 60 meters would increase the salt removal rate to 0.68 centimeter, or approximately 0.7 centimeter per

10,000 years. The difference between using a 0.31 to 0.62 centimeter increase or a 0.34 to 0.68 centimeter increase is insignificant for the purposes of the illustration.

To clarify the discussion, the second paragraph on Page 5-2 will be reworded. The ninth sentence in the second paragraph will be revised to read:

> "For a Bell Canyon aquifer flow rate of 0.135 m^3/yr-m and a chloride concentration increase of 55 kg/m^3 (numerical model results), the average dissolution cavity height in 10,000 years would be 0.34 centimeter."

The eleventh sentence will read:

> "If the aquifer thickness is assumed to be 60 meters rather than 30 meters, the average salt removal corresponding to a 55-kg/m^3 chloride increase would be 0.68 centimeter per 10,000 years and 17 centimeters in 250,000 years."

<u>Comment No. 32</u>

"Page 5-4, 5th line from top, ref. Figure 5-2: The "dissolution controlled by diffusion" curve on Figure 5-2 does not pass through the point defined by flow rate = 0.135 m^3/yr/m and height = 0.34 cm. The results of the numerical modeling as presented on Page 4-13 indicate that flow rate = 0.135 m^3/yr/m and height = 0.34 cm is the solution to the numerical modeling problem. Is the "dissolution" curve in Figure 5-2 correct?"

<u>Response:</u>

The straight-line curve in Figure 5-2, representing dissolution controlled by the Bell Canyon aquifer, is based on a constant increase in chloride concentration of 50 kg/m^3 (Note 1 in the figure) over an aquifer length of 16,500 meters. The curve defining dissolution controlled by diffusion is derived from the numerical model predictions of dissolution-induced concentration increases for varying aquifer flow rates. The diffusion-controlled dissolution curve shown in Figure 5-2 of the April 1982 draft report was constructed for illustrative purposes using a smaller diffusion coefficient than was determined by the calibration. The sensitivity analysis described in Appendix B shows the effect of the diffusion coefficient on the salt dissolution rate. The dissolution curve using the calibrated diffusion coefficient value of 8.7×10^{-3} m^2/yr (Table B-2) increases from 0.14 centimeter at 0.038 m^3/yr-m, to 0.34 centimeter at 0.135 m^3/yr-m, and remains approximately horizontal at 0.40 centimeter from 0.2 to 0.5 m^3/yr-m. Figure 5-2 of the final report has been redrafted to show the results obtained from the calibrated diffusion model.

Comment No. 33

"Page 5-6: Going back to the analytical model; for an aquifer flow rate of 0.135 m^3/yr/m and a chloride concentration change of 50 kg/m^3 in 16,500 m, underneath the repository, the amount of salt dissolved over the 16,500 m line is 4.1 x 10^{-4} kg/yr/m^2. If this amount of chloride all dissolved from one fracture, the amount of chloride passing through this fracture is 6.8 kg/yr/m, which is slightly less than the 10 kg/yr/m being used here. Therefore, the results presented in Figure 5-2 may be slightly higher than what can actually occur, subject to any sensitivity analysis and the assumption of porous flow in the DMG. An approach to maximize salt dissolution would be to use a chloride concentration change of 150 kg/m^3, which is the change from one end of the DMG to the other. Using this approach, one gets about 20 kg/yr/m of salt dissolution through a fracture."

Response:

The discussion beginning at the bottom of Page 5-6 and continuing through the first paragraph on Page 5-7 refers to the "worst case" dissolution of salt through a fracture as controlled by the Bell Canyon aquifer. The steady state diffusion case referred to in Comment No. 33 is discussed in Section 4.4. In a fashion similar to the procedure used to estimate average salt dissolution, the rate at which salt can be removed from a fracture (i.e., the dissolution rate) is assumed to equal the product of the aquifer flow rate and the downgradient increase in salt concentration over the concentration already existing directly below the fracture. The chloride concentration beneath the fracture was assumed to be 120 kg/m^3, which is low compared to the observed concentration below the WIPP facility, and the downgradient concentration was set equal to the maximum or saturation level of 190 kg/m^3 chloride. For a flow rate of 0.135 m^3/yr-m, the potential chloride removal rate from the fracture is approximately 10 kg/yr-m (product of 0.135 m^3/yr-m and 70 kg/m^3) which corresponds to salt removal at a 16 kg/yr-m rate. Clarification of this and other items regarding the worst case analysis in the report is presented following Comment No. 35.

Comment No. 34

"Page 5-6, 5th line from bottom: As mentioned earlier, work by Wooding (1960) indicates that convection can occur in fractures smaller than 1.5 millimeter."

Response:

This comment is addressed in the responses to Comment Nos. 13 and 35.

Comment No. 35

"Page 5-6, 2nd paragraph: The calculation of fracture width is not quite clear. If a fracture is capable of transporting 6×10^4 kg/m^2/yr (Page 3-11) of salt, it is capable of transporting 3.64×10^4 kg/m^2/yr of chloride. If fracture width is calculated by QWC/3.64×10^4 kg/m^2/year, then the fracture width curve in Figure 5-4B should be lowered. Again, Wooding (1960) indicates convection can occur in fractures with an aperture smaller than 1.5 mm."

Response:

The salt transport rate of 6×10^4 kg/yr-m^2 through a fracture, referred to on Page 3-11, is the rate that could develop due to convective mass transport in a fracture. However, since 6×10^4 kg/yr-m^2 is four orders of magnitude greater than the Bell Canyon aquifer's capacity to remove the salt from the fracture, this dissolution rate is unrealistic. As discussed in the response to Comment No. 33, a conservative estimate of the Bell Canyon aquifer's capacity to remove chloride from a fracture is 10 kg/yr-m (16 kg/yr-m salt removal). Potential cavity sizes above a fracture were estimated for a range of chloride removal rates (0 to 30 kg/yr-m) as shown in Figure 5-4. For a given removal rate, the fracture width is the minimum width that could transport the indicated amount of chloride from the dissolution zone down to the Bell Canyon aquifer (100 meters) by a combination of convective and diffusive mechanisms. The magnitudes of convective and diffusive transport that could develop were determined by combining Equations (3-1), (3-5), and (3-6) to give an analytical expression for total salt transport through a fracture as a function of the diffusion coefficient, fracture height, fluid viscosity, concentration difference between the top and bottom of the fracture, and the fracture width. By holding the chloride concentration difference constant at 70 kg/m^3 (190 to 120 kg/m^3 variation) and equating salt transported through the fracture with salt removed by the aquifer, the fracture width becomes a linear function of the Bell Canyon salt removal rate. For a particular salt removal rate, a larger fracture than indicated on the curve of Figure 5-4 could produce the same dissolution rate.

To better explain the fracture width calculation, a revision in the text of Section 5.2.1 will be made. The two sentences beginning on the ninth and twelfth lines of Page 5-6 will be rephrased as follows:

> "Similar to the procedure used to estimate average salt dissolution, the rate at which salt can be removed from the fracture (i.e., the dissolution rate) is assumed to equal the product of the aquifer flow rate and the downgradient increase in salt concentration above the concentration existing directly below the fracture. For the worst case analysis, the downgradient chloride concentration is the maximum or saturation value, 190 kg/m^3 (315 kg/m^3 salt concentration)."

The second paragraph on Page 5-6 will be revised to read:

> "Figure 5-4(A) illustrates the rate of development of a cylindrical cavity for a chloride removal rate of 10 kg/yr-m (16 kg/yr-m salt removal rate). The dissolution rate is based on an aquifer flow rate of 0.135 m^3/yr-m and a chloride concentration increase from 120 kg/m^3 beneath the fracture to 190 kg/m^3 downgradient of the fracture. Figure 5-4(B) illustrates the potential cavity sizes in 10,000 years for a range of chloride removal rates. Also shown are the minimum fracture widths required to transport the indicated chloride removal rates. For a given removal rate, the fracture width is the minimum width that could transport the indicated amount of chloride from the dissolution zone down to the Bell Canyon (100 meters) by a combination of convective and diffusive mechanisms. The magnitudes of convective and diffusive transport that could develop were determined by combining Equations (3-1), (3-5), and (3-6) to give an analytical expression for total salt transport through a fracture as a function of the diffusion coefficient, fracture height, fluid viscosity, concentration difference between the top and bottom of the fracture, and the fracture width. By holding the chloride concentration difference constant at 70 kg/m^3 (190 to 120 kg/m^3 variation) and equating salt transported through the fracture with salt removed by the aquifer, the fracture width becomes a linear function of the Bell Canyon aquifer salt removal rate. For a particular salt removal rate, a larger fracture than indicated on the curve of Figure 5-4 would produce the same dissolution rate.

The paragraph beginning at the bottom of Page 5-6 will be reworded as follows:

> "A chloride removal rate of 10 kg/yr-m (equivalent to a halite dissolution rate of about 16 kg/yr-m) requires a minimum fracture width on the order of 0.3 millimeter and may result in a dissolution cavity, based on the geometry shown in Figure 5-3, with a radius of approximately 7 meters in 10,000 years for the implausible worst case. Figure 5-6 illustrates the computed hypothetical cavity relative to the stratigraphy beneath the WIPP facility. The computed width of fracture is a minimum value required to sustain the indicated chloride transport rate. If the fracture width were greater than the minimum value, the rate of salt removal would be

unchanged. This is because the dissolution rate is limited to 16 kg/yr-m due to the Bell Canyon aquifer salt removal capacity."

Comment No. 36

"Page 5-12, bottom paragraph: The simple statement that 400 m thickness over a 1 m cavity with a 94 m diameter should be enough structural support is weak and not convincing. Some more justification of this idea should be provided."

Response:

The size of the potential cavity (either the seven meter radius or one meter height with 93 meter diameter) in comparison with the overburden strata thickness of more than 400 meters between the WIPP facility floor and the potential cavity is negligible. The very slow propagation of the dissolution front would be even slower than the closure due to salt creep, which means that the potential cavity could never reach the theoretical dimensions used in the discussion. Also, the overall deformation of the overburden would have only limited upward propagation and would most likely occur only within the lower portions of Halite I.

The third and fourth sentences of the last paragraph on Page 5-12 will be reworded as follows:

> "As is evident in Figure 5-6, more than 400 meters of overburden exist between the implausible worst case potential cavities and the floor of the WIPP underground facility. As a result, the propagation of the dissolution front would cause a creep deformation of the overburden salt prompting closure of the cavities. Considering the extremely small volume of salt removed in comparison with the total strata thickness, the vertical propagation of this deformation would probably be limited to the lower section of the Halite I Formation."

Comment 37

"Table 4-1: What is the basis for the dispersivity of 3.048 meters shown in Table 4-1?"

Response:

Values of longitudinal dispersivity ranging between 0.01 and 100 meters and transverse dispersivity values of between 0.001 and 50 meters have been used in mass transport evaluations (Freeze and Cherry, 1979). The dispersivity is a function of grain size distribution, anisotropic characteristics of the porous medium, and the tortuosity of the medium. In the simulation of salt dissolution in the DMG, a value of 3.048 meters (10 feet) was used for both longitudinal and transverse dispersivity. This value was selected based on literature data for similar materials (Freeze and Cherry, 1979 and Bear, 1975); but, due to the inherent variability of this parameter, a range of dispersivities (0.3048 to 30.48 meters) was investigated in the sensitivity analysis. Figure B-1 shows that the salt dissolution rate is very insensitive to the dispersivity of the Bell Canyon aquifer, indicating that the use of 3.048 meters in the salt dissolution simulation has little impact on the conclusions of the study.

REFERENCES

The following references are used in the responses to Comment Nos. 1 through 37 and General Comment Nos. I through VI. Each reference appears in the format that will be used in the final report:

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FRACTURE FLOW IN THE RUSTLER FORMATION

SAND 82-1012

ENVIRONMENT department

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STATE OF NEW MEXICO

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September 8, 1982

Mr. Joseph M. McGough
Project Manager of WIPP
WIPP Project Office
U.S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. McGough:

Enclosed are our review comments regarding the draft report "Fracture Flow in the Rustler Formation: Waste Isolation Pilot Plant (WIPP), Southeast New Mexico (Draft Interim Report)", SAND82-1012, May, 1982, Sandia National Laboratories.

We are looking forward to hearing your comments regarding our review.

Sincerely,

Robert H. Neill
Director

RHN:eg

2-058AG2-18-2-1-1

Enclosure

cc: TSC, IEA
W. Weart, Sandia

REVIEW COMMENTS
CONCERNING

FRACTURE FLOW IN THE RUSTLER FORMATION: WASTE ISOLATION PILOT PLANT (WIPP) SOUTHEAST NEW MEXICO (DRAFT INTERIM REPORT)

Comments by

Environmental Evaluation Group
Environmental Improvement Division
N. M. Health and Environment Department
P. O. Box 968
Santa Fe, NM 87503

September 8, 1982

REVIEW OF "FRACTURE FLOW IN THE RUSTLER FORMATION: WASTE ISOLATION PILOT PLANT (WIPP), SOUTHEAST NEW MEXICO (DRAFT INTERIM REPORT)"

INTRODUCTION

A detailed review of the draft interim report entitled "Fracture Flow in the Rustler Formation: Waste Isolation Pilot Plant (WIPP), Southeast New Mexico" has been made by staff members of the Environmental Evaluation Group. The draft report presents some new information and ideas regarding the hydrology of the Rustler aquifer, most notably the direction of flow and the transport capabilities of the aquifers. The following comments are intended to get more clarification of some of the data interpretations presented in the report and to present some additional concerns the Environmental Evaluation Group has regarding flow in the Rustler Formation.

The "Costs and Merits Evaluation for Stipulated Agreement Activities" (pages 37 and 38) attached to the August 31, 1981 letter from Schueler to Goldstein does not clearly state the items that are to be addressed in the interim report. However, the comments represent the concerns of the Environmental Evaluation Group at this time and should be addressed in the final report regarding fracture flow in the Rustler, which is due during February, 1983.

DISCUSSION

The following items were referred to in the "Cost and Merits Evaluation for the Stipulated Agreement Activities," and subsequent correspondence between Schueler and Goldstein. We believe they were not adequately addressed in the Interim Report.

Proposed Work

- The best model to represent the flow path and aquifer characteristics in the Rustler will be developed.

Expected Results

- If the results are such that additional consequence analyses should be run, they will be incorporated into the study.

Schueler Letter

Item 10 in the October 30, 1981 letter from Schueler to Goldstein reads: "If results of tracer studies warrant, a model for multiple fracture flow will be developed. Discrete fracture flow (a one fracture flow path) is not considered to be a credible mechanism; this will be indicated and discussed in the report(s) on the Rustler aquifers."

It is recognized that some of these omissions would logically be presented in the final, rather than the interim report. However, it appears the fracture flow study is being conducted on two premises that have not yet been justified:

1. That the Culebra aquifer is critical and thus it is not necessary to study the Magenta aquifer. The conclusions that initial flow in the Culebra is to the southeast away from Nash Draw raises the question of whether flow in the Magenta may reach the more permeable Nash Draw area in shorter time. (see our comments regarding page 43). It is noted that the Cost and Merit Evaluation refers to Rustler aquifers and makes no mention of restricting investigations and evaluations to the Culebra aquifer.

2. That discrete fracture flow (a one fracture flow path) is not credible. A justification of this conclusion was promised in the October 30, 1981 letter and is necessary before one can dismiss the need to model discrete fracture flow.

GENERAL COMMENTS

Portions of the report summarize the transmissivity, storage coefficient, porosity and dispersivity of the various field test data. It appears that the details of these tests are presented in Bentley et. al. (1981, in preparation), Ward and Gonzalez (1981, in preparation) and Gonzalez et. al. (in preparation), which are not yet available. It would have been very useful if these reports were available for the Environmental Evaluation Group to consult while reviewing the draft fracture flow report. In addition, Walter (1981, in preparation) would have been useful to review in order to evaluate the three-well technique for anisotropy. These reports should be made available to the Environmental Evaluation Group prior to issuance of the final report on fracture flow.

The report summary could address several additional items. At present it concludes the following:

- Culebra flow through the WIPP site is to the southeast
- the direction of the major component of the transmissivity tensor is from northwest to southeast
- depth averaged hydraulic conductivities decrease eastward from Livingston Ridge.

It also summarizes the transmissivities storage coefficients and porosities determined from the various tests. An additional item that needs to be addressed in the summary section concerns the nature of the fracture hydraulic conductivity. The report mentions double porosity flow (page 23) and discrete flow (page 35 and 44) but uses methods of analyses developed by Papadopulos (1965), Grove and Beetem (1971) and Sauty (1980), which are based on porous media flow. The report appears to conclude (page 35 and 44) that the dominant mode of transport in the Culebra is through discrete fractures. If this is true, the data may have to be reevaluated with models of flow through discrete fractures. A conclusion concerning the nature of fracture flow should be made before the regional transport model is developed.

The physical meaning of the values of the transmissivity storage coefficient, anisotropy, porosity and dispersivity in terms of fracture flow should be addressed.

For instance, is the anisotropy due to alternating vertical bands of highly transmissive rock and low transmissive rock that trend norhtwest to southeast or due to karst channels recharging the aquifers.

The porosity of 18% determined from the H-2 nest of wells appears high for a fractured rock. At the H-6 nest of wells the porosity appears to exhibit some directional characteristics, when it should not.

In addition, the data presented in the report indicate that Culebra flow in the repository area is to the southeast. Previous studies have indicated that flow is to the south and southwest. This data may indicate other discharge areas for the Culebra. An increased flow path that might result from the gradient presented in this report indicates that the Magenta may provide faster releases of radionuclides to the biosphere than the Culebra.

SPECIFIC COMMENTS

"ABSTRACT", 13th to 18th lines

The term "principal to minor transmissivity tensor" should be changed to "major to minor components of the transmissivity tensor." The term "principal transmissivity component" should be changed to "the principal direction of the major component of the transmissivity tensor" or "The orientation of the principal axes of the transmissivity tensor is northwest by southeast for the major component and northeast by southwest for the minor component." A statement about the variability of the transmissivity with respect to distance from the outcrop should also be included in the "abstract."

page 4, 2nd paragraph

Mercer and Gonzalez (1981) indicate a strong westward gradient from WIPP to Nash Draw in the Magenta dolomite. Have any calculations of travel time from WIPP to Nash Draw been made for the Magenta and compared to travel times for the Culebra?

The Culebra's southeast gradient through the repository, as indicated on Figure 16, shows that contamination from a repository breach may either never reach Nash Draw or may take longer than the 40,000 years previously estimated. If the Culebra travel times are significantly increased, the Magenta may provide quicker radioactive releases to the biosphere than the Culebra. Estimates of travel time from the repository to Nash Draw through the Magenta should be provided in this paragraph.

What are the data and assumptions that went into the calculation of the 40,000 year travel time from ERDA-9 to Malaga Bend? Is this number taken from some other work?

<u>page 7, 1st and 2nd lines</u>

The sentence should be changed to read something like "the major and minor components and principal directions of the transmissivity tensor."

<u>page 8, bottom paragraph</u>

Figure 16 indicates that the hydraulic gradient is to the southeast through the facility. Why does this paragraph say south and then southwest toward Malaga Bend? The statement appears to be referring to the previously assumed flow path shown in Figure 3, but it certainly is not clear.

<u>page 9</u>

Table 1 should be checked for errors. The "Fresh Water Altitude" for P-18 on the table and the altitude used for construction of Figure 16 appear to differ by 100 feet. Other "Fresh Water Altitudes" that appear to need checking belong to wells H-5, H-8, H-9, H-10, W-28 and W-30. In addition, the surface altitude of H-9 is 100' higher than that presented in Seward ("Abridged Borehole Histories for the Waste Isolation Pilot Plant (WIPP) Studies," SAND 82-0080). This may lower the fresh water altitude to 2976 at H-9. It is probable that the fractured nature of the dolomite may be causing the anomalous water levels. The water level at H-5 appears to be associated with a structural anomaly of the Culebra Dolomite (see attached Figures 1 and 2 and comment regarding page 44 and 45).

<u>page 11, 1st paragraph</u>

References for transmissivity values should be provided.

page 14, 10th line

Line should read "minor components and principal directions of the transmissivity tensor."

<u>page 14, 2 bottom lines</u>

It would be nice if the reference were already published to check the theory and to see the report contents.

page 15, 1st paragraph

The description of test procedures indicate that the "a" well at each pad was pumped. However, the anisotropy results of Table 2, Table 3 and Table 4 provide no results from pumping the "a" well. Why are the results from pumping the "a" well not presented? Was the "a" well pumped at all?

page 15, last paragraph

If the tracer curves are insensitive to dispersion (dispersivity), how can it be estimated?

page 18, lines 6, 15 and 17

Change "principal" to "major."

page 19, Table 2

According to the theory of anisotropic aquifers developed by Papadopulos (1965), the response of well H-4C from pumping H-4B should produce the same T and S values as the response of well H-4B from pumping well H-4C. The T estimates for these wells differ by a factor of two for tests one and two. The range of T (not including pumping wells) for all three tests is 0.8 feet squared per day to 1.7 feet squared per day. What is the cause of this discrepancy?

page 23, 1st paragraph

Were any methods such as images, tried to locate any of the barrier boundaries? What could these boundaries be attributed to? For instance, could the boundaries be due to vertical fractures filled with an impermeable material or to a less fractured nearby region of dolomite?

The shape of the curve on Figure 7 is interesting. The early part of the curve (prior to the formation of the straight line) may be a result of no storage of water in the fractured part of the aquifer or possibly a horizontal fracture overlain by a porous block (see "Well Hydraulics in Heterogeneous Aquifer Formations" by T. D. Streltsova-Adams in Advances in Hydroscience, Vol. 11, Academic Press, 1978). In addition, it appears questionable that the flat part of the curve is attributable to flow from the blocks to the fractures. According to Streltsova-Adams (see Proceedings, Second

Invitational Well-Testing Symposium held by Earth Sciences Division, Lawrence Berkeley Laboratory, on October 25-27, 1978) the flat part of the data should not show if the ratio $(S_f + S_m)/S_p$ (S_f and S_m are storage coefficients of the fractures and the porous matrix, respectively) is less than about 5 to 11. In other words, if the straight lines on Figure 7 are less than about 0.7 to 1.0 log cycles apart, which they are on Figure 7, then the flat part of the curve should not show. This brings several questions to mind:

1. Is it possible that the straight line shows up between 200 minutes and 2000 minutes on Figure 7? If this is the case, then the data after 2000 minutes including the flat part may be attributable to the transition period between flow in fractures and "induced response."
2. If the straight line is correct and there is no double porosity system, is the flat part of the data and the "induced response" caused by a highly permeable fracture or karst channel near the well test?
3. Is the anistotropy observed in these tests due to recharge into the rocks from a highly permeable fracture or karst channel? Such a response would cause the lines of equal drawdown to have oval shapes rather than the elliptical ones caused by anisotropy. Unless there are data from more than three observation wells it may be very difficult to tell the difference between an anisotropic aquifer and an aquifer with a recharge boundary.

Figure 7 of the report shows the response of the H-4a and H-4b wells due to pumping the H-4c well. Was the response of H-4a and H-4c due to pumping H-4b similar to the data shown on Figure 7 such that a double porosity system was indicated?

page 23, last paragraph

It appears questionable that chloride is the ideal tracer to use to determine if leakage is occurring between Rustler aquifers at the H-4 site. Table 4 of Mercer et. al. indicates that the chloride concentration of both the Magenta and Culebra is 7500 mg/ℓ (Mercer J.W., Paul Davis, Kevin F. Dennehy, and Carole L. Goetz, "Results of Hydrologic Tests and Chemistry Analyses, Wells H-4A, H-4B, and H-4C at the Proposed Waste Isolation Pilot Plant Site, Southeastern New Mexico", Water-Resources Investigations 81-36, U.S. Geological Survey, May, 1981).

page 25, 2nd paragraph

The transmissivities as presented here are extremely small for a fractured rock and would tend to indicate that fracture flow is not that significant, at least in the areas that were tested. Any radionuclide transport in the Culebra would tend to be very slow because of the low transmissivities. Do fractures or karst channels capable of transmitting water exist near the WIPP site?

Table 9.2 of Walton (Walton, William C., Groundwater Resource Evaluation, McGraw-Hill, 1970) indicates the values of specific storage presented here are those for "sound rock." This would tend to indicate that any fractures in the Culebra, at least in the areas tested, are well cemented or that clean, open fractures are far apart. This suggests that fracture flow is not extensive over much of the Culebra but may be confined to long channels or fractures outside the area of influence of the pump tests. Does flow in open fractures exist in areas not tested by the pump or tracer tests?

page 27, 3rd paragraph

Was the aquifer pumped clear prior to tracer injection for the second test? If not, did the non-completion of the first tracer test affect the results of the second test? Is it possible that Segments I and II of Fig. 12 are due to the first test and Segments III and IV to the second test? If so, some type of deconvolution would be necessary to interpret the results.

page 28, 3rd paragraph

The Grove and Beetem (1971) model needs to be corrected for anisotropy. Was this done?

What were the ranges of porosities and dispersivities used in the Grove and Beetem (1971) analyses and how did they compare with the data?

page 32, 3rd paragraph

The significance of the porosities of 0.17 and 0.18 should be discussed here. These values are extremely high for a fractured rock. A fractured rock typically has a fracture porosity of 0.01 - 0.02 and less (Streltsova, 1976). The porosity values presented here are typical for a porous media. If it is assumed that a fractured system operates at the H-2 well sites, then tracer diffusion from the fracture into the porous matrix could account for the high porosity. The effect of this diffusive process has been shown to increase travel times from one point to another when compared to a process without diffusion into the matrix. (See Grisak and Pickens, "Solute Transport Through Fractured Media I: The Effect of Matrix Diffusion, Water Resources Research, vol. 16, no. 4, Aug., 1980, pp. 719-730 and Grisak et al., "Solute Transport through Fractured Media 2: Column Study of Fractured Till," Water Resources Research vol. 16, no. 4, Aug., 1980, pp 731-739). The net effect of increasing the travel time would be a high porosity. Grisak and Pickens also indicated that the diffusion of solute into the matrix would be more significant for low velocities of fluid flow in the fracture than for high velocities. With the hydraulic conductivity of the Culebra at about 0.032 feet per day, fluid velocities are probably small.

The causes of the various segments on Figure 12 should be explained. For instance, were they caused by diffusion into the matrix at one time and out of the matrix at another time? Are they caused by a convolution of the two tracer tests?

page 35, 2nd paragraph

Sauty's (1980) method should be modified for the anisotropy determined from the pump tests at the H-6 site. Since the principal axes of the transmissivity tensor are known for this site, the modification is:

$$n = \frac{Qt}{\pi b\left(\sqrt{\frac{Tyy}{Txx}}\,x^2 + \sqrt{\frac{Txx}{Tyy}}\,y^2\right)}$$

where Q = pumping rate

b = aquifer thickness

t = time of match point

x,y = coordinates of well slugged with tracer

T_{xx} = major transmissivity component

T_{yy} = minor transmissivity component

n = porosity.

In the above equation, the pumping well is at the origin and the major component of the transmissivity tensor runs between wells H-6b and H-6c as indicated from the well test data. The corrected porosities are 9.1% for the H-6b to H-6c test and 0.97% for the H-6a to H-6c test.

The 0.97% porosity appears reasonable for a fractured rock and occurs along the major axis of the transmissivity tensor. The 9.1% appears reasonable for a porous media. There is, however, almost an order of magnitude difference between the two. Since porosity is not anisotropic the disparity is probably caused by a heterogeneity in the Culebra. The suggestion of a discrete zone of flow i.e. a long highly permeable fracture, a set of parallel fractures or a karst channel, appears reasonable. Whether or not this discrete flow can be modelled adequately appears questionable. The problem lies in determining the number of discrete fractures and their locations.

<u>page 38, 1st paragraph</u>

The Safety Analysis Report (page 2.6-35) indicates that two sets of joint exist in the Delaware Basin. One of these sets strikes NW to SE, in the same direction as the major component of the transmissivity tensor. Does this joint set have some relationship to the principal axes of the transmissivity tensor? What is the possibility that vertical or near vertical fractures formed by the joint set could be missed by the drilling activities and subsequently untested by the pump testing program?

<u>page 38, 2nd paragraph to page 39, 1st paragraph</u>

The physical significance of the range of porosities to the following parameters should be discussed in more detail:

- travel times
- fracture flow or porous media flow
- the directional characteristics of the porosity.

The hydraulic conductivities should also be discussed in terms of fracture flow and porous media flow. The hydraulic conductivity values quoted in this report are averaged over the thickness of the Culebra i.e. the hydraulic conductivity is assumed to be uniform throughout the thickness of the Culebra. In a fractured media, the hydraulic conductivity is not uniform. It is peaked in a fracture and near zero outside a fracture. How would the hydraulic conductivity vary throughout the thickness of the Culebra? What effect would this variation have on travel times?

page 39, 1st paragraph

Figure 16 indicates that flow through the H-6 site is initially SSE. However the flow path appears to curve to the southeast away from Nash Draw. What is the basis for concluding that flow through H-6 reaches Nash Draw? In addition, a flow to the south-southeast would eventually have to turn toward the southwest in order to reach Nash Draw.

It further appears that Figure 16 may need some refinement. The figure does not appear to have contours based on the fresh water altitudes at H-8, H-9 and H-10. In addition, the fresh water elevation at P-18 is extremely low compared to the elevations at the other wells. The validity of the fresh water altitude is questionable because of the low hydraulic conductivity at that well. How does the fresh water altitude map change if fresh water altitudes at H-8, H-9 and H-10 are included in the map construction and P-18 is eliminated?

page 41, bottom paragraph

What is the basis for assuming 10 miles to the southeast? The data are all within 5 miles of the WIPP site. Most of the "path which would exceed 10 miles" is located in an area of very low hydraulic conductivity and in an area of unknown hydraulic gradient. In view of the southeast gradient over the study area, (Figure 16 of the draft report) how can the radionuclides discharge at Malaga Bend? The direction of the hydraulic gradient would have to turn southwest in order for a radionuclide to discharge at Malaga Bend. At present there are no data to support this. Are there other discharge areas for the Culebra?

page 43, 1st paragraph

If travel time for a non-absorbing radionuclide in the Culebra becomes greater than 40,000 years, is it possible that the Magenta's westward flow from the WIPP to Nash Draw would provide a quicker radioactive release to the biosphere than flow in the Culebra? If so perhaps future studies should concentrate on flow in the Magenta rather than on the Culebra.

page 44 ad 45, Continuing Investigations

The following are suggestions that should be useful in the continuing study of fracture flow in the Rustler:

1. A review of aerial photographs through the area defined by WIPP-29, WIPP-25, WIPP-33, H-6 and H-5 should be made to see if any geomorphic features associated with either karst hydrology or fracture hydrology exist there. Thermal infrared photographs may be useful in locating springs or shallow ground water flowing in subsurface channels. This suggestion is made for several reasons:
   a. Larry Barrows, in a presentation to EEG, indicated that an elevated gravity anomaly existed in this area. He attributes it to a possible karst channel in the Culebra.
   b. A structure contour map (see Figure 1) on top of the Culebra was generated from Table 1 of the report. It indicates a depression extending through the WIPP-25, H-6, H-5 area. This depression may be associated with a karst channel.
   c. A fresh water altitude map (see Figure 2) for the Culebra was constructed from the data presented in Table 1 of the report. The figure indicates that a ground water high is associated with the depression. The ground water high indicates a potential for some flow to the west.

   If possible the review of the aerial photographs should extend from the northern part of Nash Draw to Malaga Bend.

2. The application of inverse techniques to flow in the Rustler should be interesting. For the most part inverse techniques are in their infancy and are designed for porous media flow, not discrete flow. If it is decided

that fracture flow can be modeled as a porous media, then the inverse technique developed by Neuman and Yakowitz ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 1: Theory," Water Resources Research, vol. 15, no. 4, pp 845-860, 1979), Neuman et al. ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 2: Case Study," Water Resources Research, vol. 16, no. 1, pp. 33-58, 1980) and Neuman ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 3: Improved Solution Method and Added Perspective, "Water Resources Research, vol. 16, no. 2, pp 331-346, 1980) should be tried. It appears that, at present, this is the only technique that has been published with an application to a real problem. Before the inverse techniques are applied to the Rustler, it should be decided whether flow in the Culebra is discrete or porous.

3. It appears that any contamination from a repository breach in Zone II would flow to the southeast. This is based on the flow paths as determined from Figure 15 and Figure 16 of the report. The area southeast of the WIPP should be studied further in terms of piezometric head, flow direction and discharge areas.

4. The tracer test at H-7 should be run similarly to the one at H-6. This should provide some more insight into the directional characteristics of the porosity and the areal extent of this phenomenum. Because the hydraulic conductivities at H-6 and H-7 are almost the same, the time required to run a test at H-7 should be about the same as at H-6.

   If possible, two two-well tracer tests should be run at H-4 in order to determine the porosity along the major and minor components of the transmissivity tensor.

5. If it has not been done, the Grove and Beetem (1971) model, the Sauty (1980) model and the SWIFT model, if it is used, should be modified to account for the anisotropy of the Rustler Formation.

TYPOGRAPHIC ERRORS

page 11, 2nd line

"definied" should be "defined"

page 25, bottom 3 lines

Either "yields" or "obtains" should be eliminated.

page 26

"(C)" should be "(°C)."

"(mhos)" should be "(μmhos)."

page 28, 2nd line from bottom

"Increases in displace" should read "Increases in α displace."

page 36

"H-6b-c" should be "H-6a-c."

page 37

H-6a-c" should be "H-6b-c."

page 43, 3rd line

"members" should be "numbers."

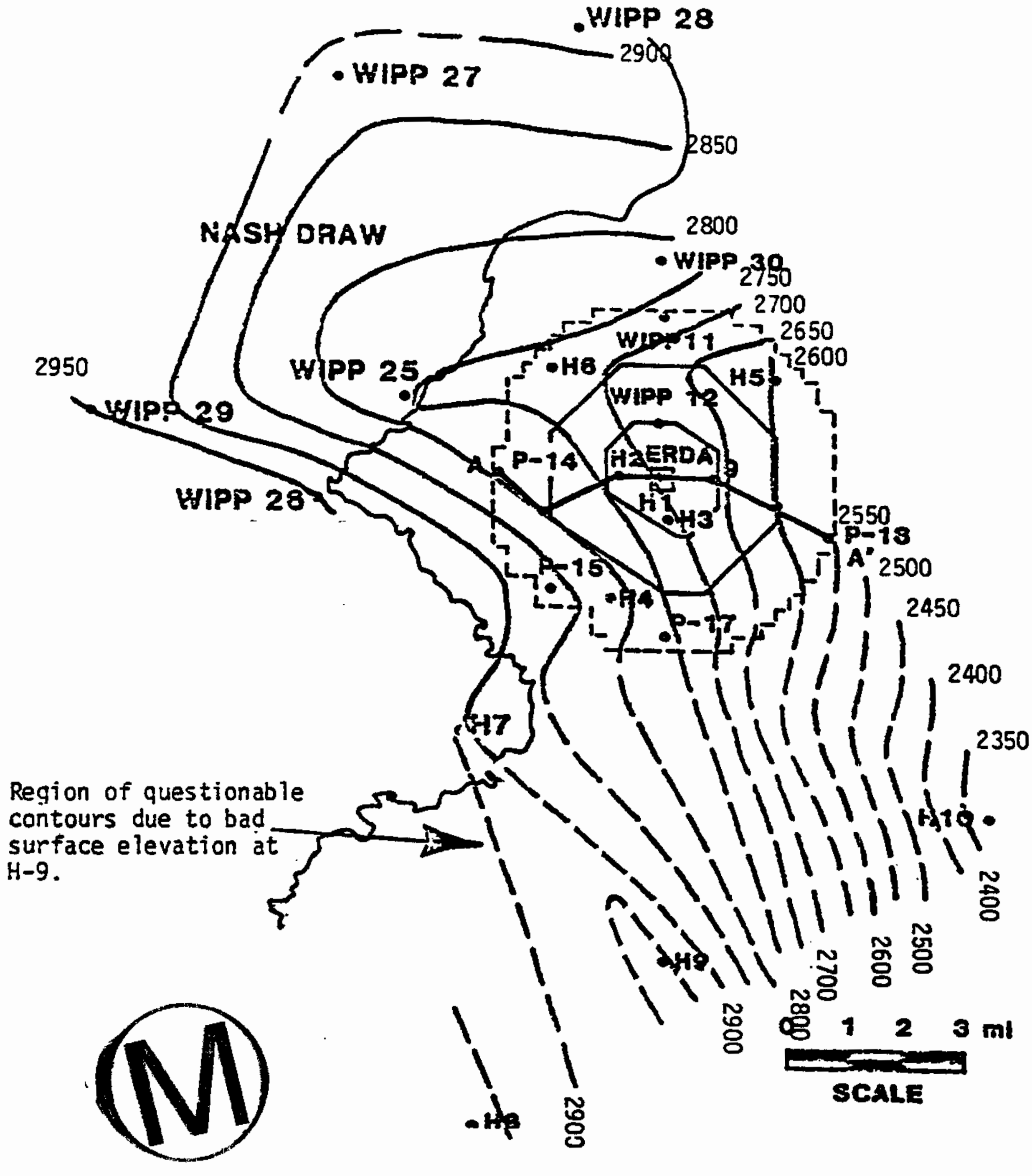

Figure 1. Structure Contours on Top of Culebra

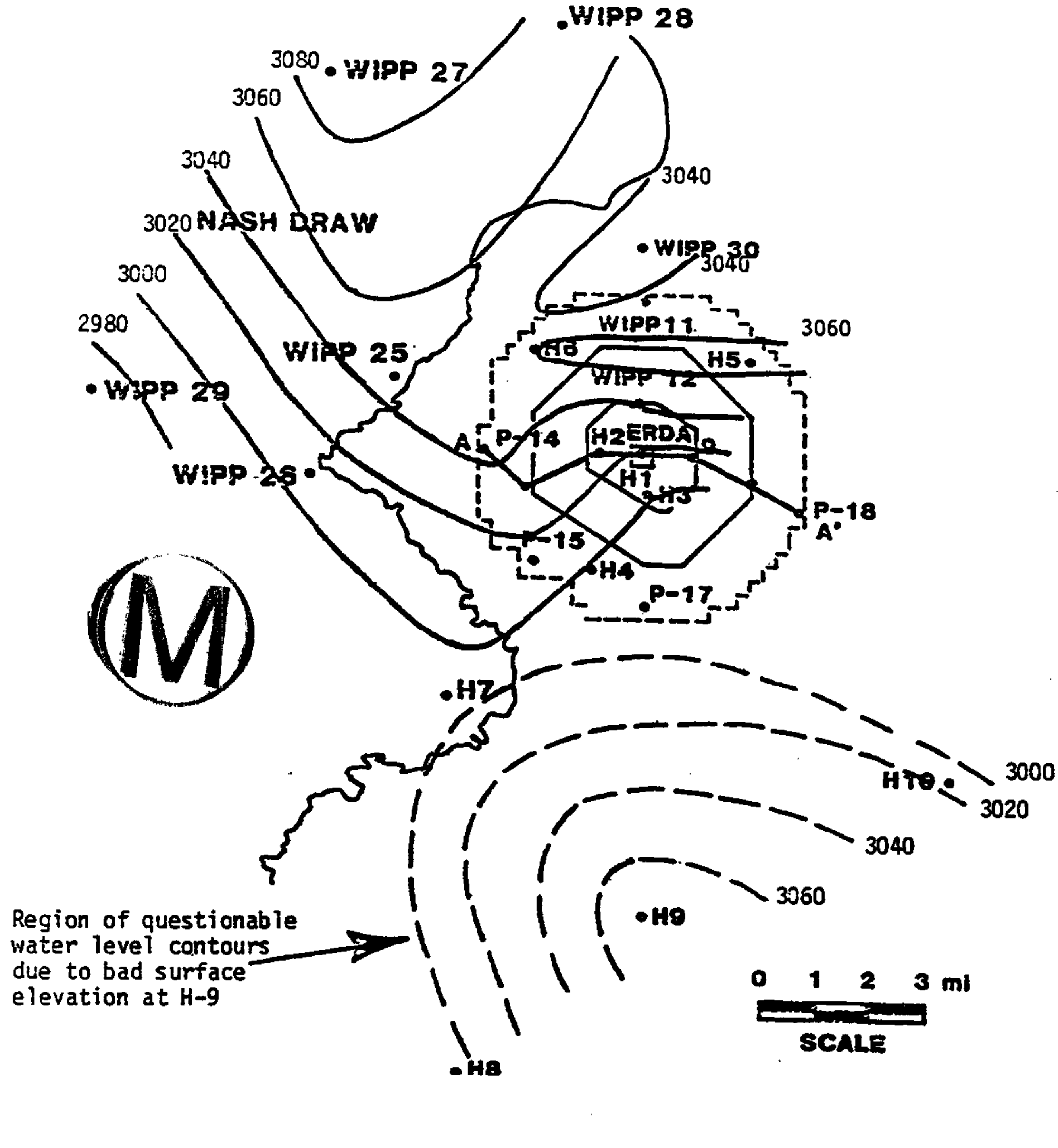

Figure 2. Fresh Water Altitude Contours for Culebra

RESPONSE TO EEG COMMENTS ON "DRAFT INTERIM REPORT ON FRACTURE FLOW IN THE RUSTLER FORMATION"

EEG Comment: (Proposed Work - p. 1)

In the "Cost and Merits Evaluation for the Stipulated Agreement Activities," the following proposed work was identified: "The best model to represent the flow path and aquifer characteristics in the Rustler will be developed." This item was not adequately addressed in the interim report.

DOE Response:

The interim report does not address specifically the best model for flow path and aquifer characteristics of the Rustler. This "best model" will be formulated when the tracer/pump tests are completed.

EEG Comment: (Expected Results - p. 2)

In the "Cost and Merits Evaluation for the Stipulated Agreement Activities" the following expected results were identified: "If the results are such that additional consequence analyses should be run, they will be incorporated into the study." This item was not adequately addressed in the interim report.

DOE Response:

The consequence analyses, if warranted, will be performed by TSC for DOE. Though they are part of the study, the EEG should not expect consequence analyses as part of the interim or final reports on fracture flow in the Rustler.

EEG Comment: (Schueler letter, premise 1, p. 2)

The premise that the Culebra aquifer is critical and thus, it is not necessary to study the Magenta aquifer has not yet been justified.

DOE Response:

The premise that the Culebra is the critical aquifer has been justified for years on the basis of fluid volume, transport times, and discharge point. If the additional data and analysis indicate this premise is no longer justified, additional consequence analysis for the Magenta may be appropriate.

The evaluation of fracture flow in the Rustler Formation has been restricted to the Culebra aquifer on the basis of available hydrologic evaluation of the three fluid-bearing zones of the Rustler and their relationship to release scenarios developed in the EIS. In short, the Culebra Dolomite exhibits the most potential to contain fluids and to be capable of solute transport over a large distance. The Rustler-Salado contact is practically devoid of transmissive property (10^{-4} ft^2/day) and the Magenta Dolomite varies from 10^{-1} to 10^{-4} under the site. Many holes show the Magenta devoid of fluids especially along the east flank of Nash Draw where it appears the Magenta is draining downward across fractured anhydrite and the ensuing gypsum (W-26, 28 and H-7a) and into the underlying Culebra aquifer.

EEG Comment: (Schueler letter, premise 2, p. 2)

The premise that discrete fracture flow is not credible has not yet been justified.

DOE Response:

Discrete fracture flow (one fracture flow path) is certainly inappropriate in view of the discussions on p. 23, for example. On pp. 35 and 38, discrete flow is described as appropriate for H-6, but this is not as one fracture flow path which might describe the system. Discrete fracture flow is not a credible mechanism for solute transport across the WIPP to a discharge area near Malaga Bend. As mentioned in the interim report, we have definite plans to model for multiple fracture block flow (double media). Furthermore, it is geologically unreasonable to conceive that one fracture exists across the WIPP towards the discharge area. The revision of the interim report will add statements summarizing the justification for this idea.

EEG Comments: (General comments, para. 1, p. 3)

The reports currently in preparation which contain details of the various field tests would be useful to the EEG to consult while reviewing the report.

DOE Response:

Yes, the reports in preparation which were cited would be useful to the EEG. The reports are being readied as Contractor Reports (SAND documents) with the intent of publishing and distributing each at or before the time of publication of the revised interim report on fracture flow.

EEG Comment: (General comments, para. 3, p. 3)

A conclusion concerning the nature of fracture flow should be made before the regional transport model is developed.

DOE Response:

The nature of the fracture flow is the point of the work being conducted. Porous media (continuous) methods were used; however, as a first approximation in analyzing the results of the hydraulic and tracer tests. This use is justified because they are not subject to the conceptual uncertainties that cloud the use of discrete fracture models and which make the results based on discrete fracture models subject to controversy. Certainly, a conclusion regarding fracture flow should be made before the regional transport model is completed.

EEG Comment: (General comments, para. 4, p. 3)

The physical meaning of the values of the transmissivity storage coefficient, anisotropy, porosity and dispersivity in terms of fracture flow should be addressed.

DOE Response:

The final report shall include a glossary of terms commonly used in the hydro-world, i.e, fracture conductivity, double porosity, porous media flow, discrete fractures, matrix permeability, transmissivity, anisotropy, porosity, dispersivity and storage. Again, the point of continuing the investigations is to determine the contribution (physical meaning?) of fracture flow. The site specific meaning of various hydraulic properties is the focus of the program.

EEG Comment: (General comment, para. 5, p. 3)

Is the anisotropy due to alternating vertical bands of highly transmissive rock and low transmissive rock that trend northwest to southeast or due to karst channels recharging the aquifers?

DOE Response:

The comment about anisotropy seems related to paragraph 4 in some way. At present, there is no hydraulic test which, unsupported by independent information, can show the cause of anisotropy. The fact that anisotropy tests at three sites were in relative agreement with each other have allowed some inferences to be drawn regarding the regional nature of the flow system. Anisotropy is explained in the report as due to fracturing, which is evidently caused by dissolution and subsidence. There is a possibility that the principal tensor orientation reflects a fracture trend due to tectonic forces. Additional testing for anisotropy will show if the direction for the principal tensor remains the same as in a broader tectonic process. A note regarding the uncertainty here will be added to the text.

There is no fundamental geohydrological process that seems appropriate to this site for developing "alternating vertical bands of highly transmissive rock and low transmissive rock." The higher transmissivities correlate with areas subjected to more apparent Rustler/top Salado salt dissolution. Here, that is interpreted as resulting in fracturing which complements the natural porosity of fluid-bearing zones in the Rustler. These holes do not indicate any direct penetration of cavernous karst features.

We strongly disagree with the use of the word karst to describe the flow system in the Rustler Formation. At the present time data are insufficient to draw such a conclusion. Furthermore, the word karst can and has been used to describe the most disparate observations, from submicroscopic solution enlargements along a fracture, to man-size caverns and house-swallowing sinkholes, such as those that occur in Florida. Unfortunately, it is often times the more lurid definition that sticks in people's minds when the word is brought up. We do not attribute the results of the anisotropy and tracer tests to karst; neither do we preclude its possible existence at the WIPP. We merely state that the use of the word is premature and therefore, inappropriate. It causes emotional responses due to its several definitions, and it puts the investigator in the almost indefensible position of proving that every break in slope of a drawdown curve is not due to a karst feature.

EEG Comment: (General comment, para. 6 & 7, p. 4)

The porosity of 18% determined from the H-2 nest of wells appears high for a fractured rock. At the H-6 nest of wells the porosity appears to exhibit some directional characteristics, when it should not. In addition, the data presented in the report indicate that Culebra flow in the repository area is to the southeast. Previous studies have indicated that flow is to the south and southwest. This data may indicate other discharge areas for the Culebra. An increased flow path that might result from the gradient presented in this report indicates that the Magenta may provide faster releases of radionuclides to the biosphere than the Culebra.

DOE Response:

Thin-section porosity at H-2 is as high as 10 percent. A matrix porosity of 18 percent for the Culebra at H-2 does not seem unreasonable. because there have not been any tests for anisotropy at the H-2 site (the reviewer may believe there have been), we do not draw any specific conclusions about the nature of flow at that site. At H-6 porosities were determined along the major (1%) and minor (11%) components of flow. Keeping in mind the concept of double-porosity medium (fracture-block concept), it is reasonable to find directional characteristics in this type of matrix. Although we presently interpret flow southeast across the site, we have no supporting data to alter our beliefs that the ground water discharges near Malaga Bend. The increased flow path does not discredit the

Culebra as the major vehicle for transport because of the previous discussion on the Magenta.

EEG Comment: (Abstract, 13th to 18th line, p. 4)

The term "principal" to minor transmissivity tensor" should be changed to "major to minor components of the transmissivity tensor." The term "principal transmissivity component" should be changed to "the principal direction of the major component of the transmissivity tensor" or "The orientation of the principal axes of the transmissivity tensor is northwest by southeast for the major component and northeast by southwest for the minor component." A statement about the variability of the transmissivity with respect to distance from the outcrop should also be included in the "abstract."

DOE Responses:

The terminology regarding transmissivity tensors is in need of change. Tensors shall be described in terms of major and minor components and to a principal direction of either a major or minor component. The reference made to distance from the outcrop is confusing. Does the reviewer mean Nash Draw? We do refer to the variation in transmissivity relative to the east flank of Nash Draw. The comment may imply inferences about recharge areas being the Nash Draw "outcrop" areas which were not ready to draw yet.

EEG Comment: (2nd para., p. 4)

Mercer and Gonzalez (1981) indicate a strong westward gradient from WIPP to Nash Draw in the Magenta dolomite. Have any calculations of travel time from WIPP to Nash Draw been made for the Magenta and compared to travel times for the Culebra?

The Culebra's southeast gradient through the repository, as indicated on Figure 16, shows that contamination from a repository breach may either never reach Nash Draw or may take longer than the 40,000 years previously estimated. If the Culebra travel times are significantly increased, the Magenta may provide quicker radioactive releases to the biosphere than the Culebra. Estimates of travel time from the repository to Nash Draw through the Magenta should be provided in this paragraph.

What are the data and assumptions that went into the calculation of the 40,000 year travel time from ERDA-9 to Malaga Bend? Is this number taken from some other work?

DOE Response:

The comment about Magenta travel times seems to be leading to an inference that Nash Draw is where the Magenta discharges. Instead, the travel time to the probable common discharge point is appropriate. Travel time is tempered by flux. The additional consequence analysis, if necessary, is the appropriate comparison.

The calculation of the 40,000 year travel time resulted from a request by D. D. Gonzalez to Intera Groundwater Consultants. The date of the request was January 1979 and was based on a very limited set of hydrologic parameters, including transmissivity, storativity and hydraulic head at four locations and only estimates in areas near Laguna Grande de La Sal and towards Malaga Bend. The assumed thickness and porosities for the Culebra Dolomite were 30 feet and 10% respectively. The particle tracking model (SWIFT) determining the streamline and travel time for a non-absorbing tracer particle released at the WIPP site calculated a streamline proceeding due south from the center of the WIPP for about five miles, then west south-westward towards Laguna Grande de La Sal, then south towards Malaga Bend. Over 80% of this travel time is attributed to flow in the five-mile long reach south of the site where our understanding of the hydraulic characteristics have not changed appreciably since 1979, except for porosities being calculated at 18% at H-2. Further discussion will be included in the final report as well as a reference to the Intera work, dated 5-22-79.

EEG Comment: (Page 8, bottom para., p. 5)

Figure 16 indicates that the hydraulic gradient is to the southeast through the facility. Why does this paragraph say south and then southwest toward Malaga Bend? The statement appears to be referring to the previously assumed flow path shown in figure 3, but it certainly is not clear.

DOE Response:

The southeast flow across much of the site still appears correct. The flow is expected to swing to the southwest based on H-8, 9, and 10. The contours of Figure 16 will be revised for the interim version, and we expect to perform additional testing in the southeast portion of the site to verify contours and hydraulic properties. The interim report will be clarified.

EEG Comment: (Page 9, p. 5)

Table 1 should be checked for errors. The "Fresh Water Altitude" for P-18 on the table and the altitude used for construction of Figure 16 appear to differ by 100 feet. Other "Fresh Water Altitudes" that appear to need checking belong to wells H-5, H-8, H-9, H-10, W-28 and W-30. In addition, the surface altitude of H-9 is 100' higher than that presented in Seward ("Abridged Borehole Histories for the Waste Isolation Pilot Plant (WIPP) Studies," SAND82-0080). This may lower the fresh water altitude to 2976 at H-9. It is probable that the fractured nature of the dolomite may be causing the anomalous water levels. The water level at H-5 appears to be associated with a structural anomaly of the Culebra Dolomite (see attached Figures 1 and 2 and comment regarding page 44 and 45).

DOE Response:

P-18 and W-30 seem anomalously low, and both wells have very low transmissivity. They will be monitored to see if they have truly regained static equilibrium. If they have not, then the use of these nonrecovered water levels makes the water level at H-5 seem anomalously high and may lead to erroneous conclusions about the formation around H-5. in addition, we are in the process of double checking those elevations at all H- and W- sites where hydro-data have been collected.

EEG Comment: (Page 11, 1st para., p. 5)

References for transmissivity values should be provided.

DOE Response:

References will be given as appropriate.

EEG Comment: (Page 14, 2 bottom lines, p. 5)

It would be nice if the reference were already published to check the theory and to see the report contents.

DOE Response:

Agreed. See previous comment.

EEG Comment: (Page 15, 1st para., p. 6)

The description of test procedures indicates that the "a" well at each pad was pumped. However, the anisotropy results of Table 2, Table 3 and Table 4 provide no results from pumping the "a" well. Why are the results from pumping the "a" well not presented? Was the "a" well pumped at all?

DOE Response:

The "a" wells could not be pumped, though the report implied they were. The tests for anisotropy require only two wells be pumped within a three-well array; however, at each pad the "a" wells developed downhole or pump complications which prohibited their pumping. Clarification will be made in the interim report.

EEG Comment: (Page 15, last para., p. 6)

If the tracer curves as insensitive to dispersion (dispersivity), how can it be estimated?

DOE Response:

The fact that the Grove and Beetem breakthrough curves are relatively insensitive to dispersivity means only that they do not give precise values of dispersivity. Single well "pump-back" and two-well convergent flow tests are the best method to determine dispersivity and these tests are being pursued.

EEG Comment: (Page 19, Table 2, p. 6)

According to the theory of anisotropic aquifers developed by Papadopulos (1965), the response of well H-4C from pumping H-4B should produce the same T and S values as the response of well H-4B from pumping well H-4C. The T estimates for these wells differ by a factor of two for tests one and two. The range of T (not including pumping wells) for all three tests is 0.8 feet squared per day to 1.7 feet squared per day. What is the cause of this discrepancy?

DOE Response

In theory, the same effective transmissivity should be observed in the observation wells in an anisotropic aquifer, but not the storage coefficient. Obviously if the observation well data yield the same T and S and if the wells are the same distance from the pumped well, then the aquifer is isotropic. Also, only in an ideal aquifer will the same values be obtained from observation wells. However, the sensitivity of the anisotropy results to errors in the drawdown interpretation should be investigated, and sensitivity tests are included in our final product.

EEG Comment: (Page 23, 1st para., pp. 6-7)

Were any methods, such as images, tried in order to locate any of the barrier boundaries? What could these boundaries be attributed to? For instance, could the boundaries be due to vertical fractures filled with an impermeable material or to a less fractured nearby region of dolomite?

The shape of the curve on Figure 7 is interesting. The early part of the curve (prior to the formation of the straight line) may be a result of no storage of water in the fractured part of the aquifer or possibly a horizontal fracture overlain by a porous block (see "Well Hydraulics in Heterogeneous Aquifer Formations" by T. D. Streltsova-Adams in Advances in Hydroscience, Vol. 11, Academic Press, 1978). In addition, it appears questionable that the flat part of the curve is attributable to flow from the blocks to the fractures. According to Streltsova-Adams (see Proceedings, Second Invitational Well-Testing Symposium held by Earth Sciences Division, Lawrence Berkeley Laboratory, on October 25-27, 1978) the flat part of the data should not show if the ratio $(S_f + S_m)/S_p$ (S_f and S_m are storage coefficients of the fractures and the porous matrix, respectively) is less than about 5 to 11. In other words, if the straight lines on Figure 7 are less than about 0.7 to 1.0 log cycles apart, which they are on Figure 7, then the flat part of the curve should not show. This brings several questions to mind:

1. It is possible that the straight line shows up between 200 minutes and 2000 minutes on Figure 7? If this is the case, then the data after 2000 minutes including the flat part may be attributable to the transition period between flow in fractures and "induced response."

2. If the straight line is correct and there is no double porosity system, is the flat part of the data and the "induced response" caused by a highly permeable fracture or karst channel near the well test?

3. Is the anisotropy observed in these tests due to recharge into the rocks from a highly permeable fracture or karst channel? Such a response would cause the lines of equal drawdown to have oval shapes rather than the elliptical ones caused by anisotropy. Unless there are data from more than three observation wells, it may be very difficult to tell the difference between an anisotropic aquifer and an aquifer with a recharge boundary.

Figure 7 of the report shows the response of the H-4a and H-4b wells due to pumping the H-4c well. Was the response of H-4a an H-4c due to pumping H-4b similar to the data shown on Figure 7 such that a double porosity system was indicated?

DOE Response:

Image-well theory was applied to drawdown data in an effort to locate groundwater "barriers," which could be attributed to skin effects, wellbore storage, pumping variations, elastic deformation, and formation barriers. A formation barrier may consist of abrupt changes in aquifer properties, such as porosity, conductivity, fracture density or orientation, recharge and discharge zones, transient or steady-state flow, vertical/horizontal permeability. Barriers may be the result of one or a combination of geologic or hydrologic parameters. Vertical communication with known overlying and underlying aquifers is practically negligible throughout the WIPP facility on the basis of observed differences in hydraulic potential and conductivities and general chemistry. We believe that the reviewer means that the slope of the transitional curve should not be zero, not that it should not show. Also, Streltsova-Adams assumes in her report that the matrix has zero permeability. If, in our case, the matrix has some permeability, then the shape of the drawdown curve may be different from her examples.

In regards to the three questions raised by the reviewer:

1. We think that the curvature of the early-time data on Figure 7 is pronounced. On log-log paper this portion of the curve is straight with nearly unit slope indicating full fracture flow or well-bore storage (probably the latter). It is entirely possible that the data after 2000 minutes is in a transitional period, but we think it is more consistent to treat the data between 2000 and 5000 minutes as a good straight-line (Jacob approx.) solution, and between 5000 and 8000 minutes as transitional (or induced response). Past 8000 minutes the line becomes approximately parallel to the earlier data. (The "INDUCED RESPONSE" arrow on Figure 7 points to the wrong part of the curve and will be corrected in the interim report.)

2. If the first break in the drawdown curve is attributed to hitting a recharge boundary, then it follows that the second break must be due to a barrier boundary. Furthermore, the shapes and permeabilities of both boundaries must be such that the effect of the second boundary must completely negate the first so drawdown may continue as if neither existed. We agree that several interpretations are possible, given that little is known about the system, but we do not believe that the drawdown data alone support the existence of a recharge boundary. In regards to "karst channel near the well," please refer to earlier discussion about so-called karst.

3. According to our dictionary, the definitions of "oval" and "elliptical" are the same. The drawdown data we used for anisotropy determinations was early-time, hopefully taken before any breaks, boundaries, or possible induced response affected the results. The anisotropy results should be free from these effects.

Some of this discussion will be included in the revision of the draft.

Well H-4a could not be pumped and the H-4b test was not run for a sufficient length of time to see the second break in the drawdown curve.

EEG Comment: (Page 23, last para., p. 7)

It appears questionable that chloride is the ideal tracer to use to determine if leakage is occurring between Rüstler aquifers at the H-4 site. Table 4 of Mercer et. al. indicates that the chloride concentration of both the Magenta and Culebra is 7500 mg/l (Mercer, J. W., Paul Davis, Kevin F. Dennehy, and Carole L. Goetz, "Results of Hydrologic Tests and Chemistry Analyses, Wells H-4A, H-4B, and H-4C at the Proposed Waste Isolation Pilot Plant Site, Southeastern New Mexico," Water-Resources Investigations 81-36, U.S. Geological Survey, May, 1981).

DOE Response:

The objective was to determine if leakage did occur during the tests; we had few other tools at out disposal (such as piezometers in confining zones or adjacent water-bearing units) to assess leakage, so water chemistry (temperature, ph, conductivity, chloride) was looked at during these tests as an alternative means. The results are not conclusive, but indicate that no leakage occurred. The text will be revised to indicate the uncertainty at H-4.

EEG Comment: (Page 25, 2nd para., p. 8) --

The transmissivities as presented here are extremely small for a fractured rock and would tend to indicate that fracture flow is not that significant, at least in the areas that were tested. Any radionuclide transport in the Culebra would tend to be very slow because of the low transmissivities. Do fractures or karst channels capable of transmitting water exist near the WIPP site?

Table 9.2 of Walton (Walton, William C., Groundwater Resource Evaluation, McGraw-Hill, 1970) indicates the values of specific storage presented here are those for "sound rock." This would tend to indicate that any fractures in the Culebra, at least in the areas tested, are well cemented or that clean, open fractures are far apart. This suggests that fracture flow is not extensive over much of the Culebra but may be confined to long channels or fractures outside the area of influence of the pump tests. Does flow in open fractures exist in areas not tested by the pump or tracer tests?

DOE Response:

The hydraulic conductivities observed at the WIPP are actually large compared to fractured crystalline rock. For example, the lowest transmissivity measured in our tests was at the H-5 site (0.04 feet squared per day), and corresponds to a hydraulic conductivity of 2×10^{-3} feet per day, which is an average for fractured crystalline rocks (Stripa Mine Project Report, 1980). It cannot be concluded that fluid movement will be slow because transmissivities are small. Solute transport may be quite rapid in a fracture flow situation. Determining solute transport capability is, of course, a major reason to perform tracer tests, which will yield indications of fluid velocities in the natural flow system.

The values of specific storage measured at the WIPP are of the order of 10^{-6}/ft, which, using Walter (Table 9.2) is reasonable for fissured and jointed rock. Lohman (Ground-Water Hydraulics, USGS Prof. Paper 708) uses a value of 10^{-6}/ft as a way to estimate storage coefficients for confined aquifers in general. A rock, such as a fairly rigid dolomite, could have a very low specific storage and still have measurable matrix and fracture porosity. Low specific storage does not mean that fracture flow is not extensive; it may only mean that there is a lack of significant compressibility in the system, both from fractures and matrix. For the reviewer to carry his suggestion one step further and imply that low specific storage within the area of pumping influence is evidence that open fracture or channel (karst?) flow exists outside the area of pumping influence, is, of course, unanswerable.

EEG Comment: (Page 27, 3rd para., p. 8)

Was the aquifer pumped clear prior to tracer injection for the second test? If not, did the non-completion of the first tracer test affect the results of the second test? Is it possible that Segments I and II of Figure 12 are due to the first test and Segments III and IV to the second test? If so, some type of deconvolution would be necessary to interpret the results.

DOE Response:

Different tracers were used in each test; thus, no interference existed.

EEG Comments (Page 28, 3rd paragraph, p. 8)

The Grove and Beetem (1971) model needs to be corrected for anisotropy. Was this done? What were the ranges of porosities and dispersivities used in the Grove and Beetem (1971) analyses and how did they compare with the data?

(Page 32, 3rd paragraph, pp. 8-9)

The significance of the porosities of 0.17 and 0.18 should be discussed here. These values are extremely high for a fractured rock. A fractured rock typically has a fracture porosity of 0.01 - 0.02 and less (Streltsova, 1976). The porosity values presented here are typical for a porous media. If it is assumed that a fractured system operates at the H-2 well sites, then tracer diffusion from the fracture into the porous matrix could account for the high porosity. The effect of this diffusive process has been shown to increase travel times from one point to another when compared to a process without diffusion into the matrix. (See Grisak and Pickens, "Solute Transport Through Fractured Media I: The Effect of Matrix Diffusion, Water Resources Research, vol. 16, no. 4, Aug., 1980, pp. 719-730 and Grisak et al., "Solute Transport through Fractured Media 2: Column Study of Fractured Till," Water Resources Research vol. 16, no. 4, Aug., 1980, pp. 731-739). The net effect of increasing the travel time would be a high porosity. Grisak and Pickens also indicated that the diffusion of solute into the matrix would be more significant for low velocities of fluid flow in the fracture than for high velocities. With the hydraulic conductivity of the Culebra at about 0.032 feet per day, fluid velocities are probably small.

The causes of the various segments on Figure 12 should be explained. For instance, were they caused by diffusion into the matrix at one time and out of the matrix at another time? Are they caused by a convolution of the two tracer tests?

(Page 35, 2nd paragraph, pp. 9-10)

Sauty's (1980) method should be modified for the anisotropy determined from the pump tests at the H-6 site. Since the principal axes of the transmissivity tensor are known for this site, the modification is:

$$n = \frac{Qt}{b \left(\frac{Tyy}{Txx} x^2 + \frac{Txx}{Tyy} y^2 \right)}$$

where Q = pumping rate
b = aquifer thickness
t = time of match point
x,y = coordinates of well slugged with tracer
Txx = major transmissivity component
Tyy = minor transmissivity component
n = porosity.

In the above equation, the pumping well is at the origin and the major component of the transmissivity tensor runs between wells H-6b and H-6c as indicated from the well test data. The corrected porosities are 9.1% for the H-6b to H-6c test and 0.97% for the H-6a to H-6c test.

The 0.97% porosity appears reasonable for a fractured rock and occurs along the major axis of the transmissivity tensor. The 9.1% appears reasonable for a porous media. There is, however, almost an order of magnitude difference between the two. Since porosity is not anisotropic, the disparity is probably caused by a heterogeneity in the Culebra. The suggestion of a discrete zone of flow, i.e., a long highly permeable fracture, a set of parallel fractures or a karst channel, appears reasonable. Whether or not this discrete flow can be modelled adequately appears questionable. The problem lies in determining the number of discrete fractures and their locations.

DOE Responses:

Several good points are brought out here. We do not yet believe that we can define the flow system at the H-2 site. A double porosity system is appealing, but anisotropy needs to be determined and further tracer tests along different flow paths need to be conducted at the site to define the flow system. Again, we do not believe that the hydraulic conductivity at the H-2 site precludes the possibility or rapid fluid movement. The final report will include the results of additional tracer and anisotropy tests and respective modification to the code developed by Grove and Beetum.

Much discussion can be related to what value of porosity is typical of fractured rock vs. porous media. A minimum of effort has been spent on acquiring field data through extended tracer and anisotropy tests to evaluate and determine what these values are and what they mean. We hope to solidify our thoughts on double porosity media after the conclusion of our tests at H-6 and 7. At this point, the number of discrete fractures and their locations are not the problem -- neither is the notion of karst channel domination. A macroscopic point of view is the solution.

The H-6 tracer results certainly imply the existence of both fracture and matrix flow, at least under the flow regime set up by the test itself. There is not necessarily a disparity in the porosity determinations, nor need the difference be caused by local heterogenities.

EEG Comment: (Page 38, 1st para., p. 10)

The Safety Analysis Report (page 2.6-35) indicates that two sets of joint exist in the Delaware Basin. One of these sets strikes NW to SE, in the same direction as the major component of the transmissivity tensor. Does this joint set have some relationship to the principal axes of the transmissivity tensor? What is the possibility that vertical or near vertical fractures formed by the joint set could be missed by the drilling activities and subsequently untested by the pump testing program?

DOE Response:

See previous discussion of principal tensor and fracture trends. The testing program would not test a set of non-intersecting or non-interconnected fractures by definition. The fact that dipping fractures are intersected requires interconnection of even vertical fractures with the borehole though the zone of influence has limits.

EEG Comments:

(Page 38, 2nd para. to Page 39, 1st para., pp. 10-11)

The physical significance of the range of porosities to the following parameters should be discussed in more detail:

- o travel times
- o fracture flow or porous media flow
- o the directional characteristics of the porosity.

The hydraulic conductivities should also be discussed in terms of fracture flow and porous media flow. The hydraulic conductivity values quoted in this report are averaged over the thickness of the Culebra, i.e., the hydraulic conductivity is assumed to be uniform throughout the thickness of the Culebra. In a fractured media, the hydraulic conductivity is not uniform. It is peaked in a fracture and near zero ouside a fracture. How would the hydraulic conductivity vary throughout the thickness of the Culebra? What effect would this variation have on travel times?

(Page 39, 1st para., p. 10)

Figure 16 indicates that flow through the H-6 site is initially SSE. However, the flow path appears to curve to the southeast away from Nash Draw. What is the basis for concluding that flow through H-6 reaches Nash Draw? In addition, a flow to the south-southeast would eventually have to turn toward the southwest in order to reach Nash Draw.

It further appears that Figure 16 may need some refinement. The figure does not appear to have contours based on the fresh water altitudes at H-8, H-9 and H-10. In addition, the fresh water elevation at P-18 is extremely low compared to the elevations at the other wells. The validity of the fresh water altitude is questionable because of the low hydraulic conductivity at that well. How does the fresh water altitude map change if fresh water altitudes at H-8, H-9 and H-10 are included in the map construction and P-18 is eliminated?

DOE Response:

How hydraulic conductivity varies within the Culebra, both vertically and horizontally, will be a very difficult study. Cores taken from and measurements taken within the new ventilation shaft will help us. In our final analysis, a variation of parameters shall be input to the final regional model to simulate a variation of travel times under differing conditions.

The potentiometric surface as shown on Figure 16 typifies a very transmissive system approaching the WIPP from the north-east but encountering, in effect, a leaky boundary defined by the decrease in hydraulic conductivity from west to east and probably influenced by the presence of "salt" within the Rustler and lower transmissivities in the Culebra Dolomite. As the flux of groundwater encounters a less permeable portion of the aquifer, it resists flow and takes the more plausible avenue - down Nash Draw where we find transmissivities much greater in a number of wells. Figure 16 exemplifies the site specific information collected on and within the boundaries of the facility. The final report will include a refinement of the data, which will include tracer and anisotropy tests at locations south-east and south of the site. The validity of the use of fresh water altitudes based on fluid density influenced by low conductivity is also our concern. A final suite of W.L. measurements and density determinations will be taken and evaluated for inclusion in the final report. There are no better estimates for discharge areas other than near Malaga Bend or south of Laguna Grande de la Sal.

EEG Comment: (Page 41, bottom para., pp. 11-12)

What is the basis for assuming 10 miles to the southeast? The data are all within 5 miles of the WIPP site. Most of the "path which would exceed 10 miles" is located in an area of very low hydraulic conductivity and in an area of unknown hydraulic gradient. In view of the southeast gradient over the study area (Figure 16 of the draft report), how can the radionuclides discharge at Malaga Bend? The direction of the hydraulic gradient would have to turn southwest in order for a radionuclide to discharge at Malaga Bend. At present there are no data to support this. Are there other discharge areas for the Culebra?

DOE Response:

See previous comments.

EEG Comment: (Page 43, 1st para., p. 12)

If travel time for a non-absorbing radionuclide in the Culebra becomes greater than 40,000 years, it is possible that the Magenta's westward flow from the WIPP to Nash Draw would provide a quicker radioactive release to the biosphere than flow in the Culebra? If so, perhaps future studies should concentrate on flow in the Magenta rather than on the Culebra.

DOE Response:

See previous comments on Magenta.

EEG Comment: (Pages 44 and 45, Continuing Investigations, pp. 12-13)

The following are suggestions that should be useful in the continuing study of fracture flow in the Rustler:

1. A review of aerial photographs through the area defined by WIPP-29, WIPP-25, WIPP-33, H-6 and H-5 should be made to see if any geomorphic features associated with either karst hydrology or fracture hydrology exist there. Thermal infrared photographs may be useful in locating springs or shallow ground water flowing in subsurface channels. This suggestion is made for several reasons:

   a. Larry Barrows, in a presentation to EEG, indicated that an elevated gravity anomaly existed in this area. He attributes it to a possible karst channel in the Culebra.

   b. A structure contour map (see Figure 1) on top of the Culebra was generated from Table 1 of the report. It indicates a depression extending through the WIPP-25, H-6, H-5 area. This depression may be associated with a karst channel.

   c. A fresh water altitude map (see Figure 2) for the Culebra was constructed from the data presented in Table 1 of the report. The figure indicates that a ground water high is associated with the depression. The ground water high indicates a potential for some flow to the west.

   If possible, the reviw of the aerial photographs shoud extend from the northern part of Nash Draw to Malaga Bend.

2. The application of inverse techniques to flow in the Rustler should be interesting. For the most part, inverse techniques are in their infancy and are designed for porous media flow, not discrete flow. If it is decided that fracture flow can be modeled as a porous media, then the inverse technique developed by Neuman and Yakowitz ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 1: Theory," Water Resources Research, vol. 15, no. 4, pp. 845-860, 1979), Neuman et al. ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 2: Case Study," Water Resources Research, vol. 16, no. 1, pp. 33-58, 1980) and Neuman ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 3: Improved Solution Method and Added Perspective, "Water Resources Research, vol. 16, no. 2, pp. 331-346, 1980) should be tried. It appears that, at present, this is the only technique that has been published with an application to a real problem. Before the inverse techniques are applied to the Rustler, it should be decided whether flow in the Culebra is discrete or porous.

3. It appears that any contamination from a repository breach in Zone II would flow to the southeast. This is based on the flow paths as determined from Figure 15 and Figure 16 of the report. The area southeast of the WIPP should be studied further in terms of piezometric head, flow direction and discharge areas.

4. The tracer test at H-7 should be run similarly to the one at H-6. This should provide some more insight into the directional characteristics of the porosity and the areal extent of this phenomenon. Because the hydraulic conductivities at H-6 and H-7 are almost the same time, the time required to run a test at H-7 should be about the same as at H-6.

   If possible, two two-well tracer tests should be run at H-4 in order to determine the porosity along the major and minor components of the transmissivity tensor.

5. If it has not been done, the Grove and Beetem (1971) model, the Sauty (1980) model and the SWIFT model, if it is used, should be modified to account for the anisotropy of the Rustler Formation.

DOE Response:

Item 1.a. Bachman (1980, 1981) examined karst features extensively through Nash Draw, along the Pecos, and in the site area. He attributed the fill and depression at WIPP 33 to a karst-type process by which Nash Draw expands. In his field work and review of aerial photos, he does not attribute geomorphic features at the site to karst processes. Barrows found anomalously low gravity indicating which he infers as due to removal of mass by dissolution (= karst). Barrows does not restrict karst to the Culebra - it is more likely in the gypsum units by his log correlations.

Item 1.b. Whether the gravity anomaly and structure contour maps show karst channels or not is still speculation. Perhaps comparing these maps with similar ones in regions of known karst will help somewhat. If the structure contour map does delineate a west-east karst channel, it cuts through some of the highest transmissivities tested at the WIPP (WIPP 25 and H-6), as well as the lowest (WIPP 30 and H-5). It also trends parallel to the minor component direction of the transmissivity tensor determined at H-6 and H-5; that is, the transmissivity is least in the direction of the channel.

Item 1.c. Figure 16 will be revised as previously stated. WIPP 30 is still being monitored, and all potentiometric data will be revised to be current for the interim report.

Item 2. Those suggestions are well taken and shall be considered. Inverse techniques are subject to criticism; however, significant strides are being made towards utilizing these techniques and determining whether fracture media can be treated as porous media (Neuman, U of Arizona); C. Wilson, and J. B. Long, LBL). We do have the insight to perform these evaluations in determining whether we are dealing with fracture or porous - the objective of our site specific studies.

Item 3. Locations for testing in the southeastern part of the site have been of some interest. DOE 1 was considered, but the operations may have been unsuitable for the conversion of the hole to hydro testing. However, that pad and borehole continue to be candidates for further testing. Anisotropy tests at H-9 and H-10 are also being considered.

Item 4. See report, p. 7, last line; also p. 45.

Item 5. See p. 44.

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HEALTH ENVIRONMENT department

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February 18, 1983

Mr. Joseph M. McGough
Project Manager
WIPP Project Office
U.S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. McGough:

Subject: DOE response to EEG comments on "Draft Interim Report on Fracture Flow in the Rustler Formation"

We have evaluated the DOE response to EEG comments on the above cited document. For the most part, the responses were adequate. In some cases, additional text descriptions are suggested in our evaluation. One point, however, will require additional investigation and discussion.

We question the premise that only the Culebra aquifer is critical for contaminant transport scenarios. The Magenta should also be considered a migration pathway. Although the transmissivity of the Magenta is nearly a factor of 10 smaller than that of the Culebra, the flux through each aquifer is also dependent on the hydraulic gradient. Based on the limited data available to EEG at this time, the hydraulic gradient to the northwest in the Magenta (Mercer and Gonzalez, 1981) is steeper than the gradient to the south or southeast in the Culebra. Therefore, the flux through each aquifer may not be as different as the transmissivity difference would suggest. If the Magenta discharges into the Culebra near Nash Draw, as is suggested by the DOE response to the EEG comment regarding the Schueler letter dated Oct. 30, 1981, premise 1, (see page 2 of the enclosure), then a repository breach could send contaminants south--southeast thrugh the Culebra as DOE has suggested and northwest through the Magenta and eventually into the Culebra at Nash Draw. The contaminant in the Culebra at Nash Draw would move toward Malaga Bend as has been suggested for a contaminant in the Culebra moving southeast from the WIPP. Although the discharge point may be the same, the travel times may differ greatly. However, present data are inadequate to precisely define the discharge points. Therefore until such time as the flow direction in the Culebra is accurately known, two migration paths should be considered.

Enclosed are our detailed evaluations of DOE responses to EEG comments.

Sincerely,

Robert H. Neill
Director

RHN:KR:eg

cc: TSC, IEA

EEG EVALUATION OF
THE DOE RESPONSE TO EEG COMMENTS ON
"DRAFT INTERIM REPORT ON FRACTURE FLOW IN THE RUSTLER FORMATION"

EEG Comment: (Proposed Work - p. 1)

In the "Cost and Merits Evaluation for the Stipulated Agreement Activities", the following proposed work was identified: "The best model to represent the flow path and aquifer characteristics in the Rustler will be developed." This item was not adequately addressed in the interim report.

DOE Response:

The interim report does not address specifically the best model for flow path and aquifer characteristics of the Rustler. This "best model" will be formulated when the tracer/pump tests are completed.

EEG Evaluation:

The response is adequate at this time. It was hoped that the draft preliminary report would contain some initial ideas regarding the best model to use.

EEG Comment: (Expected Results - p. 2)

In the "Cost and Merits Evaluation for the Stipulated Agreement Activities" the following expected results were identified: "If the results are such that additional consequence analyses should be run, they will be incorporated into the study." This item was not adequately addressed in the interim report.

DOE Response:

The consequence analyses, if warranted, will be performed by TSC for DOE. Though they are part of the study, the EEG should not expect consequence analyses as part of the interim or final reports on fracture flow in the Rustler.

EEG Evaluation:

The response is adequate at this time. However, it is EEG's understanding that an additional report regarding a consequence analysis of fracture flow in the Rustler Formation may be prepared by the TSC. It should be pointed out that this additional report is part of the stipulated agreement and should be prepared prior to the site validation declaration.

EEG Comment: (Schueler letter, premise 1, p. 2)

The premise that the Culebra aquifer is critical and thus, it is not necessary to study the Magenta aquifer has not yet been justified.

DOE Response:

The premise that the Culebra is the critical aquifer has been justified for years on the basis of fluid volume, transport times, and discharge point. If the additional data and analysis indicate this premise is no longer justified, additional consequence analysis for the Magenta may be appropriate.

The evaluation of fracture flow in the Rustler Formation has been restricted to the Culebra aquifer on the basis of available hydrologic evaluation of the three fluid-bearing zones of the Rustler and their relationship to release scenarios developed in the EIS. In short, the Culebra Dolomite exhibits the most potential to contain fluids and to be capable of solute transport over a large distance. The Rustler-Salado contact is practically devoid of transmissive property (10^{-4} ft^2/day) and the Magenta Dolomite varies from 10^{-1} to 10^{-4} under the site. Many holes show the Magenta devoid of fluids especially along the east flank of Nash Draw where it appears the Magenta is draining downward across fractured anhydrite and the ensuing gypsum (W-26, 28 and H-7a) and into the underlying Culebra aquifer.

EEG Evaluation:

The premise that the Culebra is the critical aquifer seems to be based on old data. Piezometric head maps for the Culebra Dolomite as presented in the interim report and Mercer and Gonzalez (1981) are different from maps published earlier (see "Final Environmental Impact Statement, Waste

Isolation Pilot Plant." DOE/EIS-0026, Oct., 1980; or "Review and Analysis of Hydrogeologic Conditions near the site of a Potential Nuclear-Waste Repository, Eddy and Lea Counties, New Mexico," USGS, OFR 77-123, February, 1977). The earlier maps treated the Culebra Dolomite and Magenta Dolomite as one hydrologic unit. The Culebra Dolomite and Magenta Dolomite have been treated as two distinct hydrologic units only since 1979. Since then, data have shown a westward dipping hydraulic gradient in the Magenta Dolomite. The data in the interim report even changes some of the conceptions regarding the distribution of hydraulic conductivity than that presented in the "Final Environmental Impact Statement."

The EEG concern regarding this matter is the potential contamination of the Culebra Dolomite in Nash Draw caused by a repository breach into the Magenta Dolomite. See addition evaluation of EEG comment regarding 2nd paragraph, page 4 (pages 9 and 10 of this evaluation).

EEG Comment: (Schueler letter, premis 2, p. 2)

The premise that discrete fracture flow is not credible has not yet been justified.

DOE Response:

Discrete fracture flow (one fracture flow path) is certainly inappropriate in view of the discussions on p. 23, for example. On pp. 35 and 38, discrete flow is described as appropriate for H-6, but this is not as one fracture flow path which might describe the system. Discrete fracture flow is not a credible mechanism for solute transport across the WIPP to a discharge area near Malaga Bend. As mentioned in the interim report, we have definite plans to model for multiple fracture block flow (double media). Furthermore, it is geologically unreasonable to conceive that one fracture exists across the WIPP towards the discharge area. The revision of the interim report will add statements summarizing the justification for this idea.

EEG Evaluation:

The response is adequate.

EEG Comments: (General comments, para. 1, p. 3)

The reports currently in preparation which contain details of the various field tests would be useful to the EEG to consult while reviewing the report.

DOE Response:

Yes, the reports in preparation which were cited would be useful to the EEG. The reports are being readied as Contractor Reports (SAND documents) with the intent of publishing and distributing each at or before the time of publication of the revised interim report on fracture flow.

EEG Evaluation:

The response is adequate.

EEG Comment: (General comments, para. 3, p. 3)

A conclusion concerning the nature of fracture flow should be made before the regional transport model is developed.

DOE Response:

The nature of the fracture flow is the point of the work being conducted. Porous media (continuous) methods were used; however, as a first approximation in analyzing the results of the hydraulic and tracer tests. This use is justified because they are not subject to the conceptual uncertainties that cloud the use of discrete fracture models and which make the results based on discrete fracture models subject to controversy. Certainly, a conclusion regarding fracture flow should be made before the regional transport model is completed.

EEG Evaluation:

The response is adequate. The intent of the comment was to make sure that the flow system was well understood before any computer modeling was started. It sometimes happens that modeling is started before the flow system is understood.

EEG Comment: (General comments, para. 4, p. 3)

The physical meaning of the values of the transmissivity, storage coefficient, anisotropy, porosity and dispersivity in terms of fracture flow should be addressed.

DOE Response:

The final report shall include a glossary of terms commonly used in the hydro-world, i.e., fracture conductivity, double porosity, porous media flow, discrete fractures, matrix permeability, transmissivity, anisotropy, porosity, dispersivity and storage. Again, the point of continuing the investigations is to determine the contribution (physical meaning?) of fracture flow. The site specific meaning of various hydraulic properties is the focus of the program.

EEG Evaluation:

The intent of the comment was to get a feel if the transmissivities, storage coefficients, porosities, etc., were typical, high, or low for a fractured rock. Perhaps they could be related to data from other sites or rock types. After talking with other hydrologists regarding some of the above terms, the EEG feels that a glossary is a good idea.

EEG Comment: (General comment, para.. 5, p.3)

Is the anisotropy due to alternating vertical bands of highly transmissive rock and low transmissive rock that trend northwest to southeast or due to karst channels recharging the aquifers?

DOE Response:

The comment about anisotropy seems related to paragraph 4 in some way. At present, there is no hydraulic test which, unsupported by independent information, can show the cause of anisotropy. The fact that anisotropy tests at three sites were in relative agreement with each other have allowed some inferences to be drawn regarding the regional nature of the flow system. Anisotropy is explained in the report as due to fracturing, which is evidently caused by dissolution and subsidence. There is a possibility that the principal tensor orientation reflects a fracture trend due to tectonic forces. Additional testing for anisotropy will show if the direction for the principal tensor remains the same as in a broader tectonic process. A note regarding the uncertainty here will be added to the text.

There is no fundamental geohydrological process that seems appropriate to this site for developing "alternating vertical bands of highly transmissive rock and low transmissive rock." The higher transmissivities correlate with areas subjected to more apparent Rustler/top Salado salt dissolution. Here, that is interpreted as resulting in fracturing which complements the natural porosity of fluid-bearing zones in the Rustler. These holes do not indicate any direct penetration of cavernous karst fractures.

We strongly disagree with the use of the word karst to describe the flow system in the Rustler Formation. At the present time, data are insufficient to draw such a conclusion. Furthermore, the word karst can and has been used to describe the most disparate observations, from submicroscopic solution enlargements along a fracture, to man-size caverns and house-swallowing sinkholes, such as those that occur in Florida. Unfortunately, it is often times the more lurid definition that sticks in people's minds when the word is brought up. We do not attribute the results of the anisotropy and tracer tests to karst; neither do we preclude its possible existence at the WIPP. We merely state that the use of the word is premature and therefore, inappropriate. It causes emotional responses due to its several definitions, and it puts the investigator in the almost indefensible position of proving that every break in slope of a drawdown curve is not due to a karst feature.

EEG Evaluation:

The EEG comment responded to here was related to the previous comment and nothing specific was intended by it. A note or paragraph relating the anisotropy to tectonic forces or other geologic factors is a good idea.

We understand your concern regarding karst hydrology. Our consultant in karst hydrology believes that dissolution prongs along fractures are advancing eastward from Nash Draw. The rate of advance is very slow and the prongs should not affect the WIPP site for many tens of thousands of years. However, enlargement of fractures is a major concern and we will continue to pursue it.

EEG Comment: (General comment, para. 6 & 7, P. 4)

The porosity of 18% determined from the H-2 nest of wells appears high for a fractured rock. At the H-6 nest of wells the porosity appears to exhibit some directional characteristics, when it should not. In addition, the data presented in the report indicate that Culebra flow in the repository area is to the southeast. Previous studies have indicated that flow is to the south and southwest. This data may indicate other discharge areas for the Culebra. An increased flow path that might result from the gradient presented in this report indicates that the Magenta may provide faster releases of radionuclides to the biosphere than the Culebra.

DOE Response:

Thin-section porosity at H-2 is as high as 10 percent. A matrix porosity of 18 percent for the Culebra at H-2 does not seem unreasonable. Because there have not been any tests for anisotropy at the H-2 site (the reviewer may believe there have been), we do not draw any specific conclusions about the nature of flow at that site. At H-6 porosities were determined along the major (1%) and minor (11%) components of flow. Keeping in mind the concept of double-porosity medium (fracture-block concept), it is reasonable to find directional characteristics in this type of matrix. Although we presently interpret flow southeast across the site, we have no supporting data to alter our beliefs that the ground water discharges near Malaga Bend. The increased flow path does not discredit the Culebra as the major vehicle for transport because of the previous discussion on the Magenta.

EEG Evaluation;

The response to the high porosity at H-2 is adequate.

The response to the direction characteristics is not quite clear. Are you implying that flow between H-6b and H-6c is through discrete fractures and flow between H-6a and H-6b is through pores? The exact implication should be brought out better in the report.

The response regarding the discharge area of the Culebra Dolomite is adequate. It is hoped that the revision of Figure 16 will indicate better discharge areas of the Culebra Dolomite.

Responses regarding the Magenta Dolomite are presented elsewhere in this evaluation.

EEG Comment: (Abstract, 13th to 18th line, p. 4)

The term "principal to minor transmissivity tensor" should be changed to "major to minor components of the transmissivity tensor." The term "principal transmissivity component" should be changed to "the principal direction of the major component of the transmissivity tensor" or "The orientation of the principal axes of the transmissivity tensor is northwest by southeast for the major component and northeast by southwest for the minor component." A statement about the variability of the transmissivity with respect to distance from the outcrop should also be included in the "abstract."

DOE Responses:

The terminology regarding transmissivity tensors is in need of change. Tensors shall be described in terms of major and minor components and to a principal direction of either a major or minor component. The reference made to distance from the outcrop is confusing. Does the reviewer mean Nash Draw? We do refer to the variation in transmissivity relative to the east flank of Nash Draw. The comment may imply inferences about recharge areas being the Nash Draw "outcrop" areas which were not ready to draw yet.

EEG Evaluation:

The response regarding the transmissivity tensor terminology is adequate. The "Review Comments" also indicated that terminology regarding the transmissivity tensor on page 7, 1st and 2nd lines; page 14, 10th line; and page 18, 6th, 15th, and 17th lines also need correcting and should be changed accordingly.

It appears that the decrease of the transmissivity with respect to increasing distance from the east flank of Nash Draw is an important result of the present work. We believe the result should be included in the abstract. It was not included in the abstract of the reviewed report.

The comments regarding the abstract were intended to improve the abstract. No other inferences should have been drawn from the comments.

EEG Comment: (2nd para., p.4)

Mercer and Gonzalez (1981) indicate a strong westward gradient from WIPP to Nash Draw in the Magenta dolomite. Have any calculations of travel time from WIPP to Nash Draw been made for the Magenta and compared to travel times for the Culebra?

The Culebra's southeast gradient through the repository, as indicated on Figure 16, shows that contamination from a repository breach may either never reach Nash Draw or may take longer than the 40,000 years previously estimated. If the Culebra travel times are significantly increased, the Magenta may provide quicker radioactive releases to the biosphere than the Culebra. Estimates of travel time from the repository to Nash Draw through the Magenta should be provided in this paragraph.

What are the data and assumptions that went into the calculation of the 40,000 year travel time from ERDA-9 to Malaga Bend? Is this number taken from some other work?

DOE Response:

The comment about Magenta travel times seems to be leading to an inference that Nash Draw is where the Magenta discharges. Instead, the travel time to the probable common discharge point is appropriate. Travel time is tempered by flux. The additional consequence analysis, if necessary, is the appropriate comparison.

The calculation of the 40,000 year travel time resulted from a request by D.D. Gonzalez to Intera Groundwater Consultants. The date of the request was January 1979 and was based on a very limited set of hydrologic parameters, including transmissivity, storativity and hydraulic head at four locations and only estimates in areas near Laguna Grande de La Sal and towards Malaga Bend. The assumed thickness and porosities for the Culebra Dolomite were 30 feet and 10% respectively. The particle tracking model (SWIFT) determining the streamline and travel time for a non-absorbing tracer particle released at the WIPP site calculated a streamline proceeding due south from the center of the WIPP for about five miles, then west south-westward towards Laguna Grande de La Sal, then south towards Malaga Bend. Over 80% of this travel time is attributed to flow in the five-mile long reach south of the site where our understanding of the hydraulic characteristics have not changed appreciably since 1979, except for porosities being calculated at 18% at H-2. Further discussion will be included in the final report as well as a reference to the Intera work, dated 5-22-79.

EEG Evaluation:

The comment regarding travel time in the Magenta Dolomite is leading to an inference that the Magenta discharges there. The DOE response to the EEG comment regarding the Schueler letter, premise 1, seems to indicate that this is the case.

We disagree with the statement that "travel time to the probable common discharge point is appropriate." It is probable that the Culebra Dolomite is a usable aquifer in Nash Draw. It is productive and contains relatively good quality water. The Culebra Dolomite water quality could be deteriorated by a repository breach into the Magenta Dolomite and subsequent transport into the Culebra Dolomite. Such contamination may make the Culebra Dolomite an unusable aquifer in Nash Draw. This is the EEG concern regarding transport in the Magenta Dolomite.

The Culebra Dolomite south of the WIPP site has a low transmissivity and poor quality water. It is unlikely that it would be a usable aquifer. Therefore, for a breach into the Culebra, a travel time through the Culebra from the WIPP to Malaga Bend is appropriate.

The response regarding the calculation of the 40,000 year travel time is adequate.

EEG Comment: (Page 8, bottom para., p.5.)

Figure 16 indicates that the hydraulic gradient is to the southeast through the facility. Why does this paragraph say south and then southwest toward Malaga Bend? The statement appears to be referring to the previously assumed flow path shown in figure 3, but it certainly is not clear.

DOE Response:

The southeast flow across much of the site still appears correct. The flow is expected to swing to the southwest based on H-8, 9, and 10. The contours of Figure 16 will be revised for the interim version, and we expect to perform additional testing in the southeast portion of the site to verify contours and hydraulic properties. The interim report will be clarified.

EEG Evaluation:

In addition, it should be clearly indicated which wells were used and not used to construct Figure 16 of the draft interim report. The figure, as presented in the report, leads to confusion with regard to travel paths.

EEG Comment: (Page 9, p.5)

Table 1 should be checked for errors. The "Fresh Water Altitude" for P-18 on the table and the altitude used for construction of Figure 16 appear to differ by 100 feet. Other "Fresh Water Altitudes" that appear to need checking belong to wells H-5, H-8, H-9, H-10, W-28 and W-30. In addition, the surface altitude of H-9 is 100' higher than that presented in Seward ("Abridged Borehole Histories for the Waste Isolation Pilot Plant (WIPP) Studies," SAND82-0080). This may lower the fresh water altitude to 2976 at H-9. It is probable that the fractured nature of the dolomite may be causing the anomalous water levels. The water level at H-5 appears to be associated with a structural anomaly of the Culebra Dolomite (see attached Figures 1 and 2 and comment regarding page 44 and 45).

DOE Response:

P-18 and W-30 seem anomalously low, and both wells have very low transmissivity. They will be monitored to see if they have truly regained static equilibrium. If they have not, then the use of these nonrecovered water levels makes the water leval at H-5 seem anomalously high and may lead to erroneous conclusions about the formation around H-5. In addition, we are in the process of double checking those elevations at all H- and W- sites where hydro-data have been collected.

EEG Evaluation:

The response is adequate.

EEG Comment: (Page 11, 1st para., p.5)

References for transmissivity value should be provided.

DOE Response:

References will be given as appropriate.

EEG Evaluation:

The response is adequate.

EEG Comment: (Page 14, 2 bottom lines, p. 5)

It would be nice if the reference were already published to check the theory and to see the report contents.

DOE Response:

Agreed. See previous comment.

EEG Evaluation:

The response is adequate.

EEG Comment: (Page 15, 1st para., p. 6)

The description of test procedures indicates that the "a" well at each pad was pumped. However, the anisotropy results of Table 2, Table 3 and Table 4 provide no results from pumping the "a" well. Why are the results from pumping the "a" well not presented? Was the "a" well pumped at all?

DOE Response:

The "a" wells could not be pumped, though the report implied they were. The tests for anisotropy require only two wells be pumped within a three-well array; however, at each pad the "a" wells developed downhole or pump complications which prohibited their pumping. Clarification will be made in the interim report.

EEG Evaluation:

The response is adequate.

EEG Comment: (Page 15, last para., p. 6)

If the tracer curves are insensitive to dispersion (dispersivity), how can it be estimated?

DOE Response:

The fact that the Grove and Beetum breakthrough curves are relatively insensitive to dispersivity means only that they do not give precise values of dispersivity. Single well "pump-back" and two-well convergent flow tests are the best method to determine dispersivity and these tests are being pursued.

EEG Evaluation:

The response is adequate. Clarification regarding the statement should be made in the text.

EEG Comment: (Page 19, Table 2, p. 6)

According to the theory of anisotropic aquifers developed by Papadopulos (1965), the response of well H-4C from pumping H-4B should produce the same T and S values as the response of well H-4B from pumping well H-4C. The T estimates for these wells differ by a factor of two for tests one and two. The range of T (not including pumping wells) for all three tests is 0.8 feet squared per day to 1.7 feet squared per day. What is the cause of this discrepancy?

DOE Response:

In theory, the same effective transmissivity should be observed in the observation wells in an anisotropic aquifer, but not the storage coefficient. Obviously if the observation well data yield the same T and S and if the wells are the same distance from the pumped well then the aquifer is isotropic. Also, only in an ideal aquifer will the same values be obtained from observation wells. However, the sensitivity of the anisotropy results to errors in the drawdown interpretation should be investigated, and sensitivity tests are included in our final product.

EEG Evaluation:

It appears that the transmissivity presented in Table 2 (and Table 3 and Table 4) is the effective transmissivity as used in the draft report and is the determinate of the transmissivity tensor. It further appears that the storage coefficient presented in Table 2 is really the quantity:

$$S(\text{table}) = \frac{S}{r^2} \; \frac{Txx\, y^2 - 2Txy\, xy + Tyy\, x^2}{Txx\, Tyy - Txy^2}$$

where S is the aquifer storage coefficient; Txx, Txy, and Tyy are the various components of the transmissivity tensor; x and y are the coordinates of the observation well if the pumping well is at the origin of the axes; and r is the distance between the pumping well and the observation well ($r^2 = x^2 + y^2$).

If the aquifer is homogeneous but not isotropic, then the drawdown response at H-4C caused by pumping H-4B should be the same as the drawdown response at H-4B caused by pumping H-4C. The observation well drawdown in a homogeneous anisotropic aquifer is

$$\$ = \frac{Q}{4\pi(Txx\, Tyy - Txy^2)}\, W\,(Uxy)$$

where

$$Uxy = \frac{S}{4t} \; \frac{Txy\, x^2 - 2T_{xy}\, xy + T_{xx} y^2}{(Txx\, Tyy - Txy^2)}$$

and $\$$ is the observation well drawdown, Q is the pumping rate, S is the aquifer storage coefficient, W (Uxy) is the well function with the argument Uxy and x and y are the coordinates of the observation well if the pumping well is at the origin of the axes. If the H-4B well is the pumping well as in Test 1, then the observation well H-4C has the coordinates x and y. If the role of each well is reversed as in Test 2 the coordinates of the H-4C well, now the observation well, are now -x and -y, which, when entered into the above Uxy equation, produce the same Uxy values as positive x and y. Therefore, the drawdown response at the H-4B well caused by pumping the H-4C well is the same as the drawdown at the H-4C well caused by pumping the H-4B well. This is the only well pair where this is true. The respective effective transmissivity and storage coefficient (table) for the two wells should be equal. However, the effective transmissivity differs by a factor of 2 and the storage coefficient (table) differs by a factor of 1.5. These are large differences and should be explained.

The sensitivity analyses proposed are a good idea.

EEG Comment: (Page 23, 1st para., pp. 6-7)

Were any methods, such as images, tried in order to locate any of the barrier boundaries? What could these boundaries be attributed to? For instance, could the boundaries be due to vertical fractures filled with an impermeable material or to a less fractured nearby region of dolomite?

The shape of the curve on Figure 7 is interesting. The early part of the curve (prior to the formation of the straight line) may be a result of no storage of water in the fractured part of the aquifer or possibly a horizontal fracture overlain by a porous block (see "Well Hydraulics in Heterogeneous Aquifer Formations" by T.D. Streltsova-Adams in Advances in Hydroscience, Vol. 11, Academic Press, 1978. In addition, it appears questionable that the flat part of the curve is attributable to flow from the blocks to the fractures. According to Streltsova-Adams (see Proceedings, Second Invitational Well-Testing Symposium held by Earth Sciences Division, Lawrence Berkeley Laboratory, on October 25-27, 1978) the flat part of the data should not show if the ratio $(S_f + S_m)/Sp$ (S_f and S_m are storage coefficients of the fractures and the porous matrix, respectively) is less than about 5 to 11. In other words, if the straight lines on Figure 7 are less than about 0.7 to 1.0 log cycles apart, which they are on Figure 7, then the flat part of the curve should not show. This brings several questions to mind:

1. Is it possible that the straight line shows up between 200 minutes and 2000 minutes on Figure 7? If this is the case, then the data after 2000 minutes including the flat part may be attributable to the transition period between flow in fractures and "induced response."

2. If the straight line is correct and there is no double porosity system, is the flat part of the data and the "induced response" caused by a highly permeable fracture or karst channel near the well test?

3. Is the anisotropy observed in these tests due to recharge into the rocks from a highly permeable fracture or karst channel? Such a response would cause the lines of equal drawdown to have oval shapes rather than the elliptical ones caused by anisotropy. Unless there are data from more than three observation wells, it may be very difficult to tell the difference between an anisotropic aquifer and an aquifer with a recharge boundary.

Figure 7 of the report shows the response of the H-4a and H-4b wells due to pumping the H-4c well. Was the response of H-4a and H-4c due to pumping H-4b similar to the data shown o Figure 7 such that a double porosity system was indicated?

DOE Response:

Image-well theory was applied to drawdown data in an effort to locate groundwater "barriers," which could be attributed to skin effects, wellbore storage, pumping variations, elastic deformation, and formation barriers. A formation barrier may consist of abrupt changes in aquifer properties, such as porosity, conductivity, fracture density or orientation, recharge and discharge zones, transient or steady-state flow, vertical/horizontal permeability. Barriers may be the result of one or a combination of geologic or hydrologic parameters. Vertical communication with known overlying and underlying aquifers is practically negligible throughout the WIPP facility on the basis of observed differences in hydraulic potential and conductivities and general chemistry.

We believe that the reviewer means that the slope of the transitional curve should not be zero, not that it should not show. Also, Streltsova-Adams assumes in her report that the matrix has zero permeability. If, in our case, the matrix has some permeability, then the shape of the drawdown curve may be different from her examples.

In regards to the three questions raised by the reviewer:

1. We think that the curvature of the early-time data on Figure 7 is pronounced. On log-log paper, this portion of the curve is straight with nearly unit slope indicating full fracture flow or well-bore storage (probably the latter). It is entirely possible that the data after 2000 minutes is in a transitional period, but we think it is more consistent to treat the data between 2000 and 5000 minutes as a good straight-line (Jacob approx.) solution, and between 5000 and 8000 minutes as transitional (or induced response). Past 8000 minutes the line becomes approximately parallel to the earlier data. (The "INDUCED RESPONSE" arrow on Figure 7 points to the wrong part of the curve and will be corrected in the interim report.)

2. If the first break in the drawdown curve is attributed to hitting a recharge boundary, then it follows that the second break must be due to a barrier boundary. Furthermore, the shapes and permeabilities of both boundaries must be such that the effect of the second boundary must completely negate the first so drawdown may continue as if neither existed. We agree that several interpretations are possible, given that little is known about the system, but we do not believe that the drawdown data alone support the existence of a recharge boundary. In regards to "karst channel near the well," please refer to earlier discussion about so-called karst.

3. According to our dictionary, the definitions of "oval" and "elliptical" are the same. The drawdown data we used for anisotropy determinations was early-time, hopefully taken before any breaks,

boundaries, or possible induced response affected the results. The anisotropy results should be free from these effects.

Some of this discussion will be included in the revision of the draft.

Well H-4a could not be pumped and the H-4b test was not run for a sufficient length of time to see the second break in the drawdown curve.

EEG Evaluation:

If possible, distances and directions to barriers, estimated from the method of images should be provided. A description of possible barriers mentioned here should also be included in the text.

Streltsova-Adams does not assume that the matrix has zero hydraulic conductivity; she assumes that the transmissivity of the porous blocks is so small compared to the transmissivity of the fractures that the transmissivity of the blocks can be neglected. If the blocks had zero hydraulic conductivity, then a mechanism to transport fluid from the blocks to the fractures would not exist and there would be no transition curve.

The response to question 1 is adequate for the most part. The log-log plot that shows the unit slope should be included and described in the report. In addition, a USGS publication (Reed, J.E., "Type Curves for Selected Problems of Flow to Wells in Confined Aquifers," Techniques of Water-Resources Investigations of the United States Geological Survey, Book 3, Chapter B3, 1980) indicates that the drawdown response at an observation well far from a pumping well of finite diameter is much steeper than unit slope. Therefore, the unit slope is not likely to be caused by wellbore storage effects, but more likely the full fracture flow mentioned in the DOE response.

The response to question 2 is adequate.

The response to question 3 is adequate. However, the EEG dictionary defines oval as an egg shape. Perhaps "egg shaped" instead of "oval" would have been a better term.

The response to the comment concerning the H-4 pumping is adequate.

EEG Comment: (Page 23, last para., p. 7)

It appears questionable that chloride is the ideal tracer to use to determine if leakage is occurring between Rustler aquifers at the H-4 site. Table 4 of Mercer, et. al., indicates that the chloride concentration of both the Magenta and Culebra is 7500 mg/l (Mercer, J.W., Paul Davis, Kevin F. Dennehy, and Carole L. Goetz, "Results of Hydrologic Tests and Chemistry Analyses, Wells, H-4A, H-4B, and H-4C at the Proposed Waste Isolation Pilot Plant Site, Southeastern New Mexico," Water-Resources Investigations 81-36, U.S. Geological Survey, May, 1981.

DOE Response:

The objective was to determine if leakage did occur during the tests; we had few other tools at our disposal (such as piezometers in confining zones or adjacent water-bearing units) to assess leakage, so water chemistry (temperature, ph, conductivity, chloride) was looked at during these tests as an alternative means. The results are not conclusive, but indicate that no leakage occurred. The test will be revised to indicate the uncertainty at H-4.

EEG Evaluation:

The response is adequate.

EEG Comment: (Page 25, 2nd para., p. 8)

The transmissivities as presented here are extremely small for a fractured rock and would tend to indicate that fracture flow is not that significant, at least in the areas that were tested. Any radionuclide transport in the Culebra would tend to be very slow because of the low transmissivities. Do fractures or karst channels capable of transmitting water exist near the WIPP site?

Table 9.2 of Walton (Walton, William C., Groundwater Resource Evaluation, McGraw-Hill, 1970) indicates the values of specific storage presented here are those for "sound rock." This would tend to indicate that any fractures in the Culebra, at least in the areas tested, are well cemented or that clean, open fractures are far apart. This suggests that fracture flow is not extensive over much of the Culebra but may be confined to long channels or fractures outside the area of influence of the pump tests. Does flow in open fractures exist in areas not tested by the pump or tracer tests?

DOE Response:

The hydraulic conductivities observed at the WIPP are actually large compared to fractured crystalline rock. For example, the lowest transmissivity measured in our tests was at the H-5 site (0.04 feet squared per day), and corresponds to a hydraulic conductivity of 2×10^{-3} feet per day), which is an average for fractured crystalline rocks (Stripa Mine Project Report, 1980). It cannot be concluded that fluid movement will be slow because transmissivities are small. Solute transport may be quite rapid in a fracture flow situation. Determining solute transport capability is, of course, a major reason to perform tracer tests, which will yield indications of fluid velocities in the natural flow system.

The values of specific storage measured at the WIPP are of the order of 10^{-6}/ft, which, using Walton (Table 9.2) is reasonable for fissured and jointed rock. Lohman (Ground-Water Hydraulics, USGS Prof. Paper 708) uses a value of 10^{-6}/ft as a way to estimate storage coefficients for confined aquifers in general. A rock, such as a fairly rigid dolomite, could have a very low specific storage and still have measurable matrix and fracture porosity. Low specific storage does not mean that fracture flow is not extensive; it may only mean that there is a lack of significant compressibility in the system, both from fractures and matrix. For the reviewer to carry his suggestion one step further and imply that low specific storage within the area of pumping influence is evidence that open fracture or channel (karst?) flow exists outside the area of pumping influence is, of course, unanswerable.

EEG Evaluation:

Comparisons of the transmissivity and/or hydraulic conductivities with other fractured rocks should be made in the report. The comparison should be made to other dolomitic rocks not just fractured crystalline rocks.

The values of specific storage presented in the interim report range from 3.5×10^{-7}/ft to 8.3×10^{-7}. The higher values seem to occur at H-5 and H-6 and the low value at H-4. Perhaps fissures and joints could exist at H-5 and H-6. However, the specific storages calculated at these wells are at the upper limit of the "sound rock" values and slightly below the lower limit for "fissured and jointed rock." The specific storage calculated at H-4 is in the "sound rock" range.

EEG Comment: (Page 27, 3rd para., p.8)

Was the aquifer pumped clear prior to tracer injection for the second test? If not, did the non-completion of the first tracer test affect the results of the second test? Is it possible that Segments I and II of Figure 12 are due to the first test and Segments III and IV to the second test? If so, some type of deconvolution would be necessary to interpret the restults.

DOE Response:

Different tracers were used in each test; thus, no interference existed.

EEG Evaluation:

The response is adequate. Perhaps this should be brought out in the report.

EEG Comments: (Page 28, 3rd paragraph, p. 8)

The Grove and Beetem (1971) model needs to be corrected for anisotropy. Was this done? What were the ranges of porosities and dispersivities used in the Grove and Beetem (1971) analysis and how did they compare with the data?

(Page 32, 3rd paragraph, pp. 8-9):
The significance of the porosities of 0.17 and 0.18 should be discussed here. These values are extremely high for a fractured rock. A fractured rock typically has a fracture porosity of 0.01 - 0.02 and less (Streltsova, 1976). The porosity values presented here are typical for a porous media. If it is assumed that a fractured system operates at the H-2 well sites, then tracer diffusion from the fracture into the porous matrix could account for the high porosity. The effect of this diffusive process has been shown to increase travel times from one point to another when compared to a process without diffusion into the matrix. (See Grisak and Pickens, "Solute Transport Through Fractured Media I: The Effect of Matrix Diffusion, Water Resources Research, vol. 6, no. 4, Aug., 1980, pp. 719-730 and Grisak, et al. "Solute Transport through Fractured Media 2: Column Study of Fractured Till,"Water Resources Research, vol. 16, no. 4, Aug., 1980,, pp. 731-739). The net effect of increasing the travel time would be a high porosity. Grisak and Pickens also indicated that the diffusion of solute into the matrix would be more significant for low velocities of fluid flow in the fracture than for high velocities. With the hydraulic conductivity of the Culebra at about 0.032 feet per day, fluid velocities are probably small.

The causes of the various segments on Figure 12 should be explained. For instance, were they caused by diffusion into the matrix at one time and out of the matrix at another time? Are they caused by a convolution of the two tracer tests?

Page 35, 2nd paragraph, pp. 9-10:
Sauty's (1980) method should be modified for the anisotropy determined from the pump tests at the H-6 site. Since the principal axes of the transmissivity tensor are known for this site, the modification is:

$$n = \frac{Qt}{b\left(\frac{T_{yy}}{T_{xx}} x^2 + \frac{T_{xx}}{T_{yy}} y^2\right)}$$

where Q = pumping rate

b = aquifer thickness

t = time of match point

x,y = coordinates of well slugged with tracer

Txx = major transmissivity component

Tyy = minor transmissivity component

n = porosity

In the above equation, the pumping well is at the origin and the major component of the transmissivity tensor runs between wells H-6b and H-6c as indicated from the well test data. The corrected porosities are 9.1% for the H-6b to H-6c test and 0.97% for the H-6a to H-6c test.

The 0.97% porosity appears reasonable for a fractured rock and occurs along the major axis of the transmissivity tensor. The 9.1% appears reasonable for a porous media. There is, however, almost an order of magnitude difference between the two. Since porosity is not anistropic, the disparity is probably caused by a heterogeneity in the Culebra. The suggestion of a discrete zone of flow, i.e., a long highly permeable fracture, a set of parallel fractures or a karst channel appears reasonable. Whether or not this discrete flow can be modelled adequately appears questionable. The problem lies in determining the number of discrete fractures and their locations.

DOE Responses:

Several good points are brought out here. We do not yet believe that we can define the flow system at the H-2 site. A double porosity system is appealing, but anisotropy needs to be determined and further tracer tests along different flow paths need to be conducted at the site to define the flow system. Again, we do not believe that the hydraulic conductivity at the H-2 site precludes the possibility or rapid fluid movement. The final report will include the results of additional tracer and anisotropy tests and respective modification to the code developed by Grove and Beetem.

Much discussion can be related to what value of porosity is typical of fractured rock vs. porous media. A minimum of effort has been spent on acquiring field data through extended tracer and anisotropy tests to evaluate and determine what these values are and what they mean. We hope to solidify our thoughts on double porosity media after the conclusion of our tests at H-6 and H-7. At this point, the number of discrete fractures and their locations are not the problem - neither is the notion of karst channel domination. A macroscopic point of view is the solution.

The H-6 tracer results certainly imply the existence of both fracture and matrix flow, at least under the flow regime set up by the test itself. There is not necessarly a disparity in the porosity determinations, nor need the difference be caused by local heterogenities.

<u>EEG Evaluation</u>:

The response to the anisotropy correction to the Grove and Beetem model is adequate. The comment regarding the ranges of porosity and dispersivity was not responded to. We were concerned about the apparent emphasis on the late time data for the curve match and the humps in the data.

The response regarding the tracer test at the H-2 pad is adequate. Anisotropy and tracer tests should be run at the H-2 pad. The EEG will be waiting for results from these tests.

The response to the H-6 comment is adequate. However, it should be pointed out that zones of discrete flow in a porous media is a heterogenity.

<u>EEG Comment</u>: (Page 38, 1st para., p. 10)

The Safety Analysis Report (page 2.6-35) indicated that two sets of joints exist in the Delaware Basin. One of these sets strikes NW to SE, in the same direction as the major component of the transmissivity tensor. Does this joint set have some relationship to the principal axes of the transmissivity tensor? What is the possibility that vertical or near vertical fractures formed by the joint set could be missed by the drilling activities and subsequently untested by the pump testing program?

DOE Response:

See previous discussion of principal tensor and fracture trends. The testing program would not test a set of non-intersecting or non-interconnected fractures by definition. The fact that dipping fractures are intersected requires interconnection of even vertical fractures with the borehole though the zone of influence has limits.

EEG Evaluation:

The fact that the boreholes intersect dipping fractures should be brought out better in the report.

EEG Comments:

(Page 38, 2nd para. to Page 39, 1st para., pp. 10-11)

The physical significance of the range of porosities to the following parameters should be discussed in more detail:

o travel times

o fracture flow or porous media flow

o the directional characteristics of the porosity

The hydraulic conductivities should also be discussed in terms of fracture flow and porous media flow. The hydraulic conductivity values quoted in this report are averaged over the thickness of the Culebra, i.e., the hydraulic conductivity is assumed to be uniform throughout the thickness of the Culebra. In a fractured media, the hydraulic conductivity is not uniform. It is peaked in a fracture and near zero outside a fracture. How would the hydraulic conductivity vary throughout the thickness of the Culebra? What effect would this variation have on travel times?

(Page 39, 1st para., p. 10)
Figure 16 indicates that flow through the H-6 site is initially SSE. However, the flow path appears to curve to the southeast away from Nash Draw. What is the basis for concluding that flow through H-6 reaches Nash Draw? In addition, a flow to the south-southeast would eventually have to turn toward the southwest in order to reach Nash Draw.

It further appears that Figure 16 may need some refinement. The figure does not appear to have contours based on the fresh water altitudes at H-8, H-9 and H-10. In addition, the fresh water elevation at P-18 is extremely low compared to the elevations at the other wells. The validity of the fresh water altitude is questionable because of the low hydraulic conductivity at that well. How does the fresh water altitude map change if fresh water altitudes at H-8, H-9 and H-10 are included in the map construction at P-18 is eliminated?

DOE Response:

How hydraulic conductivity varies within the Culebra, both vertically and horizontally, will be a very difficult study. Cores taken from and measurements taken within the new ventilation shaft will help us. In our final analysis, a variation of parameters shall be input to the final regional model to simulate a variation of travel times under differing conditions.

The potentiometric surface as shown on Figure 16 typifies a very transmissive system approaching the WIPP from the north-east but encountering, in effect, a leaky boundary defined by the decrease in hydraulic conductivity from west to east and probably influenced by the presence of "salt" within the Rustler and lower transmissivities in the Culebra Dolomite. As the flux of groundwater encounters a less permeable portion of the aquifer, it resists flow and takes the more plausible avenue - down Nash Draw where we find transmissivities much greater in a number of wells. Figure 16 exemplifies the site specific information collected on and within the boundaries of the facility. The final report will include a refinement of the data, which will include tracer and anisotropy tests at locations south-east and south of the site. The validity of the use of fresh water altitudes based on fluid density influenced by low conductivity is also our concern. A final suite of

W.L. measurements and density determinations will be taken and evaluated for inclusion in the final report. There are no better estimates for discharge areas other than near Malaga Bend or south of Lagune Grande de la Sal.

EEG Evaluation:

Changing the values of parameters in the final regional transport model is good. However, the purpose of the comment was to get some feel if the reported values of hydraulic conductivity and porosity are typical or atypical of fractured rock. This does not appear to have been addressed in the response.

Until the vertical variation in hydraulic conductivity can be answered, the EEG suggests that references to hydraulic conductivity in the report be deleted. The hydraulic conductivities in the report are calculated by dividing the transmissivity by the aquifer thickness. This implies that the transmissivity is uniform over the aquifer thickness, when, in fact, the transmissivity may be concentrated in one or two fractures. In addition, it may be better to use the prosity-thickness product, which is the number really estimated from the tracer tests, rather than the calculated porosity.

The responses to the Figure 16 and the H-6 flow path comments are adequate.

EEG Comment: (Page 41, bottom para., pp. 11-12)

What is the basis for assuming 10 miles to the southeast? The data are all within 5 miles of the WIPP site. Most of the "path which would exceed 10 miles" is located in an area of very low hydraulic conductivity and in an area of unknown hydraulic gradient. In view of the southeast gradient over the study area (Figure 16 of the draft report), how can the radionuclides discharge at Malaga Bend? The direction of the hydraulic gradient would have to turn southwest in order for a radionuclide to discharge at Malaga Bend. At present, there are no data to support this. Are there other discharge areas for the Culebra?

DOE Response:

See previous comments.

EEG Evaluation:

It is hoped that the refinement of the data used to construct Figure 16 will support the previous responses.

EEG Comment: (Page 43, 1st para., p.12)

If travel time for a non-absorbing radionuclide in the Culebra becomes greater than 40,000 years, it is possible that the Magenta's westward flow from the WIPP to Nash Draw would provide a quicker radioactive release to the biosphere than flow in the Culebra? If so, perhaps future studies should concentrate on flow in the Magenta rather than on the Culebra.

DOE Response:

See previous comments on Magenta.

EEG Evaluation:

See our evaluation of your previous response to Magenta comments.

EEG Comment: (Pages 44 and 45, Continuing Investigations, pp. 12-13)

The following are suggestions that should be useful in the continuing study of fracture flow in the Rustler:

1. A review of aerial photographs through the area defined by WIPP-29, WIPP-25, WIPP-33, H-6 and H-5 should be made to see if any geomorphic features associated with either karst hydrology or fracture hydrology exist there. Thermal infrared photographs may be useful in locating springs or shallow ground water flowing in subsurface channels. This suggestion is made for several reasons:
   a. Larry Barrows, in a presentation to EEG, indicated that an elevated gravity anomaly existed in this area. He attributes it to a possible karst channel in the Culebra.
   b. A structure contour map (see Figure 1) on top of the Culebra was generated from Table 1 of the report. It indicates a depression

extending through the WIPP-25, H-6, H-5 area. This depression may be associated with a karst channel.

c. A fresh water altitude map (see Figure 2) for the Culebra was constructed from the data presented in Table 1 of the report. The figure indicates that a ground water high is associated with the depression. The ground water high indicates a potential for some flow to the west.

If possible, the review of the aerial photographs should extend from the northern part of Nash Draw to Malaga Bend.

2. The application of inverse techniques to flow in the Rustler should be interesting. For the most part, inverse techniques are in their infancy and are designed for porous media flow, not discrete flow. If it is decided that fracture flow can be modeled as a porous media, then the inverse technique developed by Neuman and Yakowitz ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 1: Theory," Water resources research, vol. 15, no. 4, pp. 845-850, 1979), Neuman et al. ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 2: Cast Study, "Water Resources Research, vol. 16, no. 1, pp. 33-58, 1980) and Neuman ("A Statistical Approach to the Inverse Problem of Aquifer Hydrology, 3: Improved Solution Method and Added Perspective, "Water Resources Research, vol. 16, no. 2, pp. 331-346, 1980) should be tried. It appears that, at present, this is the only technique that has been published with an application to a real problem. Before the inverse techniques are applied to the Rustler, it should be decided whether flow in the Culebra is discrete or porous.

3. It appears that any contamination from a repository breach in Zone II would flow to the southeast. This is based on the flow paths as determined from Figure 15 and Figure 16 of the report. The area southeast of the WIPP should be studied further in terms of piezometric head, flow direction and discharge areas.

4. The tracer test at H-7 should be run similarly to the one at H-6. This should provide some more insight into the directional characteristics of the porosity and the areal extent of this

phenomenon. Because the hydraulic conductivities at H-6 and H-7 are almost the same, the time required to run a tst at H-7 should be about the same as at H-6.

If possible, two two-well tracer tests should be run at H-4 in order to determine the porosity along the major and minor components of the transmissivity tensor.

5. If it has not been done, the Groe and Beetem (1971) model, the Sauty (1980) model and the SWIFT model, if it is used, should be modified to account for the anisotropy of the Rustler Formation.

DOE Response:

Item 1.a. Bachman (1980, 1981) examined karst features extensively through Nash draw, along the pecos, and in the site area. He attributed the fill and depression at WIPP 33 to a karst-type process by which Nash Draw expands. In his field work and review of aerial photos, he does not attribute geomorphic features at the site to karst processes. Barrows found anomalously low gravity which he infers as due to removal of mass by dissolution (=karst). Barrows does not restrict karst to the Culebra - it is more likely in the gypsum units by his log correlations.

Item 1.b. Whether the gravity anomaly and structure contour maps show karst channels or not is still speculation. Perhaps comparing these maps with similar ones in regions of known karst will help somewhat. If the structure contour map does delineate a west-east karst channel, it cuts through some of the highest transmissivities tested at the WIPP (WIPP 25 and H-6), as well as the lowest (WIPP 30 and H-5). It also trends parallel to the minor component direction of the transmissivity tensor determined at H-6 and H-5; that is, the transmissivity is least in the direction of the channel.

Item 1.c. Figure 16 will be revised as previously stated. WIPP 30 is still being monitored, and all potentiometric data will be revised to be curent for the interim report.

Item 2. Those suggestions are well taken and shall be considered. Inverse techniques are subject to criticism; however, significant strides are being made towards utilizing these techniques and determining whether fracture media can be treated as porous media (Neuman, U of Arizona); C. Wilson, and J.B. Long, LBL). We do have the insight to perform these evaluations in determining whether we are dealing with fracture or porous - the objective of our site specific studies.

Item 3. Locations for testing in the southeastern part of the site have been of some interest. DOE 1 was considered, but the operations may have been unsuitable for the conversion of the hole to hydro testing. However, that pad and borehole continue to be candidates for further testing. Anisotropy tests at H-9 and H-10 are also being considered.

Item 4. See report, p. 7, last line; also p. 45.

Item 5. See p. 44.

EEG Evaluation:

The responses to Items 1b, 1c, 2, 3 and 5 are adequate. The response to 1a indicates that perhaps the Rustler Formation gypsum units should be studied in more detail to determine if karst channels exist in those units. Channels in the gypsum could be a pathway for radionuclide transport. The response to Item 4 indicates only that tests will be run, but gives no information on how they will be run.

BRECCIA PIPES

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HEALTH ENVIRONMENT department

September 21, 1982

Joseph M. McGough
WIPP Project Manager
U. S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, NM 87115

Dear Mr. McGough:

Enclosed is a summary of our comments on the Draft "Evaluation of Breccia Pipes in Southeastern New Mexico and Their Relation to the WIPP Site," by R. P. Snyder and L. M. Gard, Jr., USGS.

We would appreciate your consideration of these comments in the preparation of the final report. As with the other formal reports required by the Stipulated Agreement, we would like to have our staff and yours meet to discuss the final version of the document before its publication.

Sincerely,

Robert H. Neill
Director

RHN:LC:eg
2-062-AG2-17-1-1
Enclosure

cc with attachment:
- George S. Goldstein, Ph.D., Secretary, Health & Environment Department
- Joe Hewett, Secretary, Highway Department
- Charles Turpen, Secretary, Energy and Minerals
- Jeff Bingaman, Attorney General
- Russell F. Rhoades, Director, Environmental Improvement Division
- Joe Canepa, Attorney at Law
- James K. Otts, Chairman, Rad-Waste Consultation Committee
- D. T. Schueler, Assistant Manager for Project of Energy Programs
- Wendell Weart, Sandia Laboratories
- TSC, IEA

EEG Comments on the USGS Draft Open File Report: Evaluation of Breccia Pipes in Southeastern New Mexico and Their Relation to the WIPP Site. by R. P. Snyder and L. M. Gard, Jr., USGS

INTRODUCTION

These comments are based upon a critical reading of the report and many of the references cited in it. The report has achieved in most respects, the purpose of presenting "all available pertinent up-to-date data and analyses concerning the existence of breccia pipes in the basin and the reef, potential for future breccia pipe development, and their significance to WIPP," as required by the Stipulated Agreement between the State of N. M. and DOE. In fact, the report has exceeded the requirements and expectations in many respects. A few recommendations to improve the quality of the report are given below.

GENERAL COMMENTS

Mechanics and Age of Formation of Breccia Pipes Over the Reef:

The authors of this report have done an excellent job in studying and reporting the characteristics of the known breccia pipes viz. at Hills A and C. Their conclusions on the mechanics and age of formation of breccia pipes (pp. 93-104) are primarily based on these detailed studies.

The authors have hypothesized that the initial collapse took place in a cavity in the Capitan limestone with the Tansill and Yates formations dropping into the cavity until the thick beam of the Fletcher Anhydrite was reached. In the second stage, the Fletcher beam failed, resulting in a catastrophic collapse of all the overlying formations in this cavity. Subsequent removal of salt from the Rustler and Salado formations around the margins of the pipe resulted in the outward-dipping beds at the surface.

Basically, this appears to be a sound hypothesis. However, a few difficulties with it are listed below.

a. Neither of the two exploratory boreholes (WIPP-31 and WIPP-16) drilled in the breccia pipe Hills A and C was drilled deep enough to encounter the Capitan Reef limestone. In fact, WIPP-16 was drilled only to the middle of Salado and the anhydrite cored at the bottom (1903 to 1981 feet) of WIPP-31, "is tentatively assigned to the Fletcher Anhydrite" (p. 42).

b. The probability of right conditions existing for the proposed mechanism appear to be very high all over the reef. Why then do the four known breccia pipes (Hills A, B, C and Wills-Weaver) lie within a five mile radius? Such localization indicates additional restrictive conditions which are not included in this hypothesis.

c. The outward dip of the Mescalero Caliche beds from the known pipes (e.g. at Hill A) has been interpreted to indicate "removal of halite from around the pipe" (p. 100). This removal of halite has been ascribed to a dissolution front which is very briefly described on p. 31. In the pipes too, halite is missing from the Rustler formation. At WIPP-31 drilled at Hill A, the cores show a chaotic collapse involving the Rustler formation, whereas WIPP-16 (at Hill C) encountered nearly intact Rustler formation in the pipe. And yet, the halite is missing from the Forty-niner and Tamarisk members of Rustler as found inside the pipe in WIPP-16. Did the collapse at Hill C occurred after the regional removal of salt from Rustler formation at this point? If so, how does one explain the outward dipping of the Triassic and younger strata at Hill C?

d. The mechanism of removal of halite and other soluble minerals from the fragments of Salado and Rustler formations found in the breccia pipe at Hill A (WIPP-31) is hypothesized on p. 98. It states that, following the collapse of Fletcher Anhydrite "beam", the unsaturated water filling the cavity would be forced upwards. Later, "much of the halite would be dissolved by this water and eventually the now saturated water would move downward and out through the existing paths in the reef." It is not clear how this would have occurred since the standing water implies either an impermeable base or a high hydraulic head and what would cause either of the two conditions to change for dissolution of salt and removal of the resulting brine?

Possibility of Breccia Pipes in the Basin

The report has concluded that, "known locations where deep dissolution occurs and forms structures called breccia pipes are limited to areas over the buried Capitan Reef." In support of this conclusion, the report has presented the results of investigation of suspected breccia pipes in the Delaware Basin and has shown why those features are not breccia pipes. However, the description of "Karst domes" (p. 14) needs to be improved to clearly show how "the formation of these domes is related to dissolution of the soluble portions of the units." Similarly, the idea of "blanket dissolution" (p. 84) to explain the features such as at WIPP-32 needs to be described more fully.

The report has not considered the possibility of a breccia pipe forming at depth in the basin. A description of Anderson's "brine density flow" (e.g. Anderson, 1980) and a discussion of why this mechanism is not expected to be forming a breccia pipe at depth through upward stopping, at the WIPP site, should be included in this report. The question of occurrence of breccia pipes in the Delaware Basin should be addressed from a genetic point of view, using the information from other evaporite basins and specific stratigraphic and hydrologic information from the Delaware Basin. Not having found one is not an argument against the potential presence of one.

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Page 92, last sentence: Why is it assumed that the pipes go down only to Zechstein formation and not even lower? Is there other evidence of preferential, deep-seated dissolution of salt from the Zechstein formation?

Page 93, line 15: The title of this section includes the age of the breccia pipes. The section, however, is a summary of earlier work and avoids assigning an age to the pipes. The section on page 105, which deals with possible effect on the WIPP site, mentions an age of 400,000 - 500,000 years ago.

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EEG Comments on Draft USGS report by Snyder & Gard entitled
"Evaluation of Breccia Pipes in Southeastern New Mexico
and their Relation to the WIPP Site"

Comments Reflecting Alternate Interpretations

General comment c.--"The outward dip of the Mescalero Caliche beds from the known pipes (e.g. at Hill A) has been interpreted to indicate "removal of halite from around the pipe" (p. 100). This removal of halite has been ascribed to a dissolution front which is very briefly described on p. 31. In the pipes too, halite is missing from the Rustler formation. At WIPP-31 drilled at Hill A, the cores show a chaotic collapse involving the Rustler formation, whereas WIPP-16 (at Hill C) encountered nearly intact Rustler formation in the pipe. And yet, the halite is missing from the Forty-niner and Tamarisk members of Rustler as found inside the pipe in WIPP-16. Did the collapse at Hill C occur after the regional removal of salt from Rustler formation at this point? If so, how does one explain the outward dipping of the Triassic and younger strata at Hill C?"

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RESPONSE.--The USGS has considered a wide range of interpretations, perhaps including the above, within their peer review and approval system. The interpretations presented are the ones they feel best explain the mechanisms involved. They suggest that alternates may be presented in technical journals with wide scientific forums, if sufficient reasons exist.

Comments which deal with previous work

"Possibility of Breccia Pipes in the Basin

The report has concluded that, "known locations where deep dissolution occurs and forms structures called breccia pipes are limited to areas over the buried Capitan Reef." In support of this conclusion, the report has presented the results of investigation of suspected breccia pipes in the Delaware Basin and has shown why those features are not breccia pipes. However, the description of "Karst domes" (p. 14) needs to be improved to clearly show how "the formation of these domes is related to dissolution of the soluble portions of the units." Similarly, the idea of "blanket dissolution" (p. 84) to explain the features such as at WIPP-32 needs to be described more fully."

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RESPONSE.--The comments are directed toward questions on previous work which is accepted and credited for this report. This is not the proper forum for their discussion.

Comments which would require additional studies

General comment b.--"The probability of right conditions existing for the proposed mechanism appear to be very high all over the reef. Why then do the four known breccia pipes (Hills A, B, C and Wills-Weaver) lie within a five mile radius? Such localization indicates additional restrictive conditions which are not included in this hypothesis."

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Comments to be considered in later USGS Publications

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"Page 3, first paragraph: Questions 3, 4, 5 and 7 need more detailed treatment in the report."

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"Page 54, last sentence: The sentence states that the pipes at Hills A and C occurred at widely spaced times. On page 103, line 11, the statement is made that the two pipes formed at nearly the same time. Some clarification is desirable."

RESPONSE.--All of these comments deal with a request for more information, or, additional thoughts to consider which are not central to the purpose of determining the importance of breccia pipes to the integrity of the facility. These more properly belong in the realm of scientific inquiry and we understand the USGS is preparing a report in their Circular series which will treat these questions.

Comments which are primarily editorial in nature

General comment a.--"Neither of the two exploratory boreholes (WIPP-31 and WIPP-16) drilled in the breccia pipe Hills A and C was drilled deep enough to encounter the Capitan limestone. In fact, WIPP-16 was drilled only to the middle of Salado and the anydrite cored at the bottom (1903 to 1981 feet) of WIPP-31, "is tentatively assigned to the Fletcher Anhydrite" (p. 42)."

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RESPONSE.--We believe you will find that most of these were cleared up in the final, approved version of the report. Those which were not are principally a matter of editorial style of the USGS. Incidentally WIPP-16 was bottomed in the Rustler, not the Salado.

BRINE RESERVOIR REPORT

TME-3153

"Equal Opportunity Employer"

STATE OF NEW MEXICO

ENVIRONMENTAL EVALUATION GROUP
320 Marcy Street
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HEALTH ENVIRONMENT department

February 24, 1983

Mr. Joseph M. McGough
Project Manager
WIPP Project Office
U.S. Department of Energy
P.O. Box 5400
Albuquerque, New Mexico 87115

Dear Mr. McGough:

Enclosed are our review comments on the draft of "Brine Reservoirs in the Castile Formation, Southeastern New Mexico" (TME-3153). Appropriate personnel from EEG would be happy to meet again with the authors of this report, if further clarifications of our comments are desired. We will look forward to hearing your response to these comments.

Sincerely,

Robert H. Neill
Director

RHN:LC:eg

2-112AG2-21-10-1

cc: TSC, IEA

REVIEW COMMENTS

ON

THE DRAFT OF "BRINE RESERVOIRS

IN THE CASTILE FORMATION, SOUTHEASTERN NEW MEXICO"

(TME-3153, December 1982)

by

Environmental Evaluation Group

Environmental Improvement Division

N. M. Health and Environment Department

P. O. Box 968

Santa Fe, NM 87503

February, 1983

EEG Review Comments on the draft of "Brine Reservoirs in the Castile Formation, Southeastern New Mexico" (TME-3153)

INTRODUCTION

These review comments are based upon a critical reading of the report and many of the references cited in the report. The report was evaluated to see whether it has achieved its stated purpose of determining "the characteristics and origin of these reservoirs and evaluate their potential impact on the integrity and stability of the WIPP site" (Executive Summary, p. 2, TME-3153), and whether the conclusions are supported by observed facts, experiments and analyses.

The comments are divided under the categories of Geology, Hydrology and Chemistry, following the organization of the subject report.

GENERAL COMMENTS

1. GEOLOGY

Location of the Brine

It should be realized at the outset that each borehole which encountered brine in the Castile formation did not necessarily encounter a separate "reservoir," unless it can be so proven on the basis of geology, geohydrology or geochemistry.

It is accepted that there are thirteen reported encounters of pressurized brine in the Castile formation in the northern Delaware Basin (12 shown on Fig. G-11 plus "H and W Danford Well No. 1" in Sec. 9, T 22S, R 29E- see EEG-7, p. 66). In addition, there are "numerous reports of small brine occurrences with sub-artesian heads in other parts of the basin" which suggests " a fairly uniform distribution of fluid throughout the Castile" (subject Report, p. G-41).

Previous DOE documents (e.g. TME-3080) stated that brine is restricted in a 6 mile wide "deformation front" which borders the buried Capitan Reef to the south. The subject document has extended this zone to "six to twelve miles" (p. G-37), presumably to include the Belco-Hudson and WIPP-12 encounters. There doesn't appear to be any scientific reason for drawing these boundaries, because if a future well encounters brine, say, 15 miles away from the reef, the boundary would have to be extended further. In any case, the twelve mile zone covers the entire WIPP site and therefore it is difficult to see any significance in this arbitrary exclusion.

Concerning the brine encounters that did not flow to the surface, the report states that, "none are located in the area covered by Figure G-11" (p. G-37). It is impossible to make a statement like this, since most rotary drilling operators for deep hydrocarbon wells would not report brine encounter in Castile unless it created a problem for them.

Stratigraphic and Structural Control of Brine Encounters

Pressurized brine has been found in Anhydrite-III unit of Castile in every reported case. There is some question about ERDA-6 where R. Y. Anderson and C. L. Jones interpreted the upper Anhydrite layer where brine was found as A-II on the basis of visual charcteristics. It is however, very likely, that this anhydrite was A-III also (Powers, personal communication).

While it is probably true that most pressurized brine encounters are related to at least some structural disturbance, Figure G-11 does not show it. Brine occurrence numbers 1, 2, 3, 4, 5, 6 and 9 (Fig. G-11) do not seem to be related to any structure at all. According to Snyder (personal communication) the structure contour map of Fig. G-11 was prepared by C. L. Jones as a very preliminary map. EEG recommends that the final version of this report should have a map prepared by using the up-to-date borehole information as well as the seismic data such as shown in Barrows' map (Fig. G-12).

The statement, "Examination of structures in Fig. G-6 reveals that deformation is mainly confined to the Castile formation...the underlying Delaware Mountain Group does not appear to be widely involved in the structures under discussion" (p. G-39) is based on a misleading drawing of WIPP-12, ERDA-6 and ERDA-9 boreholes in Fig. G-6. How can one use a borehole to correlate horizons below its total depth? Only WIPP-12, ERDA-6 and AEC-7 show structures in Castile. WIPP-12 and ERDA-6 stopped short of the Bell Canyon and AEC-7 did not penetrate deep enough to show the structure in Bell Canyon.

The Age of Deformation

"Between late Permian and Pleistocene" (p. G-2) is indeed the widest possible "bracket" for the age of deformation. Anderson and Powers (1978) concluded that "the salt structure (in ERDA-6) is inferred as post-microfolding." Kirkland and Anderson (1970) showed that microfolding in the basin follows Cenozoic structural trends, which resulted from the uplift and tilting of the basin in early to mid-Cenozoic time (King, 1948), or in late Cenozoic (Pliocene) according to TME-3153 (p. G-9).

The subject report concludes, "The most likely mechanism is formation during or immediately after deposition as a result of slumping and flow, although tectonic stresses cannot be ruled out." (p. G-23). The only reference cited in support of this conclusion is a paper by Riley and Byrne (1961)-p. G-22. Enclosed is a copy of two figures from this paper showing photographs of structures created by piling three layers of different density materials (Fig. 1). Of course some flowage and some deformation is seen, resulting from density contrasts. Ramberg (1963, 1967, 1968) has developed an elaborate theory of gravity--controlled tectonics based on such experiments. However, the Castile microstructures have resulted from tectonic stresses during late Cenozoic, because they are basin-wide, show close relationship with megafolds and the microfold axes generally parallel the trend of Cenozoic tectonism in the area (Kirkland and Anderson, 1970). The report almost correctly summarizes the discussion on the age of deformation, "by concluding that the deformation is probably Cenozoic, and could have occurred between 25 to 1 million years ago" (p. G-43). this implies that the postulation, "the salt structures developed in response to the latest stage of basinal tilting in late Pliocene to early Pleistocene time" (p. G-43) is accepted. Since the Pliocene began 7 million years ago, the "bracket" should be 7 to 1 million years.

In this connection, Kirkland and Anderson (1970) is wrongly cited on p. G-48--this paper rejects "syndepositional movement" as the cause of microfolds.

Brine Reservoir Formation

A mechanism for the formation of brine reservoirs is discussed on page G-44 to G-47 of the subject report. Conceptually, the postulated model of producing fractures in anhydrite by the upward movement of the underlying salt, appears acceptable. However, the discussion should be expanded to explain the following points.

1. How this would happen mechanically by using average reported values for the tensile strength of anhydrite and the expected values of tensile stresses generated by underlying salt flow.
2. How were the "typical average elongations for the structures around WIPP-12 and ERDA-6" calculated (p. G-44).
3. The postulated mechanism would open the fractures in an anhydrite at the upper surface. Almost all the brine filled fractures have been encountered in the lower part of anhydrite-III layer. The explanation that these holes are probably on the flanks of structures (p. G-46) does not satisfactorily explain this contradiction since both WIPP-12 (Fig. G-12) and ERDA-6 (Fig. G-11) appear to be in the crest area of the domal structures.

Pressurization of Brine Reservoirs

The theory of dilatancy (p. G-47) does not appear to provide a reasonable explanation for the differences in reservoir pressures in ERDA-6 and WIPP-12. Using the tidal efficiency (T.E.) from groundwater hydrology (see Walton, 1970), the theoretical reservoir pressures due to a thickness of overburden can be calculated. The tidal efficiency, in general terms, is a measure of the ability of the reservoir rock to transfer a pressure change outside the reservoir to the reservoir fluid. The tidal efficiency can be defined by

$$T.\ E. \ = \ \frac{\alpha}{\alpha + \phi\beta}$$

where α = compressibility of the reservoir rock

β = compressibility of water

ϕ = porosity

β is 4.4×10^{-10} pa^{-1} and the range of α given in TME 3153 is

2.9×10^{-9} pa^{-1} $\leq \alpha \leq 1.45 \times 10^{-7}$ pa^{-1}.

For a range of porosity of 0.1 to 10 percent, the tidal efficiency varies from 1.000 to 0.985. The calculated reservoir pressures in a particular reservoir differ by less than 50 psi for the range of porosity above. This indicates that increased porosity due to fracturing will have little effect on the reservoir pressure. W. Weart, at the February 15, 1983 Quarterly Meeting between DOE and EEG mentioned some preliminary model studies at Sandia National Labs that indicate rock movement and fracture closure as a possible repressurization mechanism.

The dilatancy theory works well in the fractured metamorphic rocks cited in McNaughton (1953). If the rock compressibility is 1×10^{-10} pa^{-1} (within the range of sound rock and jointed rock as given in Freeze and Cherry, 1979) the calculated pressure difference at WIPP-12, for example, is 850 psi for a porosity variation of 0.1 to 10 percent.

The anhydrite compressibility is not in the range necessary to invoke the dilatancy theory. A much more likely explanation for the pressure differences is brine migration. The above comments are presented in greater detail in an upcoming EEG report.

Geologic Evidence of Brine Origin

The discussion under this heading in the subject report (pp. G-48, 49) can be summarized as follows.

1. Small quantities of fluids which may have been present in the rock matrix may be trapped interstitially or within grains. (No quantitative values of assumed original amount of fluids and loss during compaction and diagenesis have been presented to reach this conclusion).
2. Gypsum dehydration would explain the origin of water in the brine, but "the evidence for primary gypsum is not compelling, although dehydration waters cannot be ruled out as a minor source of brine reservoir fluid" (p. G-49).
3. "Groundwater or meteoric water does not appear to be a plausible fluid source at WIPP-12, based on the lack of evidence of dissolution features and the tight contacts observed" (p. G-49). This line of reasoning does not take into account the possibility of brine migration to its present location after its formation elsewhere.

The "evidence" presented under this section is mostly negative. What is the geologic evidence of brine origin?

2. HYDROLOGY

Reservoir Pressure

The subject report uses the "fact" of the reservoir pressures being different from each other as a strong argument favoring the lack of interconnection between different encounters of brine in the Castile formation (pp. H-1, H-36, H-55, H-56). Table H-1 lists 12 pressurized brine encounters with measured or estimated "formation pressure." Only 4 of the 12 pressures (ERDA-6, WIPP-12, Belco and Gulf Covington) were measured; the rest were estimated by using the pressure of the drilling mud necessary to stop the brine flow in the well. There are so many possibilities of errors in the estimated pressures that these should be completely ignored. Among the 4 measured pressures, the differences are not significant--ERDA-6 and Belco had 2060 psig and 2075 psig respectively, Gulf Covington reported 1972 psig with conflicting data for the initial flow rate and WIPP-12 measured 1828 psig pressure. Using this data, it is difficult to see how one can reach to conclusions like, "The persistence of high and different hydraulic heads in the Castile brine reservoirs over millions of years is the principal evidence for their isolation." (p. H-1).

The maximum pressures for wells ERDA-6 and WIPP-12 are given in terms of wellhead pressure and reservoir pressure. Using the two pressures for each well and the depth to the reservoir, (p. H-44, H-51) the fluid pressure gradient is calculated to be 0.537 psi/ft. for each well (p. H-39). The average fluid pressure gradient from the D'Appolonia Data File Report is 0.533 psi/ft for ERDA-6 and 0.538 psi/ft for WIPP-12. Why are the pressure gradients used in the analyses different from the measured data?

In ERDA-6, the different hydraulic pressure gradients affect an 11 psi difference in the maximum wellhead pressure from 615 psig at 0.533 psi/ft to 604 psig at 0.537 psi/ft.

The total reservoir volume estimates are dependent on the total pressure depletion and as such are highly suspect. For example, the wellhead pressure in ERDA-6 as of 1/5/83 was 552.5 psig and is still rising. A Horner plot extrapolation (Fig. 3 attached) indicates the pressure could go as high as 615 psig. If the fluid pressure gradient were 0.533 psi/ft, then the maximum wellhead pressure would be 615 psig. The total pressure depletion would then be zero and the total reservoir volume infinite!

The use of the maximum reservoir pressure of 604 psig versus 615 psig could make a large difference in the total reservoir volume calculation especially as the pressure in ERDA-6 continues to increase.

What is the basis for the statement that the Castile brine reservoirs have maintained their hydraulic heads over millions of years (p. H-1, H-38, H-39)? The elevation of the reservoir relative to sea level has changed over "millions of years" and so has the hydrology of the area.

Volume and Interconnection

The volume of brine reservoir encountered by WIPP-12 has been calculated to be 20 million barrels (p. H-52). Even if the reservoir is assumed to extend through one-half of the 317 feet thickness of Anhydrite-III, the brine would be found underlying an area of 140 million square feet or more than 5 square mile. The actual extent of the brine is probably several times this area, since it is unrealistic to assume that the brine fills the entire lower-half of the anhydrite layer at a uniform porosity of 0.5%.

The volume of ERDA-6 brine has been calculated to be at least 440,000 bbl. (p. H-46). Since this calculation was based on a pressure depletion of 75 psi and the pressure recovery through January 5, 1983 reached 553 psig (which is equal to 51 psi pressure depletion), the volume of the brine reservoir intercepted by ERDA-6 is most likely much larger.

The attempts to correlate the volume calculated from flow tests with the "antiforms" presume the localization of brine within such structures. This attempt is meaningless since the structures are not well defined. In the case of ERDA-6, the structure based on a very sparse borehole data (Fig. G-11) is used (p. H-47). In the case of WIPP-12 the structure interpreted from a seismic time structure map is used (Fig. G-12, p. H-53). The ERDA-6 structure is too large for the calculated brine volume (p. H-47) and the WIPP-12 structure is too small (p. H-53).

The results of interference testing (p. H-37) are inconclusive because the time of testing and observation was not sufficient for the distance between wells. ERDA-6 is about 23,000 feet away from WIPP-12 and the pressure response in the former due to pumping from the latter would take much longer than three weeks (Fig. H-13). Both ERDA-6 and WIPP-12 showed sustained recovery after one year of shut-in, and this recovery is probably generated from within a radius of influence of less than 5000 ft.

Similarly, AEC-7 is 10,000 ft. from ERDA-6 and the pressure response in that well was monitored for less than two months. Even if the tests and the monitoring had continued for a long time, the response due to interference would be extremely small considering the large distances.

Analysis of Flow Tests

All the known methods of analysis of flow test data are listed on pp. H-18 and H-19, yet only the Horner straight line method is actually used. The explanation of why the other methods were unsuitable has been provided in 10 pages (H-19 to H-28). The general explanation is that one or more of the theoretical assumptions were violated. The assumptions are no less violated in Horner's method than in others. All the results should be presented anyway--even in an appendix.

If all the data is not used, there is a possibility of biasing the results. The expression "highest quality data" is used on pages H-41, H-42 and H-43. It seems more apropriate to use all the data and present the results. If the data is poor, the results could be labeled as questionable. A range of values is more useful than a single, carefully chosen, value.

Migration of Brine

The conclusion (p. H-59) that present reservoir pressures are less than lithostatic because of brine flow into fractures, appears to be incorrect. Calculations of the lithostatic pressure by EEG indicate a minimum depressurization of the ERDA-6 brine of 500 psi and of the WIPP-12 brine of 1000 psi. These estimates are considered minimum because the present overburden thickness was used and not a pre-erosional value. In addition, the overburden was assumed to be pure halite. Within the range of formation compressibilities measured for the anhydrite, the variation of porosity of 0.1 to 10 percent caused only a 50 psi difference in the calculated lithostatic pressure.

Therefore it appears unlikely that the reduction of ancient reservoir pressure to the present level is due to increased porosity from fracturing. A more reasonable explanation is that some fluid has migrated to an area of lower potential. As the calculated lithostatic pressure in WIPP-12 is greater than ERDA-6, the WIPP-12 may be more mobile. This would appear to be supported by the observation that WIPP-12 encountered brine in clean, smooth fractures while a recrystallized, brecciated zone held the brine in ERDA-6 (p. G-35). Other brine occurrences of much lower pressure (p. G-37) may represent areas where the brine migration is at a more advanced stage.

3. CHEMISTRY

Samples (Page C-8, Sec. 3.1)

D'Appolonia describes the rationale and techniques for brine sampling very adequately and thoroughly. However, with the excetion of some data reporting tables and figures (Table C-2, C-5, C-6, C-7 and ancillary Figures) which indicate averages, and variation, there is a distinct absence of more rigorous statistical evaluations. Analysis of variance (F-test) and student's t-tests would provide a clearer indication of the reliance which may be placed on certain sample population sets (e.g., Flow Test-3 versus Flow Test-2, etc.) and their respective subsets (downhole versus flowed sample). Such additional tests would appear to be easily performed, given the detail with which D'Appolonia has assembled their basic data.

Evaluation of Mineral Saturation (§Page C-12/13; Sec. 3.3.2)

The use of saturation indices as a means of predicting the degree to which a solution is at (or near) thermodynamic equilibrium with its host rock solid phase is a useful tool. Tables C.3 and C.4 provide a summary of log Ksp and log IAP values for five mineral phases. The discussion on page C-12 and C-13 point out that if the IAP is equal or greater than the Ksp, then the solution is saturated with the phase. The data in Table C.3 and C.4 suggest that calcite as well as halite may not be saturated in ERDA-6 and WIPP-12. The more detailed data in Table C.2 were analyzed by an EEG consultant (Langmuir, 1983) and he concluded that there is undersaturation with respect to sylvite and polyhalite as well. We do agree, however, that the brines appear to be at or very near equilibrium with their surroundings.

Janecke Diagram (Page C-13; Section 3.3.2; Figure C-3)
Further details are needed concerning the Janecke diagram beginning in the last paragraph on p. C-13. This figure appears to be identical to the figure on page 993 of the paper by Harvie and Weare (1980), and shows zones which are saturated with respect to halite. It is not clear how this figure provides information relevant to ERDA-6 and WIPP-12.

Isotope Chemistry (Page C-20, C-39 and C-40, Sections 3.3.4 and 5.1.3)
The linear regression lines shown in Figures C-20 and C-21 using δD versus TDS and $\delta^{18}O$ versus TDS are interesting, but with only two points, the conclusions are not convincing. It is recommended that data on Union also be plotted with that of ERDA-6 and WIPP-12.

Sulfates (Page C-21; Section 3.3.4 , last paragraph)
This paragraph seems to suggest that the sulfate (^{34}S) of the brines is not in equilibrium with the ^{34}S of the rock. If so, this is inconsistent with the statement on p. C-22, 4th paragraph, which states that the $\delta^{34}S$ in sulfate is equal to values characteristsic of sulfates in permian evaporites. Then on p C-41, the last sentence of the first paragraph concludes that the $\delta^{34}S$ values for sulfate in brine are consistently less than the $\delta^{34}S$ values of the rock, which therefore precludes dissolution. Based on Tables C.5 and C.6, this latter statement seems to be correct.

Summary of Findings (Page C-31, Section 4.4)
Since the H_2S, methane and heavier hydrocarbons in WIPP-12 brine appear to have a thermogenic origin, and since the ^{34}S of the brine and anhydrite suggest that the WIPP-12 brines at their present location have not been exposed to high temperatures, one might conclude that the WIPP-12 brine

may have originated at depths much greater than their present location. This would also point toward a closer association with the DMG. The data also suggest an origin for ERDA-6 brine which is different from that of WIPP-12. Other possible origins of the thermogenic H_2S and hydrocarbons are discussed in Section 5.1..4, page C-48.

Seawater Evaporation Model (Page C-36, Section 5.1.2)

The 2nd paragraph on p. C-36 states that WIPP-12 brine is "probably saturated" with glauberite, whereas ERDA-6 brine is not. The results in Table C-3 suggest that ERDA-6 brine is more clearly saturated with glauberite than is WIPP-12. This would tend to refute the discussion in this paragraph, and the "Summary" on page C-38.

Seawater Evaporation Model (Pages C-44-45, Section 5.1.3)

Although the data in general seem to support a seawater evaporation model, some of the arguments used are not technically consistent with the literature. For example, suggesting on p. C-45 that reaction with marine clays will increase the δD and $\delta^{18}O$ is contrary to the literature (Savin 1980; Faure, 1977). As indicated in the Table below, the water would be depleted in ^{18}O and enriched in deuterium.

Table 1 Isotope Fractionation Factors for
Clay-Water Systems at Earth-Surface Temperatures

MINERAL	OXYGEN	HYDROGEN	REFERENCE
Montomorillonite	1.027	0.94	1
Kaolinite	1.027	0.97	1
Glauconite	1.026	0.93	1
Gibbsite	1.018	0.984	2
Illite	1.0234	-	3

1. Savin and Epstein (1970)
2. Lawrence and Taylor (1972).
3. James and Baker (1976).

SPECIFIC COMMENTS

P. G-9, 2nd para.: The age of the dike has been measured as 30±1.5 m.y. (Urry, 1936) and 34.8±0.8 m.y. (GCR, p. 3-80). Therefore, the first episode of tilting did not occur in "very early Tertiary time" but in "mid-Tertiary time".

P. G-10, 2nd para.: The apparent dip observed in the drifts at the site is approximately 2° to the south (Geotechnical Field Data Report no. 5, p. 3-3).

P. G-17, 1st para.: It is possible that the top Castile anhydrite encountered in ERDA-6 may be A-III rather than A-II. In DOE-1 core, A-III showed thin bedding laminations similar to A-II.

P. G-29, First sentence: What is the correspondence between the fracture orientations (Fig G-10) and the structure contour map of Halite II (Fig. G-11) and the seismic isochron map (Fig. G-12)?

P. G-32, 3rd para.: The equation for compressibility is given as $C_p = \frac{1}{\phi K}$ where ϕ is the effective porosity and K is the bulk modulus of the rock mass.

In this equation, if $\phi \longrightarrow 0$, $Cp \longrightarrow \infty$
and if $\phi \longrightarrow 1$, $Cp \longrightarrow Cp$ of rock mass, instead of brine.
Clearly, this equation is incorrect or correct over a limited porosity interval only.

P. G-37, 2nd para: Fig. G-11 should include the borehole "H and W Danford well no. 1" in Section 9, township 22 South, Range 29 East which encountered pressurized brine in Castile (see EEG-7, p. 66)

P. G-43, 4th para.: The conclusion about the deformation having occurred between 25 to 1 million years ago does not match with the conclusion about the most likely mechanism for deformation being "slumping and flow immediately after deposition" (p. G-23, first sentence), since the deposition occurred 225 million years ago.

P. H-1, 2nd para.: Only two brine occurrences were tested, yet here and at other places in the report reference is made to "other Castile brine reservoirs" and conclusions are drawn concerning all the brine occurrences. How are brine reservoirs identified? Does each well that encounters brine represent a separate reservoir?

P. H-1, 3rd para.: Throughout the report, ages are suggested (million years, millions of years) without any supporting evidence. Where do the ages come from?

P. H-4 section 2.2.2 Why doesn't the drainable volume have a direct bearing on the integrity of the WIPP site repository?

What is meant by drainable volume? Does it include only the large fractures or is the microfracture volume also included?

P. H-10, H-11, section 3.2.1, 2nd para.: How sensitive were the measured flow rates to these affects?

P. H-11, 1st para.: Do the gas/liquid separators restrict flow?

P. H-22, 1st para.: The correction to Horners method for fractures is empirical and based on drainage area. The drainage area is very poorly known. So how can this be justified over another method?

P. H-35, 3rd para.: As the heads in the different brine occurrences differ, lateral flow between brine occurrences is also possible.

P. H-36, 2nd para., last sentence: Substantial volumes of brine will be produced only if larger fractures are intersected. Brine in microfractures or in intact anhydrite would not enter a borehole in large enough volumes to cause a problem in normal drilling. Unless the brine caused a problem (flowing at the surface) the oil and gas drillers would not be interested in it.

Granted that no evidence exists to suggest a regional, homogeneous aquifer in the Castile Formation. However, a regional heterogeneous aquifer may exist. This aquifer would be characterized by zones of fracturing and high permeability (known brine occurrences) and zones of intact anhydrite or microfractures and low permeability. Upon fracturing, a high permeability brine reservoir could form as brine from the low permeability zone entered the fractures.

P. H-37, line 17: "fracture-enhanced" should be "large fracture enhanced." From Fig. H-8, H-9 there is no evidence that any kind of a boundary for the micro-fractures was encountered.

P. H-37, last para.: Granted that the fractures are not uniformly distributed. However if one assumes microfracture or porous media flow between the large-fracture zones of WIPP-12 and ERDA-6, a radial flow, or even a 1-D linear flow model could be used.

All the Horner tests, in fact, assume radial flow and all your results are based on Horner's method. Once you leave the large fractures, the radial flow may not be a bad assumption.

P. H-38, 1st para.: Calculations by EEG indicate that the transducer would need to raise the water level in AEC-7 by almost four feet to cause the 2 psi increase in pressure. Is that reasonable?

Page H-38, last para.: The existing hydraulic gradient may not be indicative of the geologic past. Where do you get "millions of years"?

Page H-39, line 10: It is stated that the disposal facility will be open for a few tens of years, after which it will be sealed and the pressure will return to its present state.

There is no reliable calculation on how fast the creep of salt will encapsulate and compact the repository. TME-3153 suggests 300 years.

Page H-41, bottom of page: The quantity F = correction fator when calculating permeability for a vertically fractured well is presented. An accurate estimate of this correction factor requires a knowledge of x_f/x_c, the fracture penetration. See Figure 11.12, p. 153 of Advances in Well Test Analysis, R.C. Earlougher, SPE, 1977.

Page H-43, last paragraph: Why wasn't a log-log analysis attempted for this early time data?

Page H-43, paragraph 3 and H-44, paragaph 1: Why do you expect the permeability of annydrite (core test) to be similar to that of halite (DST-2472-1/SBU).

Pages H-45 and H-46: Three volume estimates are presented.

In using the equation $V = \Delta V/(\Delta p c_t)$, it must be remembered that $\Delta p = pi - \bar{p}$ where pi = reservoir pressure prior to any brine flow and $\bar{p}$ is the average reservoir pressure after a known amount of brine flow.

The downhole pressure prior to any testing is a measure of pi. The downhole pressure following flow test 1 is not a good measure of $\bar{p}$. The surface shut-in pressure as of 10/18/82 is a measure of $\bar{p}$ if it can be demonstrated that there is no gas bubble at the head of the well. At best, only the second calculation on page H-46 is trustworthy.

Page H-46, bottom: If the largest volume figure, 2.2×10^6 bbl, is used, the circle radius is 2,646 ft. Although 2.2×10^6 bbl was an upper bound using a reservoir pressure of 1985 psig on October 18, 1982, it would not be an upper bound when ERDA-6 finally reaches equilibrium (which, because $\bar{k}$ is so small, may take years).

Page H-52: Two volume estimates for WIPP-12 are presented. The downhole pressure following flow test 2 is not a good measure of $\bar{p}$. The surface shut-in pressure of 168 psig on 10/18/82 is a good measure of $\bar{p}$ if it can be shown that the well does not have a gas cap.

H-54, lines 17-19: Already 80,000 barrels of brine have been produced from WIPP-12 with less than a 40 psi reduction in pressure. 100,000 barrels may be a reasonable volume for a single event, but multiple events could produce much, much more.

Page H-55, bullet one: Measurement in 4 wells out of 12 does not constitute most.

Page 55, Observations 1) and 2): If this means that each encounter of brine represents a different reservoir, then the observation is clearly incorrect.

Page H-56, line 18: Is $K<5 \times 10^{-5}$ md obtained from a Salado sample at the WIPP site? Sandia (SAND 81-7073) obtained an in situ permeability of the Salado salt of about 1.0×10^{-3} md.

Page H-56, 3rd and 4th para.: The data is inconclusive about the interconnection between ERDA-6 and WIPP-12. Extending the conclusion derived from such data to other brine encounters is unscientific.

Page H-57: The permeabilities estimated are dependent on the fractures encountered. The high k at ERDA-6 is less than the low k at WIPP-12. Does that indicate two distinct zones of hydraulic characteristics or simply chance fracture encounters?

Page H-58, 2nd para.: Storage capacity and permeability are hydraulically unrelated parameters. The relationship in ERDA-6 and WIPP-12 is coincidental.

Figures 2 (Exec. Summ.), G-6, H-14: Show the boreholes only down to the total depths. Do not correlate below T.D. Also, the key map scale (in the upper right hand corner) is incorrect.

Figure H-12: Gonzales (in SAND 82-1012) gave the fresh water head of well H-1 as 3012.5 ft.

EDITORIAL COMMENTS

P. G-43, line 14: The word "probably" is misspelled.

P. G-44, line 10: "Figure G-12" should be "Figure G-13".

P. G-45, line 7: "Figure G-11" should be "Figure G-13".

P. C-8, Section 3.0, third line: The word "preceded" is misspelled.

P. C-22, Section 4.0, third line: The word "preceded" is misspelled.

P. C-26s, Section 4.3.2, first line: The word "preceding" is misspelled.

P. C-34, Section 5.1.2, 15th line: "Figure C-29" should be "Figure C-28".

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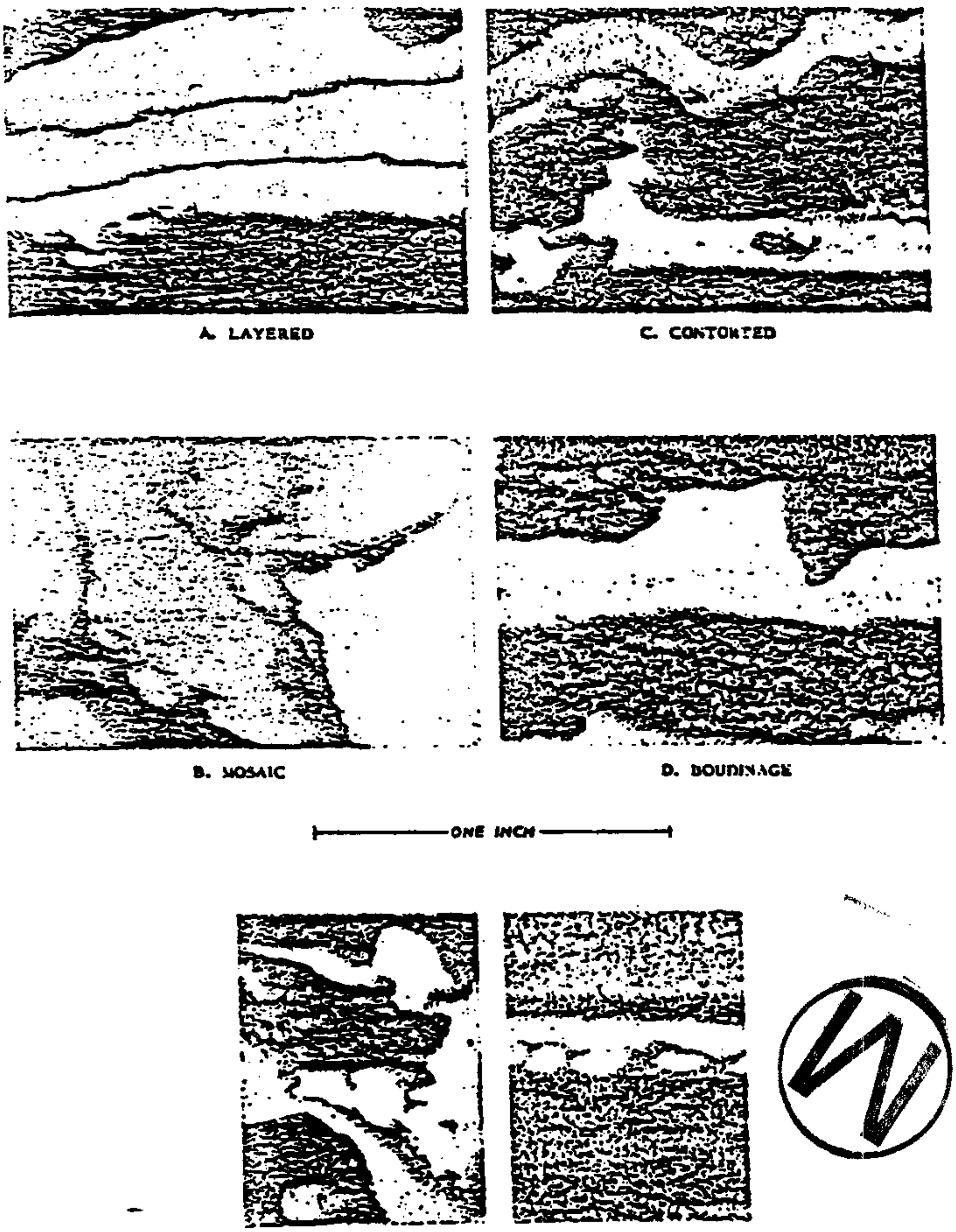

Fig. 4.—Anhydrite structures formed in model experiments.

From Riley and Byrne (1961)

FIGURE 1

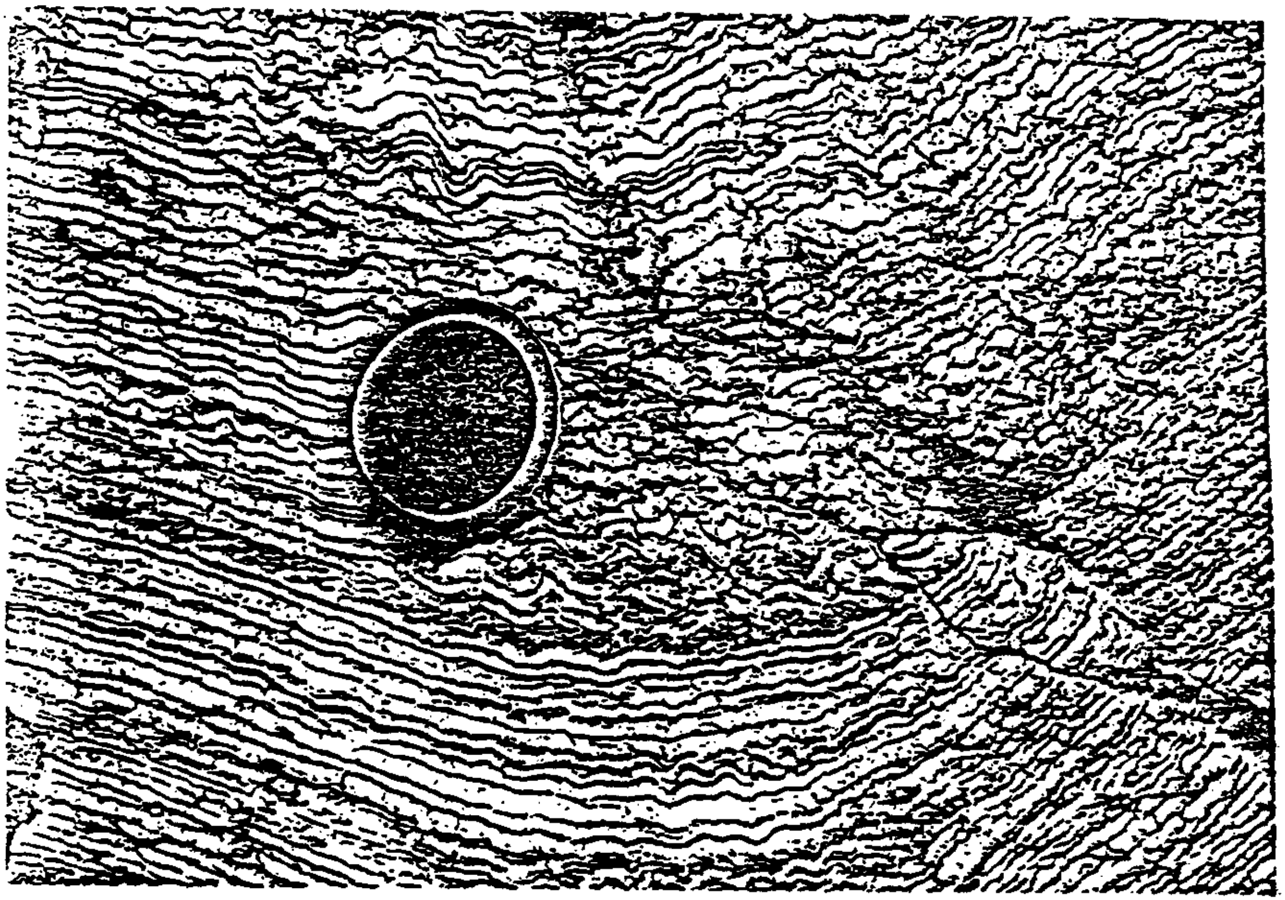

Fig. 12 Microfolding in Castile at the Stateline outcrop, Stop 3-5. Camera lens-cap is for scale.

(photo: Lokesh Chaturvedi)

From EEG-7

FIGURE 2

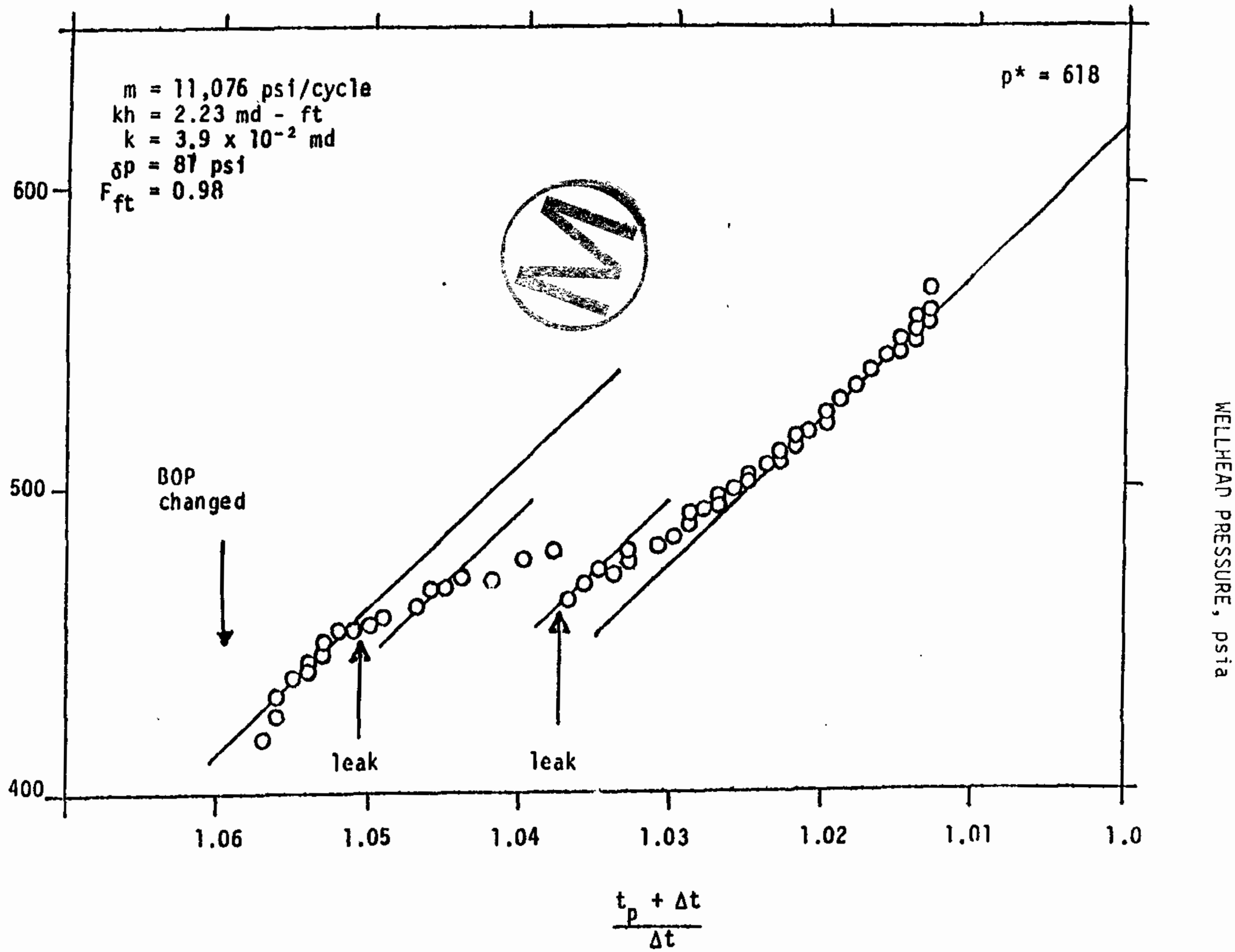

FIGURE 3. Horner plot of pressure buildup following the BOP change.

PLANS FOR SIMULATED WASTE EXPERIMENTS

SAND 82-0547

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STATE OF NEW MEXICO

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May 27, 1982

Joseph M. McGough
WIPP Project Manager
U. S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, NM 87115

Dear Mr. McGough:

There is attached a summary of our comments and recommendations concerning the Draft of "Simulated Waste Experiments Planned for the Waste Isolation Pilot Plant (WIPP), printed March, 1982.

We would appreciate knowing your response to these views.

Sincerely,

Robert H. Neill
Director

RHN:eg

2-031-AG2-20-2
cc: TSC, IEA
Enclosure

REVIEW COMMENTS

CONCERNING

SIMULATED-WASTE EXPERIMENTS PLANNED FOR THE WASTE ISOLATION PILOT PLANT

DRAFT FOR REVIEW

Printed March, 1982

Comments by

Environmental Evaluation Group

Environmental Improvement Division

Health and Environment Department

P. O. box 968

Santa Fe, New Mexico 87504-0968

May, 1982

General Comment

The description of the experiments often is too brief to permit a satisfactory technical review. We would appreciate receiving a copy of the Test Plan for each experiment when that becomes available in draft so that we may have an opportunity to comment prior to its final preparation.

Specific Comments

1. Section 2.2.2 (a), page 8. EEG agrees that waste form stability and leachability can be evaluated by in situ tests; however, there appears to be very little attention given in the SWE plan to the in situ evaluation of the TRU waste form stability and leachability. There is a need for information at an early stage to validate the TRU waste acceptance criteria, to assure safe waste handling procedures, and to plan for retrieval if deemed necessary. Therefore the SWE should include experiments designed to provide in situ investigations of TRU waste form interactions. Of particular concern is the radiolytic production of explosive gas mixtures in 210ℓ drums within three months to five years (Reference 4). It is recognized that such in situ studies would require drums containing actual TRU wastes, however, because the results are essential to an assessment of retrievability, the experiments should be considered under the SWE program schedule.

2. Section 3.3, pages 20-24 - The "Overtest for Simulated DHLW" experiment has two phases with the second phase being addressed to the elucidation of the mechanics of reestablishing a stable, impermeable backfill in DHLW repository rooms. It is recommended that a similar experiment be planned for the TRU waste repository room. The experiment should be addressed to the consolidation of backfill and TRU-containing drums into a stable, impermeable layer. It would provide data on the time span following closure over which a liquid breach scenario has validity.

3. Section 4.2, page 32-36 - This section does not indicate plans for verification of permeability studies for gases produced in untreated wastes. Earlier laboratory and borehole studies by Sandia (Reference 3) have shown that gas pressures on the order of lithostatic could be produced over a several hundred year period. There is question concerning the validity of these data under repository conditions, since the earlier tests were conducted either under controlled laboratory conditions or at only two depths in one borehole (Reference 4). The studies proposed by BNL on page 190 of Reference 4 should be considered.

4. Section 4.1.2(d), page 32 - Although there is considerable data available on the thermal near-field effects on rock salt, consideration should be given to the thermal effect on plastic flow under actual repository conditions.

5. Section 4.2, pages 32-36
a) Tests should be included to demonstrate ability to handle explosions or fires involving wastes. Such tests should be scheduled prior to the handling of radioactive wastes.
b) Experiments designed to verify the radionuclide leach and sorption assumptions used in the long-term consequence modeling of Reference 5 should be initiated at the earliest possible time, since meaningful data would not be available for several years.

c) This section does not indicate whether investigations of the durability of "TRU waste-drums" will include studies of the TRU waste "boxes," such as the DOT-7A FRP coated plywood box, and the RH steel drums. It is suggested that studies of the durability of these additional waste containers be included.

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3. Sandia Laboratories, "Summary of Research and Development Activities in Support of Waste Acceptance Criteria for WIPP," SAND79-1305, December 1979.

4. Brookhaven National Laboratory, "Nuclear Waste Management Technical Support in the Development of Nuclear Waste Form Criteria for the NRC," Task 2, Alternative TRU Technologies, NUREG/CR-2333, February 1982.

5. U. S. Department of Energy, "Final Environmental Impact Statement, Waste Isolation Pilot Plant," vol. 1 and 2, October 1980.

Department of Energy
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AUG 24 1982

Mr. Robert H. Neill
Director
State of New Mexico
Environmental Evaluation Group
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Santa Fe, NM 87503

Dear Mr. Neill:

EEG Comments on Simulated Waste Experiments

Enclosed for your use are responses to the comments and recommendations in your letter dated May 27, 1982, concerning the Draft of "Simulated Waste Experiments Planned for the Waste Isolation Pilot Plant (WIPP)."

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 82-0539/5985A

Enclosure

cc w/enclosure:
C. C. Little, TSC
C&C File, IEA, TSC
T. Hunter, Org. 9732, SNLA

General Comment

Our response to the EEG review comments corresponds to the EEG specific comments number. The general comment by EEG suggested that the description of experiments was too brief for satisfactory technical review. The descriptions of the Simulated Waste Experiments (SWEs) were intentionally summarized in the document. More emphasis was given to objectives and technical issues. The descriptions provided, however, are more than adequate to determine the purpose, scope, and physical configuration of the experiments. Further details will be developed prior to initiation of each experiment and the test plan for each experiment will be continually revised as the experiment progresses.

Specific Comments

1. Section 2.2.2 (a), page 8: The EEG comment concerned the requirement for in situ evaluation of the TRU waste form stability and leachability.

   Based on the considerations which follow we consider in situ tests to evaluate degradation further as unjustified and not necessary.

   Previous laboratory and field studies conducted by SNL on the TRU waste form defined the limits of waste degradation, by-products and potential consequences on environmental safety of the WIPP (SAND79-1305). These studies were conducted under accelerated conditions (higher levels of actinides, higher temperatures, etc.) to observe by-products of the degradation process. The generation of gas mixtures was well characterized and its impact on long-term storage was assessed.

   Drums of CH TRU wastes that meet the WIPP waste acceptance criteria on gas generation will not generate explosive gas mixtures from radiolytic degradation. Their rate of hydrogen production is too low (reference: SAND79-1245, Chapter 2). Actual drums of such waste have been in semi-enclosed temporary storage for years without significant operational problems associated with gas generation. TRU wastes are, however, in existence which could potentially generate explosible concentrations of gases (reference: SAND79-1245, p. 16-17); these wastes, containing large concentrations of ^{238}PU, would not meet WIPP waste acceptance criteria.

   Storage rooms in the WIPP will be ventilated and monitored, thereby preventing accumulation of hazardous concentrations of gases. Gas monitoring is generally a routine procedure and not an experiment. As such, it was not described in the SWE document, particularly since actual (TRU-contaminated) wastes are not in place during this stage of the WIPP.

2. Section 3.3, pages 20-24: The EEG comment suggested additional testing of backfills for TRU wastes. Response of candidate backfill will be examined not only in the DHLW Overtest Experiment but also in the Plugging and Sealing Tests documented in SAND81-2628. The current R&D program is structured to address the sealing potential of backfills. It includes not only the tests outlined in SAND81-2628, but also corresponding modeling and laboratory tests. Backfill for the TRU waste demonstration rooms is planned primarily for fire protection purposes and not for sealing. Sealing for the TRU waste rooms will be accomplished in access drifts using techniques evaluated in the other planned tests described in Section 4.2, Plugging and Sealing, SAND81-2628.

3. Section 4.2, pages 32-36: EEG comment concerned gas pressure buildup over a period of several hundred years. We believe that for the expected gas generation rate and range of salt permeabilities that gas pressurization will be well within acceptable limits. A study of this subject ("Potential for Salt Fracturing Due to Gas Generation" (DRAFT), 1979, D'Appolonia), in addition to the references cited by EEG, leads to this belief. The references show that significant fractures could only occur at very low permeabilities, lower than anticipated at WIPP, and at gas generation rates higher than expected for the WIPP storage horizon.

   Gas permeability in situ tests, as addressed in Section 4.2.2.1 of SAND81-2628 where a plan for permeability measurements is described for the salt formation at the WIPP facility horizon, will be performed for verification. The results of these tests will be utilized, if needed, to support previous studies on this subject.

4. Section 4.1.2 (d), page 32: EEG comment pertained to the thermal effect on salt creep rate under actual conditions. The effect of temperature on salt creep rate will be evaluted in situ as planned in the heater tests described in Sections 3.2 (12-W/m^2 mockup) and 3.3 (Overtest for Simulated DHLW). Thermal "very" near-field effects on rock salt will be examined by measuring the mock DHLW canister borehole deformation throughout the duration of the test. Detailed plans for obtaining near-field (room) and "very" near-field (around-the-canister) response data will be considered during preparation of the Test Plans.

5. Section 4.2, pages 32-36:

   a) EEG comment related to demonstrating the ability to handle explosions or fires involving storage of waste. The WIPP design has attempted to minimize fire and explosion hazards and planned operating procedures are expected to minimize these hazards both before and after placement of radioactive waste. Code of Federal Regulation (30 CFR Part 57.4-58) prohibits building of fires underground. Therefore, no underground tests to demonstrate ability to handle explosions or fires involving waste are being planned as part of the SWE or any other experimental program.

b) EEG comment suggests initiating early tests designed to verify the radionuclide leach and sorption assumption used in long-term consequence assessments for WIPP are best addressed by laboratory experiments and hydrologic tests of the Rustler aquifer. The additional benefits of local backfills and the limited release rate and solubility of radionuclides will be addressed by experiments with radioactivity described in SAND81-2628. These will address primarily defense high level waste as the effects on TRU wastes are clearly bounded by the assumptions in the SAR.

c) EEG comment suggests studies of the durability of TRU waste "boxes" such as the DOT-7A FRP coated plywood box and the RH canisters be included in the SWE TRU drum durability tests. The planned SWE TRU drum durability tests are essentially demonstrations of adequacy as established from previous studies (SAND79-1305, Chapter 7). This reference also provides adequate justification for the durability of the RH waste canisters. The TRU waste box containers will be overpacked in all cases, hence tests of bare boxes are unwarranted.

TRIP/CONFERENCE REPORT

TECHNICAL SUPPORT CONTRACTOR
WIPP PROJECT
ALBUQUERQUE, NEW MEXICO

REPORT NO. EA:82:0390

DATE OF REPORT August 30, 1982

TRIP DESTINATION or LOCATION of CONFERENCE and DATES

- Organization visited EEG visited TSC offices
- Dates of Trip/Conference August 26, 1982

SUBJECT of TRIP/CONFERENCE

Discuss Final EEG Comments On Two Stipulated Agreement Reports

ATTENDEES (Name and Organization)

R. H. Neill, NM EEG
M. Little, NM EEG
C. C. Little, TSC-W
J. S. Treadwell, DOE*
T. Hunter, SNLA*
R. Matalucci, SNLA*
K. R. Porter, TSC-D'Appolonia*

* = Part Time

DISTRIBUTION (Name and Organization)

R. K. Brown, TSC
G. L. Hohmann, TSC
W. Baer, TSC
V. F. Likar, TSC
D. K. Shukla, TSC
W. D. Weart, SNLA
T. Hunter, SNLA
J. M. McGough, DOE
J. S. Treadwell, DOE
R. L. Dintaman, DOE

- **SUMMARY of TRIP/CONFERENCE**

DOE, EEG, TSC and SNLA met to discuss the reports entitled Simulated Waste Experiments Planned for the WIPP (SAND82-0547) and Natural Resources Study, WIPP (TME-3156). Both reports have gone to the printer with only minor change to the resource study resulting from the State's final review.

- **DISCUSSION OF TRIP/CONFERENCE TRANSACTIONS** (Use Trip/Conference Continuation Sheet)

Prior to the morning meeting, the State was presented with copies of both reports-Simulated Waste Experiments (SWE) and Natural Resources. Resolution of the State's comments and incorporation of changes felt to be necessary by the reports authors had occurred earlier and the State was provided with the documents as they were to be printed. Although EEG reviewed the Natural Resources Report, they declined the opportunity to review the SWE report.

The final meeting concerned the SWE report and the DOE response to EEG's comments. After some discussion between all parties, it became obvious that there were three areas of concern by the State which were not addressed by SNLA in the SWE report but which are or will be addressed inother WIPP documents. These three areas include:

1. items relating to the WAC and waste certification,

Report Prepared by C. C. Little

Report Approved by 9/2/82

Organization Institutional and Environmental Assessments

2. items requiring details of specific tests which will not be available until specific plans are developed for each test, and

3. items not related to simulating waste but which will be covered in the overall R&D In-Situ Test Program presently undergoing final review by DOE.

EEG concerns relating to item 1 will be addressed as part of the State's review of other project documents. As such, no revision to the SWE is required. EEG concerns relating to item 2 will be addressed in the detailed SNLA test plans which will be provided to DOE prior to each test. DOE (Treadwell) observed that these plans may be provided to the State if the DOE Project Manager agrees with the State's need to review each plan -- and further observed that there was no apparent reason not to release the plans to the State. TSC (Little) pointed out that the ERDA-6, WIPP-12 and DOE-1 plans had not been released by DOE although the State had participated in a detailed review (through numerous meetings) and that most of their comments had been incorporated in the final plan for each test. EEG (Neill) reiterated the State's request to review each detailed plan. This request has not been resolved pending further consideration by the Project Office. No change will be made in the final SWE report for the second item. Relative to the third item, EEG was informed that SAND81-2628 should be issued in September or October and that no changes in this area were planned for the SWE report. Except as noted relative to EEG review of the detailed test plans, EEG concurred with the DOE/SNLA plan to not modify the SWE report.

During the detailed SWE discussion, EEG requested two documents which TSC agreed to check for availability for release. These are:

"Potential for Salt Fracturing Due to Gas Generation"
(Draft D'Appolonia - 1979)

and

"Long-Range Master Plan for Defense Transuranic Waste Management"
(DOE-TRU 8201 Draft 1982)

Finally, during the SWE discussion, EEG pointed out a potential error in the SAR Table 3.1-1 in that the overpack described does not fit over the FRP box it appears to be intended to protect from fires. TSC (Little) agreed to review the Table for a possible error. Subsequent review indicates that there is not an error, but that the Table depicts containers and overpacks which currently exist in the waste management industry. Prior to shipment of FRP boxes to WIPP, new overpacks will be constructed and placed over the FRP box.

The afternoon meeting consisted of a very brief discussion between EEG and TSC relative to the Natural Resources Study. Two editorial problems were discussed and resolved. The only remaining EEG comments will be discussed further when the revised "Interim" DOE Policy Statement is ready for issuance. Only minor changes have been made to the final Natural Resources Study, and it has been forwarded to the printer for final printing.

Both reports should be issued in final form during September, 1982.

DESIGN VALIDATION PLAN

WIPP-DOE-160

HEALTH ENVIRONMENT department

"Equal Opportunity Employer"

STATE OF NEW MEXICO

ENVIRONMENTAL EVALUATION GROUP
320 Marcy Street
P.O. Box 968
Santa Fe, NM 87504-0968
(505) 827-5481

August 24, 1982

Mr. Joseph M. McGough
Project Manager of WIPP
WIPP Project Office
U.S. Department of Energy
Albuquerque Operations Office
P. O. Box 5400
Albuquerque, New Mexico 87115

Subject: Letter from J. M. McGough to R. H. Neill, Draft Design Validation Plan, JMM 82-0496, 8/3/82

Dear Mr. McGough:

Enclosed are EEG's comments on the report "Preliminary Design Validation Plan Waste Isolation Pilot Plant (WIPP)", which was submitted by you as item 8 of Appendix B of the Stipulated Agreement between the State of New Mexico and the Department of Energy. Should you have any questions regarding these comments, please contact Dr. P. Spiegler.

Sincerely,

Robert H. Neill
Director
AG-046AG2-14-3

RHN:eg

cc: TSC, IEA

Comments on draft

"Preliminary Design Validation Plan Waste Isolation Pilot Plant (WIPP)

by

Environmental Evaluation Group
Environmental Improvement Division
N. M. Health and Environment Department
P. O. Box 968
Santa Fe, NM 87503

August 24, 1982

General Comments

1. The report is considered to be much too general to comply with requirements of the Stipulated Agreement Appendix B, between the State and DOE, and the statement of work described by DOE in the letter from D.T. Schueler to G. S. Goldstein, "Costs and Merits Evaluation for Stipulatd Agreement Activities," August 31, 1981. It is recommended that the report be extensively revised to include a detailed plan with appropriate technical rationale, to construct the test panel and to carry out the tests, and to indicate how the results will validate the key assumptions for design regarding rock mass behavior. It should include (a) establishment of priorities and schedule for various components of the test; (b) preparation of the steps in design, analysis, monitoring and review of the test program; (c) and review of the consistency of the proposed plan with the objectives an rationale for the test.

2. The report relies on references that are partially out of date. See further discussion of references below under "Specific Comments."

Specific Comments

Section 1.1
This section should include a reference to the Stipulated Agreement and a restatement of the work proposed by DOE in the letter from D. T. Schueler to G. S. Goldstein, "Cost and Merit Evaluation for Stipulated Agreement Activities," 8/31/1981.

Section 1.4
The SPDV underground facilities also include an exploratory drift into the area of the repository. This drift was recommended by DOE in lieu of the horizontal coring activities.

Section 1.6
The layout and configuration of the underground openings are not based on experience gained in existing potash mines in the Carlsbad area. In fact, the first underground design was by Serata Geomechanics. The design was rejected

when the room closure rates could not be verified. The present design has a slow room closure rate that permits retrieval of waste 5 to 10 years following emplacement. Retrieval of waste and modular design of the repository are important criteria in the present underground design. The criteria require that substantial barriers of undisturbed salt be left between modules to ensure isolation of each module from other modules.

Section 2.1

The objectives of the preliminary design validation plan are to enhance the level of confidence and credibility of the current design of haulageways and storage rooms. To do this, it is necessary to have some preliminary data that will show that the haulageways and storage rooms will remain stable during the waste emplacement and retrieval period. The objectives of the preliminary design validation plan have been succinctly stated in report SAND 81-25/628* as follows:

- To validate the design for the WIPP access shafts and TRU waste disposal demonstration rooms.
- To evaluate the amount and rate of shaft convergence and room creep deformation and to correlate these data with model predictions.
- To perform a preliminary evaluation of creep in salt and of the steady-state creep model.
- To evaluate instrumentation systems for accuracy and the reliability of measurements made with them in rock salt and to document the suitability of the system for future measurements.
- To evaluate the response of in situ formations such as clay seams and other material layers in addition to the salt.
- To collect large numbers of samples of rock salt and other materials and to conduct laboratory and bench-scale tests to determine the mechanical properties of these samples.

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*R. V. Matalucci, C. L. Christensen, T. O. Hunter, M. A. Molecke, D. E. Munson, Waste Isolation Pilot Plant (WIPP) Research and Development Program: In Situ Testing Plan. Draft report SAND 81-2628.

3.0 plan

This section does not describe a plan, rather, it describes a preliminary proposal for a plan. An excellent description of the plan can be found in report SAND 81-2628,* section 4.1.2.1, preliminary Design Validation, contains much more specific information than is included in this draft and should be incorporated, at least in summary, if it is still current.

4.0 Documentation

Section 4.2
The section should mention that as part of the Stipulated Agreement, a document entitled "Results of SPDV Site Validation Experiment" will be issued in March 1983 (latest revised date from DOE).

5.0 WIPP Design Development

Section 5.1
A statement should be made that indicates that Ref. 5 is outdated due to numerous recent design changes. This reference contains the early underground design by Serata Geomechanics. It was never revised because it was decided to include all the updating in the Title II design. The layout and configuration is not based largely on the experience gained from potash mining in the Carlsbad area (see comments for Section 1.6).

The last sentence which states that the extraction ratio for WIPP is more conservative than the extraction ratio in commercial salt and potash mines is misleading since the two cases have opposite goals. In commercial potash mining the aim is to extract as much ore as possible and to have the rooms close as fast as possible thereafter. (No need for empty drifts in which workers could get lost.) In WIPP the aim is to have haulageways and storage rooms that will remain stable during the waste emplacement and retrieval periods.

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*R. V. Matalucci, C. L. Christensen, T. O. Hunter, M. A. Molecke, D. E. Munson, Waste Isolation Pilot Plant (WIPP) Research and Development Program: In Situ Testing Plan. Draft report SAND 81-2628.

Section 5.5

The last sentence, "the modeling techniques mentioned in para. 5.3 will attempt to define long term creep behavior" is incorrect. The techniques have only been used to evaluate creep for the first ten years following room construction. Long term creep requires terms that describe the inertia of the backfilling and the waste cans to the creep. The Thermal/Structural Interactions experiments of the WIPP Research and Development Program will provide data on long term creep.

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

RECEIVED
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EVALUATION GROUP

NOV 2 4 1982

Mr. R. H. Neill
Director
State of New Mexico
Environmental Evaluation Group
P. O. Box 968
Santa Fe, NM 87504

Dear Mr. Neill:

Design Validation Plan

Enclosed for your review is the final draft of the Design Validation Plan required by Item 8 of Appendix B of the Stipulated Agreement. This revision incorporates the results of our discussions of September 21, 1982 on this document. Because of the extensive changes to the document resulting from your comments, we are reissuing the report for your final review. We would appreciate your comments before December 10 since we would like to go to the printer on December 17. This schedule will allow us to issue the final printed report before the end of 1982.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 82-0823

Enclosure

cc w/o enclosure:
J. Treadwell, WIPP/PO, AL
J. Smrha, B, AL
C. C. Little, TSC, AL

cc w/enclosure:
C&C File, IEA, TSC

"Equal Opportunity Employer"

STATE OF NEW MEXICO
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ENVIRONMENT department

December 15, 1982

Mr. Joseph M. McGough
Project Manager on WIPP
WIPP Project Office
U. S. Department of Energy
P. O. Box 5400
Albuquerque, NM 87115

Dear Mr. McGough:

Subject: Design Validation Plan, Rev. 4, 11/15/82. Letter WIPP: JMM 82-0823, dated 11/24/82.

We have reviewed the above cited document and are pleased to note that it has been revised to address EEG's comments in my letter of August 24, 1982 as well as those items discussed at our meeting on September 21, 1982. The document provides a good description of the tests to be performed to demonstrate the soundness of the design of WIPP. Aside from a few detailed comments, we have no further comments concerning this document. However, we have one suggestion for the preliminary design validation report.

The design validation plan provides a description of the geological observations that will be made and of the data that will be accumulated during the SPDV phase of the WIPP. It does not convey the impression that data analysis will play an important role in the final design of the WIPP repository. For example, unlike the description of the tests in the document SAND 81-2628, there is no discussion of expected results. Also, there is no mention of possible design alterations. The section, "Drawings, Figures, Logs" of Appendix B, does not indicate any preliminary calculations. We believe that data analysis is important to the validity of the design validation report and the preliminary design validation report should reflect this by having two subsections on expected results; one in section 8 "Geological Behaviour--Shafts", and the other in section 9 "Geological Behaviour--Horizontal Openings."

Detailed comments on the design validation plan are enclosed.

Sincerely,

Robert H. Neill
Director

RHN:PS:eg

2-93-A02-14-3-1

Enclosure

Detailed Comments on Design Validation Plan

1. Page 6, last line.

   The paragraph should point out that the exploratory drift is to be excavated to the south.

2. Page 7, Figure 1-2.

   The figure should have an arrow indicating the north-south direction.

3. Page 15, 2nd paragraph or line 12.

   The term "through SPDV" appears to be meaningless. SPDV will go on until September '83, which is past March '83.

4. Page 16, item 2a.

   Is there a typing error in the date 4/31?

5. Page 17, 1st paragraph.

   There is no commitment in the paragraph to furnish the data as available after the final design validation report to the EEG.

6. Page 20, item f).

   A statement indicating the locations of drillholes or other plans to monitor Marker Bed 139 and height of clay seams above roof should be added.

7. Page 20, bottom of Page.

   The following item should be added:
   k) Geophysical measurements to determine possible anomalies above or below the drift.

8. Page 22, section 4.1.

   Most of the documents to be furnished under the Stipulated Agreement can be viewed as part of the site characterization program. They should be referenced in this section.

9. Page 23, Figure 4.1.

   This figure should be replaced by the latest design which shows the repository in the southern region of the site.

10. Page 25, Figure 4.2.

   The direction of this cross-section should be indicated.

11. Page 31, 3rd paragraph or line 25.

The sentence "After a retrieval period of five years, the rooms with waste emplaced will have been completely backfilled with salt." is unclear.

12. Page 36, last line.

The sentence is incomplete. It should be as follow: A schedule of activities included in the performance of the Design Validation Plan is presented on p. 16.

13. Page 47, item 13.

The item should point out that the correlation goes from WIPP-12 to DOE-1.

Department of Energy
Albuquerque Operations Office
P.O. Box 5400
Albuquerque, New Mexico 87115

FEB 11 1983

FEB 15 1983
EVALUATION GROUP

Mr. Robert H. Neill
Director
State of New Mexico
Environmental Evaluation Group
P.O. Box 968
Santa Fe, NM 87503

Dear Mr. Neill:

Conference Report for DOE/EEG Meeting, January 26, 1983

Enclosed for your information, is a conference report for the subject meeting on the validation process and forthcoming reports. I believe, based on my observations at the meeting, that we are in agreement on the planned activities and reports leading to DOE's pending decision relative to our proceeding will full facility construction.

At the present time, we are making arrangements for an EEG tour of the underground facility including the complete south drift on February 16, 1983. This will be the earliest opportunity under our present schedule during which all mine conditions will be suitable for such a tour. We also plan to conduct the seventh quarterly review in our Albuquerque office on February 15, 1983. We have arranged for a Ross flight to Carlsbad the morning of February 16. The flight will return late that afternoon.

If there are any questions on our plans, please contact me at your convenience.

Sincerely,

J. M. McGough
Project Manager
WIPP Project Office

WIPP:JMM 83-0111

Enclosure

cc:
See Page 2

TECHNICAL SUPPORT CONTRACTOR
WIPP PROJECT
ALBUQUERQUE, NEW MEXICO

REPORT NO. EA:83:0037

DATE OF REPORT January 28, 1983

TRIP DESTINATION or LOCATION of CONFERENCE and DATES

- Organization visited EEG/DOE/TSC/B/SNLA Meeting

- Dates of Trip/Conference January 26, 1983

SUBJECT of TRIP/CONFERENCE

See Attachment I

ATTENDEES (Name and Organization)

DISTRIBUTION (Name and Organization)

R. K. Brown, TSC
G. L. Hohmann, TSC
D. K. Shukla, TSC
H. Taylor, B
J. Smrha, B
W. Weart, SNLA
T. Hunter, SNLA
J. M. McGough, DOE
J. S. Treadwell, DOE
T. Shea, DOE
R. Dintaman, DOE

- SUMMARY of TRIP/CONFERENCE

The parties met to discuss DOE's response to EEG comments on the Design Validation Plan and to discuss documentation being prepared to support the April 1, 1983 DOE decision relative to the initiation of full facility construction. EEG agreed with the resolution of comments and DOE's planned documentation to support their decisions.

- DISCUSSION OF TRIP/CONFERENCE TRANSACTIONS (Use Trip/Conference Continuation Sheet)

The subject meeting was conducted in accordance with the attached agenda (Attachment II). After a brief opening by DOE during which it was explained that the Project Office had reassigned certain functional responsibilities, TSC presented (Attachment III) a summary of the hierarchy of reports which have been and are being prepared to support the suitability of the site and preliminary design. The relationship of documentation to the Stipulated Agreement was discussed to ensure a mutual understanding of required submittals. The greater significance of documentation supporting site suitability was also discussed, and all parties agreed that preliminary design validation will be less important in the decision to proceed because the design is continually evolving over the life of the facility. It was pointed out that all supporting documents will be provided to EEG and the State reading rooms, but that DOE will print a larger number of the documents responding to item 2 of the Stipulated Agreement to respond to public requests for information. At the conclusion of these discussions, all parties were in agreement concerning the planned documentation and schedules for review. EEG did feel that,

Report Prepared by C. C. Little *C.C. Little*

Organization TSC - WIPP Project

Report Approved by *[signature]*

although there was no requirement to do so at this time, DOE should address the draft EPA standard on site suitability -- no commitment was made to do this until the regulations are promulgated and DOE has reviewed the final rules.

The next agenda item, discussion of EEG comments on the Design Validation Program Plan, was led by Bechtel. EEG's comment had been provided earlier in a letter to the Project Office and the discussion concerned revisions to the document by Bechtel. EEG was pleased with the revisions to the Design Validation Program Plan. Bechtel indicated they would finalize the report for issuance as a DOE document. Bechtel also pointed out that the Preliminary Design Validation Report presently scheduled for March 31, 1983 would not include a comparison of predictive calculations versus actual results in the mine since earlier predictions were not directly applicable to the final horizon. During the discussions, EEG questioned whether or not the project was continuing to use radar to preview conditions ahead of the continuous minor. DOE indicated that, as had been observed in potash mines, the use of radar was less efficient than periodic probe hole drilling and that the use of radar had been discontinued. EEG also requested further details relative to the northernmost location of TRU waste relative to WIPP-12 under the present design. It was pointed out that this was related to the final decommissioning plan which had not been developed, but that if no TRU waste was permanently disposed of in the experimental area that the northernmost waste would be more than 6000 feet horizontally from WIPP-12. If during decommissioning TRU waste was placed in the experimental area, this waste would be slightly less than one mile horizontally from WIPP-12.

The next agenda item, site suitability report contents, was directed by SNLA. During this discussion, it was pointed out that the summary would include a discussion of the 21 site qualification criteria delineated in WIPP-DOE-116. The summary report would not address the issues in detail, but would instead rely on the other documentation developed in support of this final decision on site suitability.

The final agenda item, contents of the report on results of SPDV site validation experiments, was directed by TSC. A draft table of contents (Attachment IV) was provided and discussed. EEG felt that the report should contain information on the petrography of the inner bedded materials and characterization of the individual aquifers in the shaft mapping report. TSC pointed out that neither of these items were required by WIPP-DOE-116 and that the last item would be very difficult (maybe impossible) to obtain at this time. TSC/DOE agreed to evaluate the possibility of providing the requested petrographic information.

HEALTH & ENVIRONMENT department

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STATE OF NEW MEXICO

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April 5, 1983

Mr. Joseph McGough
Project Manager on WIPP
WIPP Project Office
U.S. Department of Energy
P.O. Box 5400
Albuquerque, New Mexico 87115

Subject: Design Validation Plan

Dear Mr. McGough:

The document Design Validation Plan (WIPP-DOE-160) Reference 9 attached to your letter of 3/24/83 is sufficiently responsive to issues on questions raised in both correspondence and meetings on the attached reference list. The document fulfills item 8 of the Stipulated Agreement.

Sincerely,

Robert H. Neill
Director

RHN:ps

Attachment

Z-123AG-2-14-3-1

cc: TSC, IEA

References

1. WIPP:JMM 82-0496, Transmittal of Draft Design Validation Plan, J.M. McGough to R.H. Neill, 8/9/82.

2. AG-046 AG2-14-2, Comments on Draft Preliminary Design Validation Plan Waste Isolation Pilot Plant (WIPP), R.H. Neill to J.M. McGough, 8/24/82.

3. EEG Conference Report 49, 9/28/82.

4. WIPP:JMM 82-0823, Design Validation Plan, J. McGough to R.H. Neill, 11/29/82.

5. 2-93-AG2-14-3-1, Comments on Design Validation Plan, Rev. 4, R.H. Neill to J. McGough, 12/15/82.

6. EEG Conference Report 58, 1/27/83.

7. WIPP:JMM 83-0111, Conference Report for DOE/EEG Meeting, January 28, 1983, J.M. McGough to R.H. Neill, 2/15/83.

8. WIPP:JMM 83-0118, Advance Copy of Design Validation Plan, J.M. McGough to R.H. Neill, 2/9/83.

9. WIPP:JMM 83-0211/6552A, Transmittal of WIPP-DOE-160, Design Validation Plan, January 1983, J.M. McGough to R.H. Neill, 3/24/83.

EEG-12 Little, Marshall S., Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP, May 1982.

EEG-13 Spiegler, Peter., Analysis of the Potential Formation of a Breccia Chimney beneath the WIPP Repository, May, 1982.

EEG-14 Not published.

EEG-15 Bard, Stephen T., Estimated Radiation Doses Resulting if an Exploratory Borehole Penetrates a Pressurized Brine Reservoir Assumed to Exist Below the WIPP Repository Horizon, March 1982.

EEG-16 Radionuclide Release, Transport and Consequence Modeling for WIPP. A Report of a Workshop Held on September 16-17, 1981, February 1982.

EEG-17 Spiegler, Peter, Hydrologic Analyses of Two Brine Encounters in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, December 1982.

EEG-18 Spiegler, Peter, Origin of the Brines Near WIPP from the Drill Holes ERDA-6 and WIPP-12 Based on Stable Isotope Concentration of Hydrogen and Oxygen, March 1983.

EEG-19 Channell, James K., Review Comments on Environmental Analysis Cost Reduction Proposals (WIPP/DOE-136) July 1982, November 1982.

EEG-20 Baca, Thomas E., An Evaluation of the Non-radiological Environmental Problems Relating to the WIPP, February 1983.

EEG-21 Faith, Stuart, et al., The Geochemistry of Two Pressurized Brines From the Castile Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, April 1983.

EEG-22 EEG Review Comments on the Geotechnical Reports Provided by DOE to EEG Under the Stipulated Agreement Through March 1, 1983, April 1983.

EEG-23 Neill, Robert H., et al., Evaluation of the Suitability of the WIPP Site, May 1983.

EEG-24 Neill, Robert H. and James K. Channell Potential Problems From Shipment of High-Curie Content Contact-Handled Transuranic (CH-TRU) Waste to WIPP, August 1983.

EEG-25 Chaturvedi, Lokesh, Occurrence of Gases in the Salado

Formation, March 1984.

EEG-26 Spiegler, Peter, Environmental Evaluation Group's Environmental Monitoring Program for WIPP, October 1984.

EEG-27 Rehfeldt, Kenneth, Sensitivity Analysis of Solute Transport in Fractures and Determination of Anisotropy Within the Culebra Dolomite, September 1984.

EEG-28 Knowles, H. B., Radiation Shielding in the Hot Cell Facility at the Waste Isolation Pilot Plant: A Review, November 1984.

EEG-29 Little, Marshall S., Evaluation of the Safety Analysis Report for the Waste Isolation Pilot Plant Project, May 1985.

EEG-30 Dougherty, Frank, Tenera Corporation, Evaluation of the Waste Isolation Pilot Plant Classification of Systems, Structures and Components, July 1985.

EEG-31 Ramey, Dan, Chemistry of the Rustler Fluids, July 1985.

EEG-32 Chaturvedi, Lokesh and James K. Channell, The Rustler Formation as a Transport Medium for Contaminated Groundwater, December 1985.

EEG-33 Channell, James K., John C. Rodgers and Robert H. Neill, Adequacy of TRUPACT-I Design for Transporting Contact-Handled Transuranic Wastes to WIPP, June 1986.

EEG-34 Chaturvedi, Lokesh, (edi), The Rustler Formation at the WIPP Site, January 1987.

EEG-35 Chapman, Jenny B., Stable Isotopes in Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP Area, October 1986.

EEG-36 Lowenstein, Tim K., Post Burial Alteration of the Permian Rustler Formation Evaporites, WIPP Site, New Mexico, April 1987.

EEG-37 Rodgers, John C., Exhaust Stack Monitoring Issues at the Waste Isolation Pilot Plant, November 1987.

EEG-38 Rodgers, John C., Kenney, James W., A Critical Assessment of Continuous Air Monitoring Systems At The Waste Isolation Pilot Plant, March 1988.

EEG-39 Chapman, Jenny B., Chemical and Radiochemical Characteristics of Groundwater in the Culebra Dolomite, Southeastern New Mexico, March 1988.

ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-23

EEG-23

EVALUATION OF THE SUITABILITY OF THE WIPP SITE

Robert H. Neill
James K. Channell
Lokesh Chaturvedi
Marshall S. Little
Kenneth Rehfeldt
Peter Spiegler

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

May 1983

Environmental Evaluation Group
Reports

EEG-1 Goad, Donna. A Compilation of Site Selection Criteria, Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, June 1979.

EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volumes I and II, December 1978.

EEG-3 Neill, Robert H., et al, eds. Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U. S. Department of Energy, August 1979.

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(Continued on back cover)

EVALUATION OF THE SUITABILITY OF THE WIPP SITE

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CONTENTS

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site, the design of the repository, its planned operation, and its long-term stability. These analyses include assessments of reports issued by the U.S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U.S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

Robert H. Neill
Director

EXECUTIVE SUMMARY

The determination of the suitability of the site for WIPP is only the first major phase in the evaluation of the radiological impact of the repository on the public health and safety. The Environmental Evaluation Group (EEG) will continue to independently review the design of the facility, the operational procedures (including safety criteria and quality assurance), the criteria for packaging and shipment of the waste, the plans, procedures and results of the WIPP experiments, emergency preparedness, adherence to EPA and pertinent NRC regulations, and other important features of the project.

EEG has concluded from existing evidence that the Los Medanos site for the WIPP project has been characterized in sufficient detail to warrant confidence in the validation of the site for the permanent emplacement of approximately 6 million cubic feet of defense trasuranic waste. This conclusion is based on the assumption that the maximum surface dose rate for the unshielded remote-handled transuranic waste (RH-TRU) canisters will be 100 rem per hour with a maximum radionuclide concentration of 23 curies per liter as indicated in Table E-3 of the Final Environmental Impact Statement for WIPP. The Site and Preliminary Design Validation (SPDV) program, through the drilling of two shafts to the selected repository level at 2160 feet below the surface and excavation of about 9000 feet of tunnels, has confirmed the interpretations made about the subsurface geological conditions at the site.

For an assessment of the potential radiation effects of the nuclear waste repository on the public health and safety, it is necessary to understand the regional geological and hydrological setting. A large amount of work has been done to understand these conditions and to address several specific issues which have arisen as a result of such studies. However, in an assessment effort of this magnitude, it is almost inevitable that some questions remain unanswered at a given time in the decision-making process. EEG has identified work which still needs to be done at the Los Medanos site in order to improve confidence in the worst case scenario models of possible breaches of the repository. Also, it is anticipated that some of the additional information will be necessary to assure compliance with the EPA standard when it is promulgated.

EEG strongly recommends that the following important commitments be obtained from DOE prior to beginning the full facility construction.

Recommended Commitments from DOE Prior to Beginning the Construction

1. The WIPP will comply fully with the U.S. Environmental Protection Agency standard for the disposal of transuranic wastes, when it is promulgated. WIPP does not appear to meet some parts of the proposed standard.

2. The maximum surface-dose rate for the unshielded Remote Handled Transuranic Waste (RH-TRU) canisters will be 100 rem per hour with a maximum radionuclide concentration of 23 curies per liter as indicated in Table E-3 of the Final Environmental Impact Statement for WIPP.

3. No potash mining will be allowed in Zones I, II and III of the WIPP site. Deviated drilling for oil and gas from outside the WIPP site to reach under the WIPP site at depths greater than 6000 feet may be allowed. The federal government shall exercise active institutional control at the site for this purpose for at least 100 years after repository decommissioning.

4. DOE shall provide to the State certified data and final reports as appropriate for the studies and investigations listed herein by July 1, 1985, and allow for a 60 day review and comment period by the State and general public. DOE shall consider and respond to such comment within 30 days.

The following lists certain investigations currently in process or planned by DOE and additional work which EEG recommends that the State should demand if the construction is allowed to proceed.

Studies Recommended by EEG

1. Investigate the depression of the marker beds in the lower part of the Salado formation, centered two miles north of the WIPP shafts.

2. Perform computer modeling of groundwater flow in the Rustler aquifers.

3. Conduct the following hydrology tests:
   a) A long duration pumping test at the well H-3.
   b) *Measure the anisotropy of the hydraulic conductivity at test pads* H-1, H-2, and H-3.
   c) Perform convergence tracer tests at wells H-1, H-3 and H-4.
   d) Perform convergence tracer tests at well H-6 using sorbing tracers.

<u>Continuing or Planned DOE Studies</u>

1. Evaluate and field test non-invasive geophysical methods to identify possible occurrence of brine under the repository.

2. Analyze the drawdown data in test holes H-1, H-2 and H-3 caused by the excavation of WIPP shafts.

3. Publish the results of solute transport modeling in the Rustler aquifers.

4. Analyze the Rustler aquifer waters for environmental isotopes (Carbon-14, Chlorine-36, Uranium-234, Uranium-238) to aid in understanding the groundwater flow direction and relative velocity.

5. Drill the planned additional wells for hydrologic testing, viz. H-11 and H-12. Obtain the cores while drilling these wells to determine the extent of fracturing and solution residues throughout the Rustler formation.

6. Conduct a water balance study for the WIPP site.

7. Study the mechanics of removal of salt from the Rustler formation at and near the site.

8. Drill a shallow auger-hole in the depression in the SW corner of Sec. 30, T225, R 31E in Zone III to address the suspicion of this depression being a doline.

9. Further study marker bed 139 (MB139) underlying the repository horizon to determine its origin and its effect on the repository.

List of Figures

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INTRODUCTION

On March 31, 1983, the Department of Energy issued the "Summary of the Results of the Evaluation of the WIPP Site and Preliminary Design Validation Program" (WIPP-DOE-161). This publication contains a "Summary of the Evaluation of the WIPP Site Suitability" by W. D. Weart of Sandia National Laboratories and an Executive Summary of the Preliminary Design Validation Report by Bechtel National, Inc. The report concludes that the Los Medanos site fulfills the intent of all the site qualification factors and should, therefore, be used for the Waste Isolation Pilot Plant project. It also concludes that "the major WIPP design elements and design bases have been validated by observation or measurement."

The Environmental Evaluation Group (EEG) is charged with the responsibility of evaluating the suitability of the site for carrying out the mission of WIPP by analyzing all the reports and other information which form the background to the DOE evaluation of the site. The results of this evaluation are being conveyed to the appropriate State authorities to help them formulate the State's position on whether to oppose the beginning of construction of the Waste Isolation Pilot Plant project.

A summary of EEG's involvement since November 1978 is provided in the Appendix to indicate the extent of evaluation process for the past 4 1/2 years. During the past year alone, EEG has received approximately 40 major and numerous supporting reports from DOE concerning various aspects of the evaluation of the site.

The "Summary of the evaluation of the WIPP Site Suitability" by W. D. Weart of Sandia National Laboratories, contained in the U. S. Department of Energy document (WIPP-DOE-161, March, 1983) is based on the 21 site qualification factors formulated in the Site Validation Program (WIPP-DOE-116, October 1982). The specific issues on which EEG has expressed its concerns in the past (EEG-3, EEG-6, EEG-7, EEG-10, DOE/State Stipulated Agreement, 1981) are included in the 21 site qualification factors. Rather than comment on the adequacy of the WIPP site with respect to each of the 21 factors, the discussion in this report is arranged according to issues which EEG considers important in evaluating both the operational and the long-term integrity of the site. The section on Conclusions and Recommendations provides a summary of EEG analyses of the issues of site suitability.

The Environmental Evaluation Group organized a meeting on "Evaluation of WIPP Site Suitability" at Carlsbad on May 12 and 13, 1983. The purpose of the meeting was to present EEG's tentative conclusions on the issues of WIPP site suitability to a group of 40 invited scientists and engineers which included scientists from State agencies, members of the National Academy of Sciences Panel on WIPP; several University professors from New Mexico and from Stanford, University of Arizona and Pennsylvania State; U. S. Geological Survey scientists; scientific personnel from DOE and its contractors e.g. Sandia, and D'Appolonia. While the discussions, comments and recommendations made at this meeting were considered in the preparation of this report, the conclusions reflect the views of the Environmental Evaluation Group and do not necessarily reflect the views of others.

As the title of this report suggests, only the issues directly related to the suitability of the site are addressed here. Other issues including transportation, waste acceptance criteria, the absence of engineered barriers, and adherance to EPA and NRC regulations will be dealt with separately.

RESOLUTION OF SPECIFIC ISSUES

DISSOLUTION

1.0 Blanket Dissolution

Geologists who have studied the Delaware Basin generally agree that the Ochoan evaporite deposits of upper Permian age have undergone erosion and shallow dissolution in the Basin. This regional dissolution must have been initiated with the tilting of the basin and injection of water from the Capitan aquifer downdip to the east into the evaporite deposits. Since halite is the most soluble of the ochoan evaporites, it has been dissolved where the unsaturated waters have managed to attack it. The sequence from the oldest to the youngest of the Delaware Basin evaporites is Castile, Salado and Rustler formations, respectively. Figure 1 shows the western edges of the Castile and Salado halite. The edge of the salt in the youngest, i.e., the Rustler formation, is farther east and it criss-crosses the WIPP site in a general north-south direction (Fig. 2).

The effects of the regional dissolution nearest the WIPP site can be observed in Nash Draw, a dog bone shaped depression immediately west of the WIPP site. Nash Draw is approximately 15 miles long in the north-south direction and its width ranges from approximately 5 miles to as much as 12 miles. Bachman (1980, 1981) studied and mapped this depression in detail and concluded that it has been formed by a process of "solution and fill," which is active today. Based upon the dating of a volcanic ash layer associated with the Gatuna formation which is exposed at the ridge on the eastern margin of Nash Draw and using the marker beds in Salado, Bachman (1980) concluded that about 200 feet of subsidence has occurred in this depression during the past 600,000 years. Using this observation, Bachman (1974) calculated an average rate of 330 feet per million years for the vertical dissolution. Assuming that the edge of the Salado salt has moved from the Capitan Reef front to its present location during the past 7 to 8 million years (since the Ogallala time), Bachman and Johnson (1973) concluded that the horizontal rate of movement of the blanket dissolution front is about 6 to 8 miles per million years. It should, of course, be recognized that these are very rough average rates of movement of the dissolution front. The front itself may be expected to move faster under less arid climatic conditions. Also, an advancing "tongue" of the front may reach a point faster than the front itself.

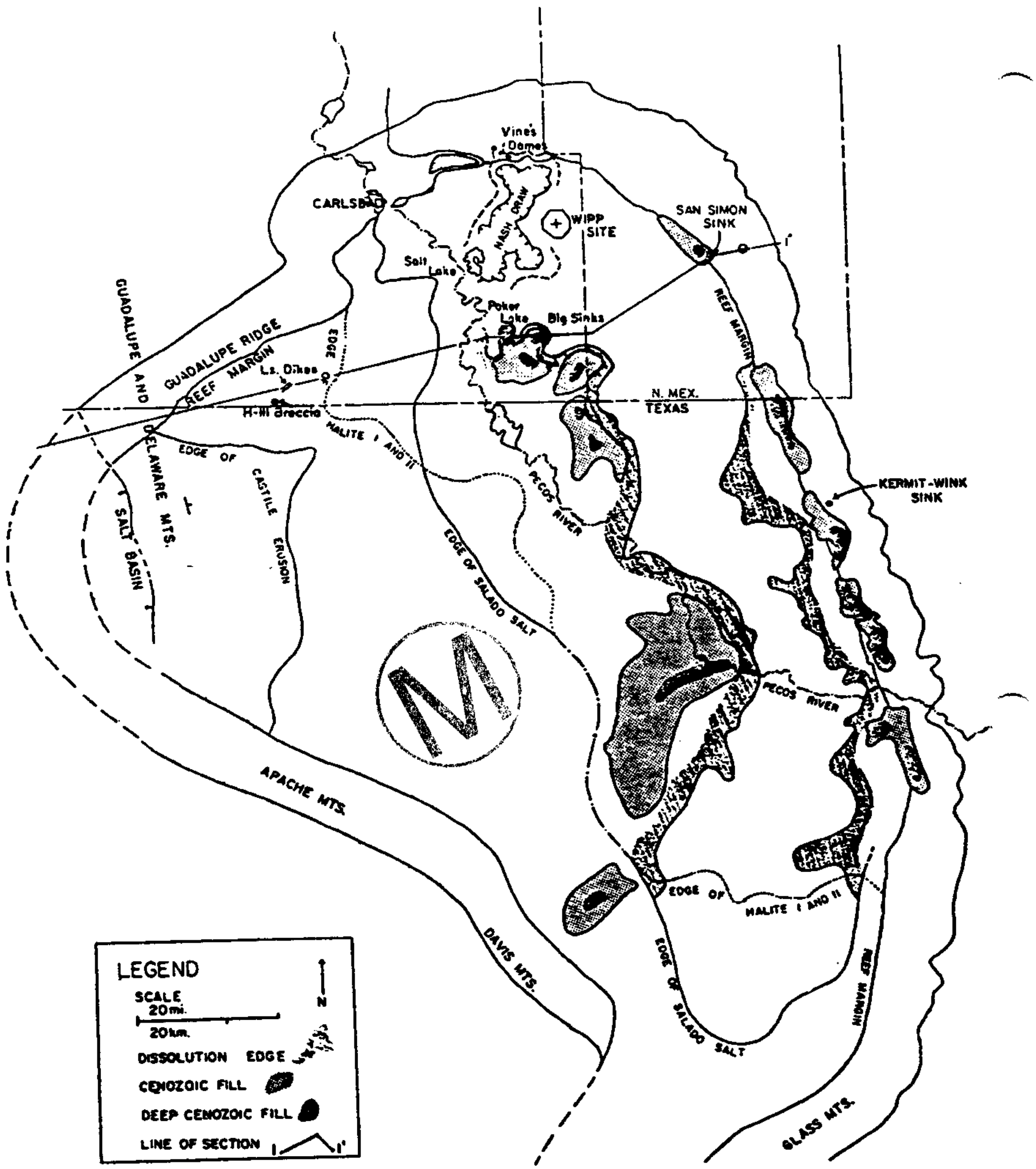

Figure 1. Map of Delaware Basin showing location of Capitan reef, major dissolution depressions, and western dissolution of evaporites and of major salt units (from Anderson, 1981)

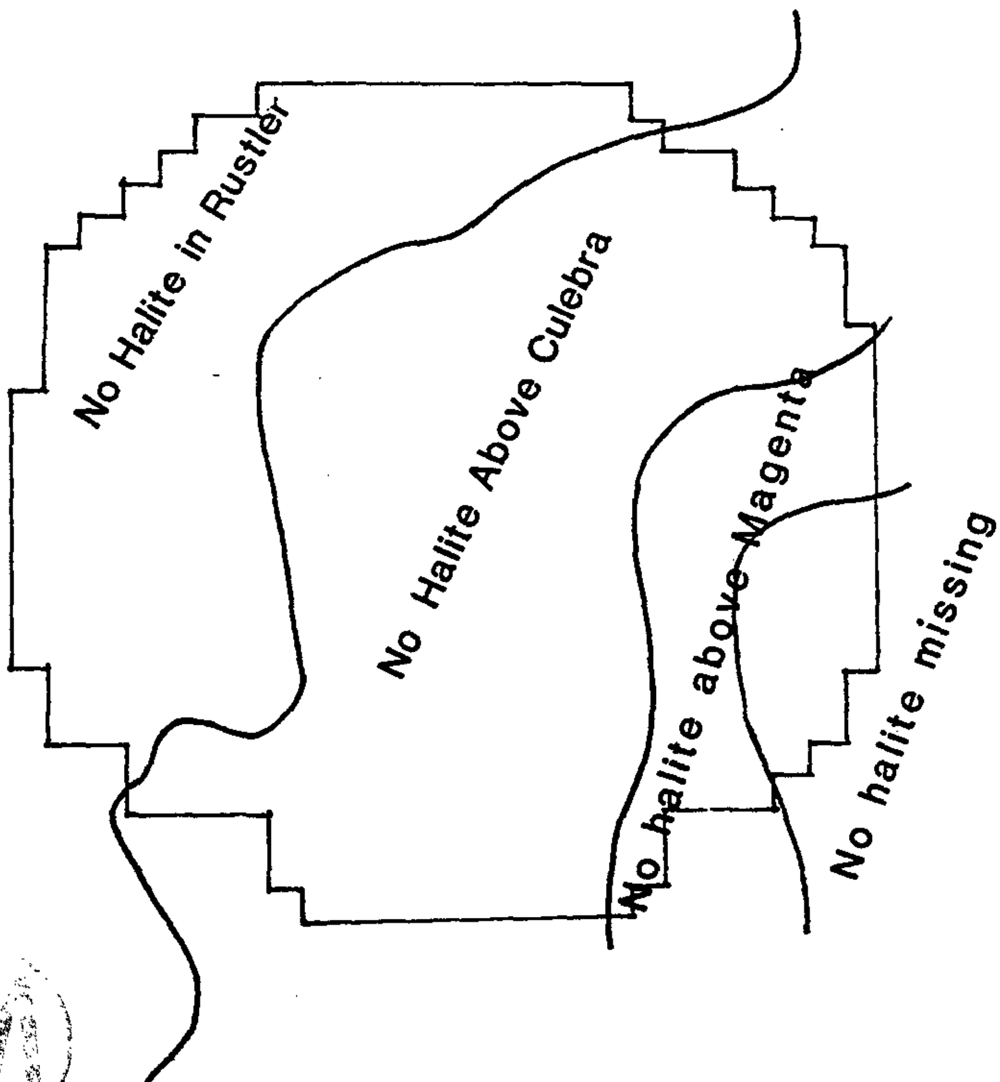

Figure 2. Extent of removal of salt from the Rustler formation at the WIPP site (Modified from Snyder, 1983)

Using the above rates for horizontal and vertical dissolution, it can be shown that it would take approximately 225,000 years for the front to travel approximately two miles to reach the western edge of the WIPP repository and would start dissolving salt from upper Salado, about 1500 feet above the repository horizon. It would then require at least 2 to 3 million years for the removal of 1500 feet of salt by dissolution, at the rate of 330 to 500 feet per million years. In spite of the very approximate nature of the estimated rates of advance of the dissolution front, and the possibility of a more rapid advance of a segment of the front, these calculated rates provide sufficient safety from an advancing front of blanket shallow dissolution of salt towards the WIPP site.

2.0 Deep Dissolution

The hypothesis of preferential removal of salt from the lower Salado and Castile formations has been called "Deep" dissolution. In attempting to correlate the varved evaporite sequence of the Castile formation and the overlying Salado, Anderson et al. (1972) concluded that large quantities of bedded salt were missing from the middle of the evaporite sequence near the center of the basin. Using the correlation of acoustic logs across several lines in the Delaware Basin, Anderson et al. (1978) concluded that (a) the preferred dissolution horizons from which salt has been removed by dissolution occur between the Halite III salt of the Castile formation and the 136 marker bed of the Salado formation, and (b) the large depressions in the basin, first identified by Malley and Huffington (1953), were the result of selective dissolution of lower Salado salt beds. Anderson (1981) further developed the idea of deep-seated dissolution and concluded that deep-seated dissolution has occurred around the margin of the basin where the Capitan aquifer is in contact with the Permian evaporites and within the basin where selective dissolution in the lower Salado has undercut the overlying salt beds. He calculated that more than 70% of the original salt has already been removed from the lower Salado horizon in the basin.

For the mechanics salt removal salt through the process of deep dissolution, Anderson (1981) invoked the "brine density flow" which had been proposed earlier (Anderson and Kirkland, 1980) for the formation of breccia pipes. This mechanism requires a connection between the lower Salado and the *underlying Delaware Mountain Group aquifer. It was hypothesized that this* aquifer supplies unsaturated water to the overlying evaporites through a fracture system and the brine produced after dissolution of the salt is also removed through this aquifer. Using the reported (Hiss, 1975) values of hydraulic conductivity of 0.0049 m/day and a chlorinity of 150 g/ℓ for the DMG aquifer, Anderson (1981) calculated that this aquifer, where it is in contact with the reef, can remove the volume of salt missing from the Salado in 1.5 million years.*

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*There appears to be a discrepency in Anderson's calculation here.

According to Anderson (1981), Figure 3, $[(10 - 49) + (13.9 - 3.8)] \times 10^{11}\ m^3 = 7.11 \times 10^{12}\ m^3$ of salt has been removed from lower Salado.

For hydraulic conductivity, K = 0.173 m/day (maximum measured value)
hydraulic gradient, i = 0.0025 m/m
Cl = 150 gms/liter = 247 g/ℓ of NaCl
= 247 kg/m^3 of NaCl

NaCl density ≈ 2.2 g/ml
= 2200 kg/m^3

Salt removal is $\frac{247\ kg/m^3}{2200\ kg/m^3} = 0.112\ m^3\ salt/m^3\ water$

If the thickness of the DMG aquifer is 100 m, the volumetric flux of water per one meter width of aquifer is

$Q = K.i.100$
$= 4.33 \times 10^{-2}\ m^3/d\text{-}m$
$= 15.8\ m^3/yr\text{-}m$

In 1.5×10^6 years, the flow is,
$15.8 \times 1.5 \times 10^6 = 2.37 \times 10^7\ m^3/m\text{-width}$

And the amount of salt removed is
$0.112 \times 2.37 \times 10^7 = 2.65 \times 10^6\ m^3\ salt/m - width$

In 1.5×10^6 years

Width of Flow	Volume of Salt Removed
50 km	$1.33 \times 10^{11}\ m^3$
100 km	$2.65 \times 10^{11}\ m^3$
150 km	$3.98 \times 10^{11}\ m^3$

Even with conservative assumptions, the volume of salt removed as calculated by EEG is 20 to 50 times less than that calculated by Anderson.

Wood et al (1982) conducted a detailed study of the potential of the DMG aquifer to remove the dissolved salt as hypothesized by Anderson (1981). They studied the potential dissolution mechanisms of diffusion and convection from the halite zones of Castile and Salado to the Bell Canyon (DMG) and the Capitan Reef aquifers, and reached the following conclusions.

- The diffusion and possibly very weak convection result in removal of halite from the Castile. Convection may be significant at locations adjacent to the Capitan Reef aquifer.

- Salt removal by the diffusion process would produce an advancement of the dissolution front of only 0.3 centimeter in 10,000 years.

EEG (1983, pp. 75-93) has questioned several assumptions and analyses contained in this study but has accepted the conclusion that the known properties of the DMG aquifer make it an unlikely pathway for supply and removal of water needed to carry out the dissolution at a massive scale as asserted by Anderson (1981).

Anderson (1982) countered that the interpretation of geophysical logs from hundreds of wells in the basin clearly shows that the upper Castile and lower Salado salt is missing under a large part of the basin and that it has been removed by dissolution during the Pleistocene time. If the DMG aquifer was not the pathway for the brine movement, then an alternate pathway must account for the missing salt. Anderson (1982) developed a case for the upper Anhydrite layer in the Castile formation as the conduit for the movement of unsaturated waters from west to east. The brine produced by such dissolution would escape through the Capitan Reef to the east. This mechanism is illustrated in Figure 3.

There are several unresolved questions in this postulated mechanism. Besides a very few isolated reports of minor quantities of water in the upper Castile, mainly near the Pecos river southwest of the WIPP site, the only liquid found in the Castile anhydrite is in the pressurized brine reservoirs. In spite of a large number of boreholes which have been drilled through the Castile, there is no indication of the existence of unsaturated water flowing through this zone. Therefore, the upper Castile is not an aquifer. Also, the two

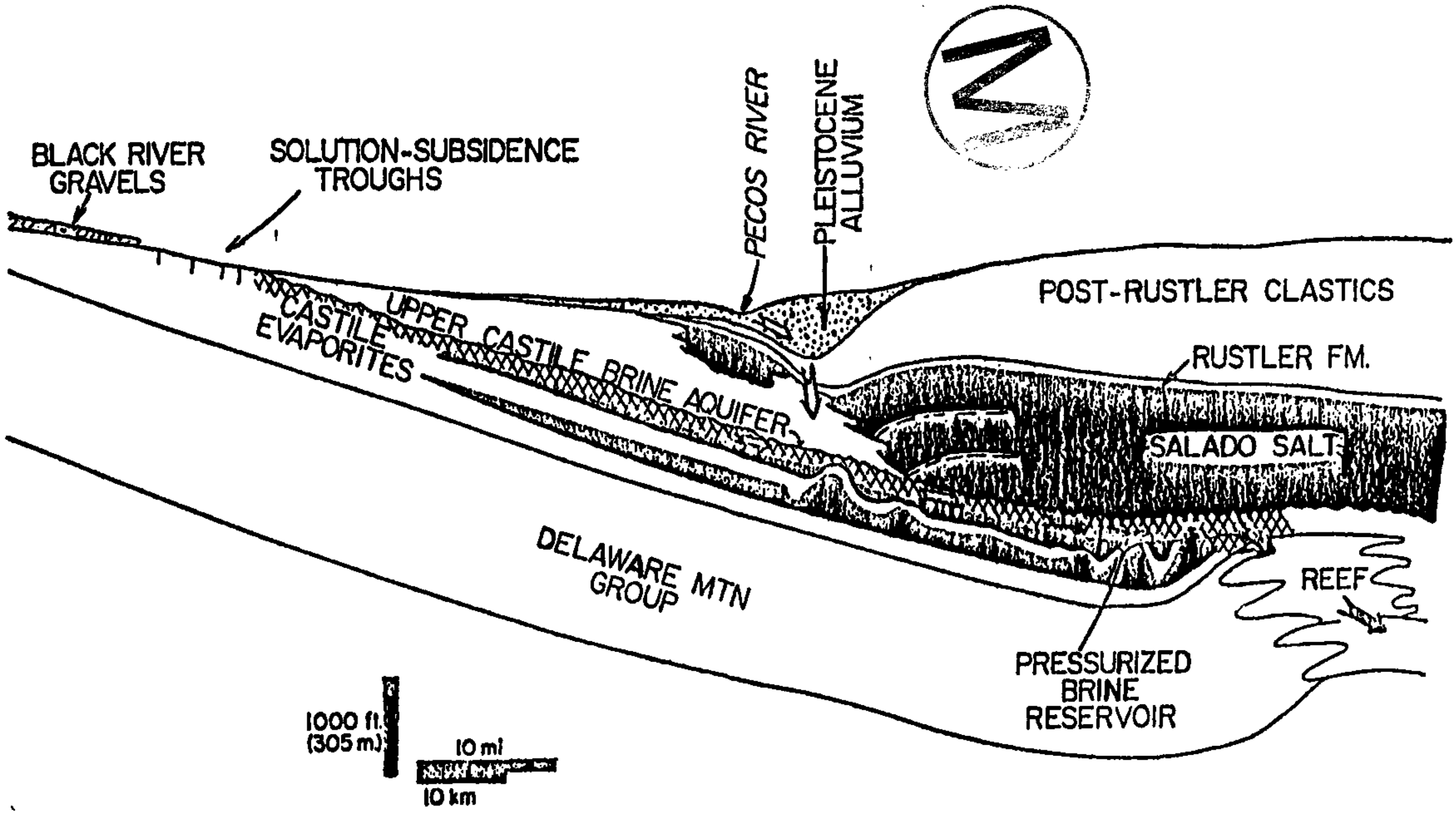

Figure 3. Diagrammatic cross section through the northern Delaware Basin, New Mexico, showing possible pathways of movement of water and brine drainage into and through upper Castile brine acquifer (from Anderson, 1982).

pressurized brine encounters which have been tested, display varied chemistry and pressures which suggests that the two encounters are not connected. Finally, the salinity of the Capitan Reef to the east is low indicating that if brines are being discharged into the Reef aquifer, the volume must be very small in comparison to the total volume of flowing water in the Reef.

It appeared in 1982 that the only way to address the question of deep dissolution was to reexamine the geophysical logs in the basin and provide alternate explanations, if any, for the missing salt. At EEG's suggestion, this work was done by Sandia National Laboratories. Lambert (1983) has drawn two isopach maps, one for the composite thickness of Anhydrite I, Halite I, Anhydrite II and Halite II of the Castile formation and another for the composite thickness of the Castile formation and the Salado formation beneath marker bed 136. These isopach maps are included here as Figures 4 and 5. Lambert (1983) has used these maps to argue that the total thickness of Castile anhydrite/halite paired units tend to remain the same throughout much of the Delaware Basin regardless of variations in thicknesses of individual halite or anhydrite beds; the observed variations in the individual beds are thus syndepositional or deformational, not dissolutional. Lambert (1983) finally concludes that there is no preferential removal of any salt horizon in the post-Permian time, aside from the dissolution in the Rustler and upper Salado.

EEG requested Anderson to comment on the Lambert (1983) work and its conclusions. In a report submitted to EEG in April 1983, Anderson (1983, a) claims that "(Lambert's) conclusions related to lower Salado dissolution are almost completely wrong." The main reason for the confusion, according to Anderson, is the lack of understanding of the nature of the boundary between the Castile and Salado formations. If one does not recognize the unconformity between the Castile and the Salado formations and thus ignores the episode of dissolution during the post-Castile/pre-Salado time, one is assuming the lower Salado and upper Castile to be a single unit. When this is done, the lateral thickness changes are compensated and evidence for later salt removal through dissolution disappears. Further, according to Anderson (1983, a), if the truncated relationships at the unconformity are recognized and used to establish a datum, the original facies variation is easily discriminated from later dissolution.

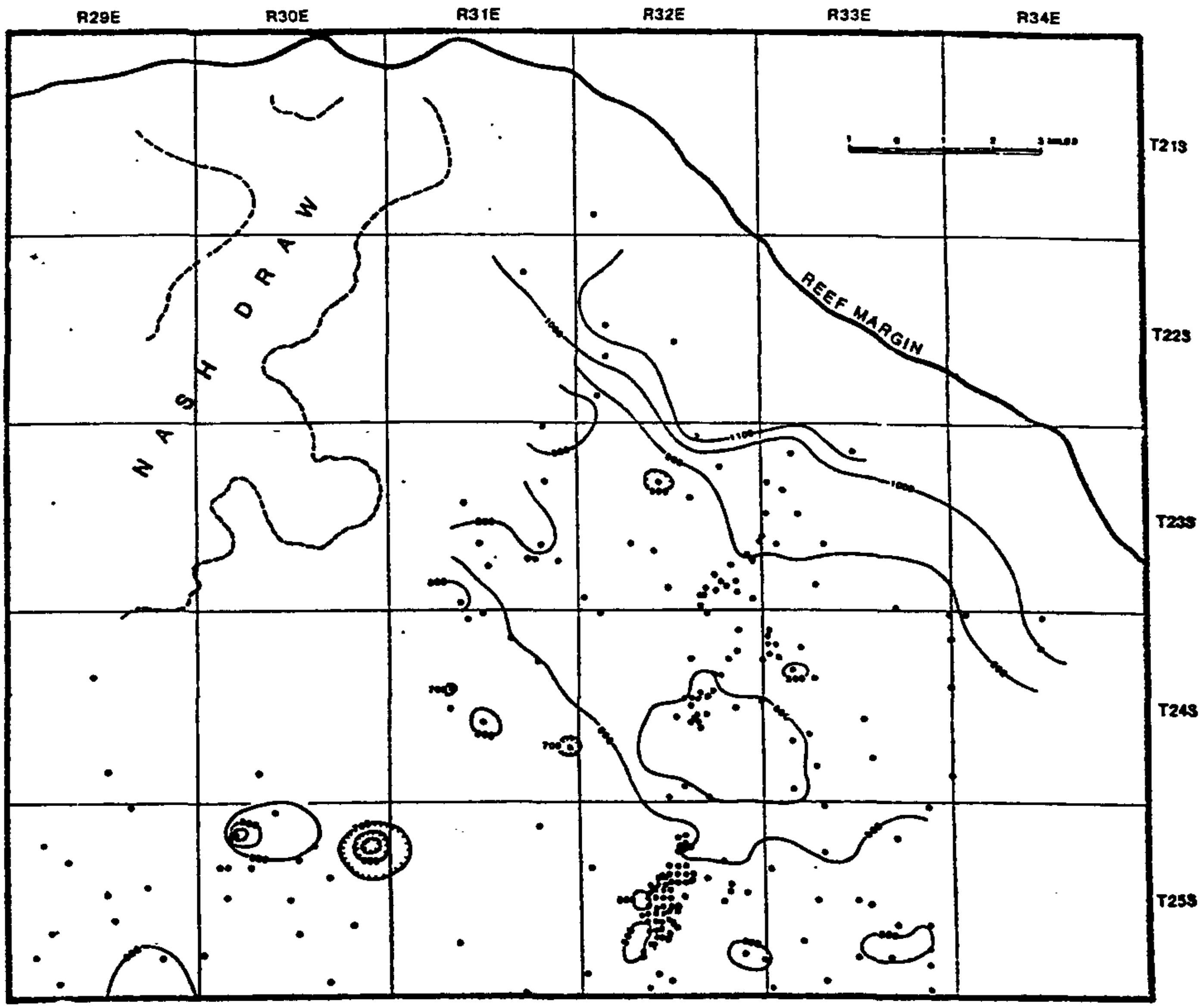

Figure 4. Isopach map of Anhydrite I, Halite I, Anhydrite II, and Halite II in the Castile Formation in the northern Delaware Basin (from Lambert, 1983)

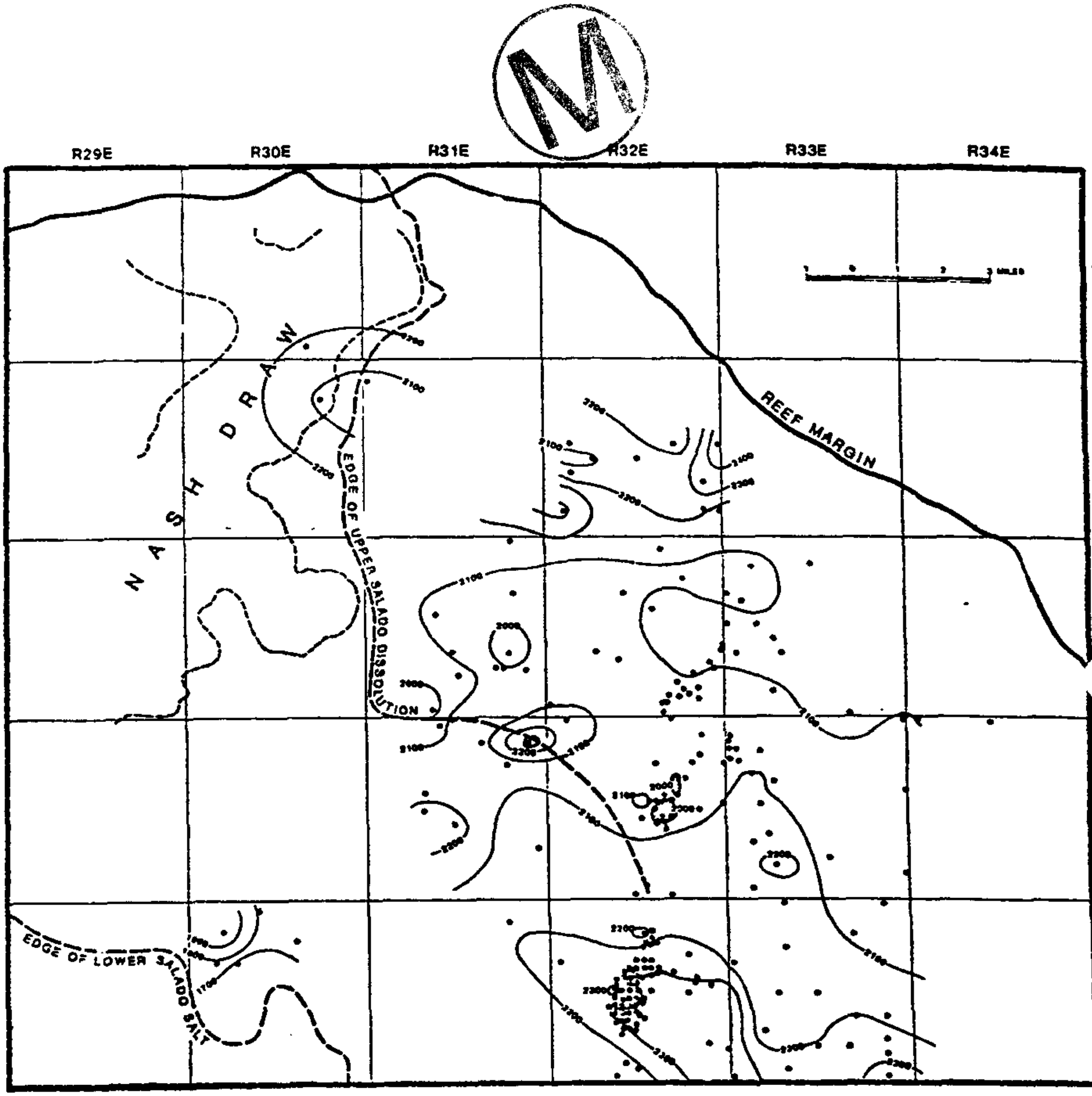

Figure 5. Isopach map of the Castile and lower Salado formation in the northern Delaware Basin (from Lambert, 1983)

In another report, Anderson (1983, b) has used a north-south cross-section in the eastern part of the basin to illustrate a one by one truncation of the salt beds in the upper Castile as one moves to the north. This line of truncation is the unconformity between the Castile and the Salado. Anderson (1983, b) has used this unconformity as an evidence for erosion and dissolution during the post-Castile/pre-Salado time. By using two other cross-sections, Anderson shows his evidence that the missing salt is in lower Salado and that the effects of facies change are separable from the effects of preferential removal of salt. By correlating the area of the bulk of the missing salt with the Malley and Huffington (1953) depressions, Anderson concludes that the dissolution occurred during the Pleistocene time since the fill in the upper part of the depressions is Gatuna, i.e. Pleistocene in age.

3.0 *Conclusions*

Roger Anderson has studied the Ochoan evaporite sequence in the Delaware Basin in great detail over a period of almost 20 years. He has advanced some very compelling evidence that a large amount of salt from the upper Castile and lower Salado units is missing, that the absence of salt follows a pattern which distinguishes it from facies changes within individual units and that the removal of salt is preferential, stratawise. The weakest argument in the Anderson hypothesis is the timing of deep dissolution. Since the assumption of timing of predominant dissolution as late Cenozoic is based on an assumed age of the Malley and Huffington (1953) depressions and the age of the basin uplift and tilting, there is room for different interpretations of the timing of deep dissolution.

On the other hand, the argument against the removal of salt, by assuming that any absence of salt is due to facies change, is not convincing. It is true that there does not seem to be a viable mechanism for preferential removal of salt at depth during geologically recent time or for this to be an active process. However, the lack of understanding of a mechanism should not be a reason to ignore the evidence for a phenomenon. EEG, therefore, accepts the existence of deep-seated dissolution as a strong hypothesis to explain the missing salt at depth.

Figure 1 shows the deep dissolution edges for the salt units, as interpreted by Anderson (1981). It should be noted that the WIPP site is situated in the northern part of the basin, away from the dissolution fronts, in a region where deep dissolution has not yet reached. The nearest point of the dissolution edge from the WIPP site is about 15 miles away. It would seem ironic to worry about the "deep dissolution" front when the front of shallow "blanket dissolution" lies only 2-3 miles west of the site and is known to be moving towards the WIPP site. The reason for this ironic concern is, of course, the lack of understanding of the deep dissolution process. According to Anderson, the basin has reached an advanced stage of dissolution and should, therefore, be rejected for nuclear waste disposal, as a whole. The EEG does not subscribe to this point of view.

There are five boreholes at the WIPP site (WIPP-9, 11, 12, 13 and DOE-1) which have penetrated the lowermost anhydrite bed (Anhydrite-I) in the Castile formation. These holes have been cored at selected intervals and geophysical logs for the entire depths have been obtained. In addition three holes outside the WIPP boundary, AEC-7 and 8 to the northeast and ERDA-10 to the southwest were drilled, cored and logged through the Castile formation. None of these seven boreholes (Fig. 6), not to mention several industry boreholes around the WIPP site, show any evidence of extensive dissolution. This points to the fact that at least the immediate area surrounding the WIPP site has not been affected by deep dissolution and is not expected to be affected in the immediate geologic future.

Anderson (1983) has pointed out two features, one on and the other near the WIPP site, which may indicate the possibility of point source dissolution. One of these is the encounter of the lower Salado marker beds e.g. MB 124, 75 feet below their expected level in an industry potash hole (F-92) 2 miles north of the center of the site. According to Davies (1983), this anomaly extends to the well WIPP-34. WIPP-14 was drilled to explore this area but was located 0.6 mile to the east of F-92 on the basis of a marked low in the gravity data which coincided with a seismic anomaly as well as a topographic low. WIPP-14 found the beds in Rustler and upper Salado essentially at the expected depths and did not find any evidence of brecciation or dissolution. However, it was drilled only 50 feet into the Salado and did not encounter any marker beds in the Salado. The other feature is five miles southeast of the center of the WIPP site. The acoustic log of the Perry Federal # 1-31 well in that area (Sec. 31, T22S, R32E) shows, according to Anderson, that 200 feet of infracowden salt is missing.

In EEG's view, a single hole anomaly out of hundreds of wells drilled through the Salado horizon in the northern Delaware Basin, especially when it is *outside the WIPP repository area, may not be very significant. The safety of* the WIPP site from deep dissolution can be assured on the basis of the deep dissolution fronts (Fig. 1) being a safe distance away from WIPP and on the results of excavations at the repository horizon already completed under the SPDV program. The 9000 ft. of drifts already completed include a one-mile north-south drift (12 feet high and 25 ft. wide), another north-south drift (1840 ft. long, 8 ft. high and 25 ft. wide), six east-west drifts (each 140 ft. long, 8 ft. high and 25 ft. wide) and four rooms (each 13 ft. high, 33 ft. wide and 300 ft. long). The thickness and continuity of strata displayed in all this excavation is dramatically uniform, and there is no evidence for dissolution at the repository horizon as seen in SPDV excavations.

The only remaining anomaly within the WIPP site is the depression of lower Salado marker beds in the well F-92. Anderson (1983) and Davies (1983) propose that this feature may have resulted from point source dissolution at depth.

4.0 Recommendations

The Department of Energy should evaluate the depression exhibited by the stucture contours on lower Salado marker beds, centered two miles north of the center of the site and should first attempt to provide a reasonable explanation for this feature. If the possibility of lower Salado dissolution causing this feature cannot be eliminated, then a drill hole should be drilled through the entire Salado and selected horizons cored to investigate the cause for this anomaly. *The feature appears to be confined to F-92 and WIPP-34 area* and WIPP-14 is outside of it. Therefore, a deepening of WIPP-14 will not answer the question.

R. Y. Anderson made four other recommendations at the May 12 and 13 meeting in Carlsbad, viz., core Slick Sink, core one of the Maley and Huffington depression, core a deep dissolution margin and investigate the regional hydrology of deep dissolution. EEG has examined these suggestions carefully and has determined that in view of our acceptance of the possibility of deep dissolution in the Basin, away from the WIPP site, it is not necessary to further prove or disprove the hypothesis. Only the feature, close to the repository, which may indicate a point source deep dissolution, should be investigated.

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BRECCIA PIPES

1.0 Definition

Breccia pipes are vertical chimneys of brecciated rock which extend through several layers of intact rock strata to root in a collapsed cavity. These features are found in many evaporite basins of the world. The diameter of a breccia pipe is generally less than 1000 feet.

2.0 Confirmed Breccia Pipes

Vine (1960) identified several domal structures in the Delaware Basin which have been explored during the investigations for WIPP, as possible breccia pipes. After extensive investigation, the existence of only two pipes (Hills A and C) has been confirmed. Geophysical and geological studies show that two others (Hills B and Wills-Weaver) are also most likely breccia pipes, although they have not been cored. All four of these features appear to be situated over the Capitan Reef limestone, which is a prolific aquifer in the area. These four features as well as other features, previously suspected to be breccia pipes in the Basin, are shown in Fig. 6. Davies (1983) has pointed out that the Hill 'C' breccia pipe is located at the southern edge of the buried Capitan Reef and since the borehole (WIPP-16), drilled to explore this pipe, was drilled only to the level of the McNutt Potash Zone of the Salado formation, it is not clear whether the Hill 'C' breccia pipe roots in the Capitan aquifer. This is a valid argument, but although it is true that the borehole WIPP-16 was not drilled deep enough to answer this question unequivocally, the feature being at the edge of the reef is sufficient cause to believe that the Capitan Reef aquifer is responsible in the creation of this feature.

3.0 Suspected Breccia Pipes

Besides boreholes WIPP-31 and WIPP-16 which were drilled at hills A and C respectively to investigate the breccia pipes, three other boreholes were drilled at suspected breccia pipe locations in the Basin. Borehole

WIPP-32, 12 miles west of the center of the WIPP site, was drilled in a small topographic high which had been described by Vine (1963) as a domal karst feature. These features (domal karst) have been extensively studied by Bachman (1982). The boreholes WIPP-13 and WIPP-33 were also drilled to explore the presence of possible breccia pipes. There was a marked electrical resistivity anomaly at WIPP-13 and a prominent topographic depression exists at the location where WIPP-33 was drilled. Collapsed breccia was not found at either of the wells.

Anderson and Kirkland (1980) have described the occurrence of collapse breccia in a borehole in Culberson County, Texas, about 55 miles south of the WIPP site (see Fig. 6). Anderson (in Chaturvedi, 1980) has described occurrences of "Castiles" which are mounds of brecciated rock that outcrop a few miles south of the New Mexico-Texas border, south of the WIPP site. Both these occurrences are in the exhumed western part of the Delaware Basin which has already undergone extensive dissolution. These are not "active" features.

4.0 Mechanics and Time of Formation

Snyder and Gard (1982) have studied the known occurrences of breccia pipes. The one studied in most detail is the Hill 'C' breccia pipe which is also encountered at the McNutt Potash Zone of the Salado formation in the Mississippi Chemical Company potash mine, 1200 feet below the surface. From the study of this exposure, the core of WIPP-16 drilled in this pipe and the core of WIPP-31 drilled in the Hill 'A' breccia pipe, Snyder and Gard (1982) have concluded that the breccia pipes are formed due to the collapse of overlying rocks in solution cavities in the Capitan Reef aquifer. This appears to be a reasonable explanation. Bachman (1980) has hypothesized that the location of all the known breccia pipes in a small area over the reef is due to the presence of an old submarine canyon in the reef in this area. On the basis of the presence of Mescalero Caliche over the breccia pipes, Bachman (1980) also concluded that the collapse occurred prior to the deposition of this caliche layer, i.e., more than 500,000 years ago.

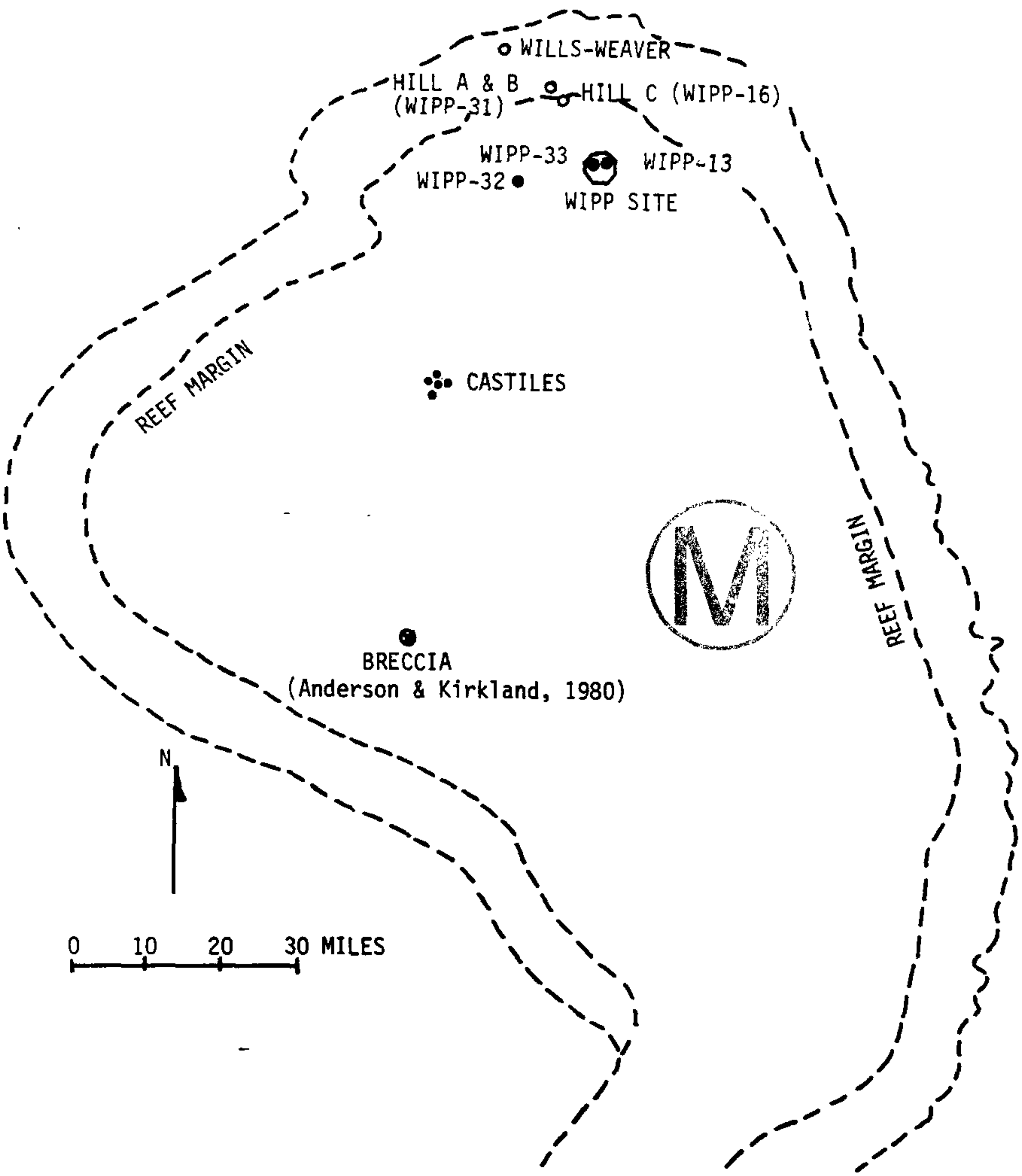

Figure 6. Map of the Delaware Basin showing features related to the Breccia Pipe issue.

5.0 EEG Conclusions

After considering all the available evidence on this question, EEG has concluded that the breccia pipes, by themselves, do not pose a threat to the WIPP repository. This conclusion is based on the following observations.

After extensive investigation in the Delaware Basin area, the existence of only two pipes (Hills A and C) has been confirmed. Geophysical and geological studies show that two others (Hill B and Wills-Weaver) are also most likely breccia pipes, although they have not been cored. All these pipes are located over the Capitan Reef limestone, which is a prolific aquifer in the area. The exhumed breccia pipes in the basin, e.g. the Castiles, are not actively developing.

Extensive potash mining operations in the Delaware Basin have encountered only one breccia pipe (Hill C) in the subsurface, and it also is most likely located over the Reef; although due to the lack of sufficient borehole control around Hill C, its location over the reef is not confirmed.

Several features in the Delaware Basin (Vine's Domes--Vine, 1960) are clearly the result of either near-surface dissolution or surficial erosion (Karst domes or mounds--Bachman, 1980).

Three holes (WIPP-13 and 32 and 33) were specifically drilled to explore suspected breccia pipes in the basin but did not encounter brecciated strata in the subsurface.

The explanation (Bachman, 1980) that the known breccia pipes were formed in the area near an old submarine canyon in the Capitan Reef, about 500,000 years ago, seems to be a reasonable explanation for the formation of breccia pipes.

- EEG has calculated the effect of a hypothetical breccia pipe developing under the repository and has concluded that the radiological impact of such a feature returning radioactive materials to the biosphere would be insignificant (Spiegler, 1982).

The question of breccia pipe formation representing deep dissolution through brine density flow (Anderson and Kirkland, 1980) is discussed in the section on Deep Dissolution.

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BRINE RESERVOIRS

1.0 Introduction

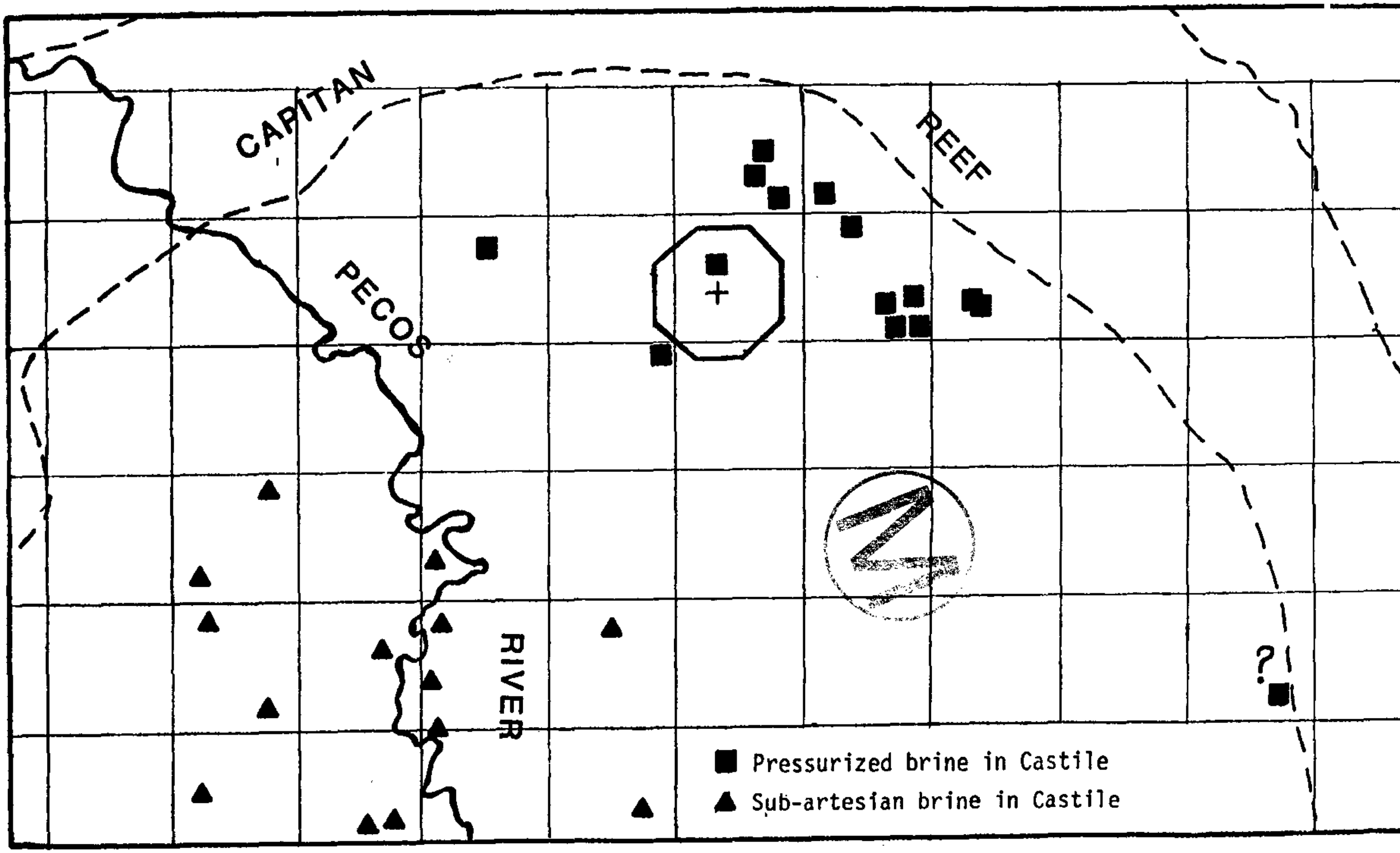
Within a few miles of the WIPP site there have been thirteen reported brine encounters during drilling in the upper anhydrite layer of the Castile Formation with sufficient pressure to produce significant flow at the land surface (Figures 7 and 8). Additionally, Snyder (1983) documents brine occurrences in the upper anhydrite layer of the Castile formation without sufficient pressure to produce a significant surface brine flow. These nonflowing artesian brines (labeled as sub-artesian on Figure 7) are generally concentrated along and west of the Pecos River; however, a few scattered occurrences are reported east of the Pecos River. The flowing artesian brines are of most concern and will be discussed in detail.

During the characterization of the WIPP site, two wells encountered pressurized artesian brine which flowed to the surface at test holes ERDA-6 and WIPP-12 (Figure 8). At EEG's insistence, DOE has tested both encounters to obtain hydrological and geochemical data (D'Appolonia, 1982). Both DOE and EEG have independently analyzed these data. DOE has reported its findings in Popielak, et al. (1983) while EEG has reported its findings in Spiegler (1982), Spiegler (1983) and Faith et al. (1983). Although the studies of these two encounters undoubtedly have improved the scientific understanding of such phenomenon, conclusions drawn from the ERDA-6 and WIPP-12 testing are applicable to only those two encounters.

2.0 Occurrence

From Figure 7, it appears that the brine encounters in boreholes do not occur randomly. Two large groups of encounters are observed northeast and east of the WIPP site. The location of these two groups appears to indicate a relationship between the pressurized brines and the Capitan Reef. The WIPP-12, Belco, and Danford encounters are isolated and away from the Reef. Although non-random, the occurrences do not follow a consistent pattern.

In each borehole that encountered pressurized brine, the brine was located in the upper anhydrite of the Castile Formation, generally anhydrite III. The


CAPITAN
REEF
PECOS
RIVER
?
Pressurized brine in Castile
Sub-artesian brine in Castile

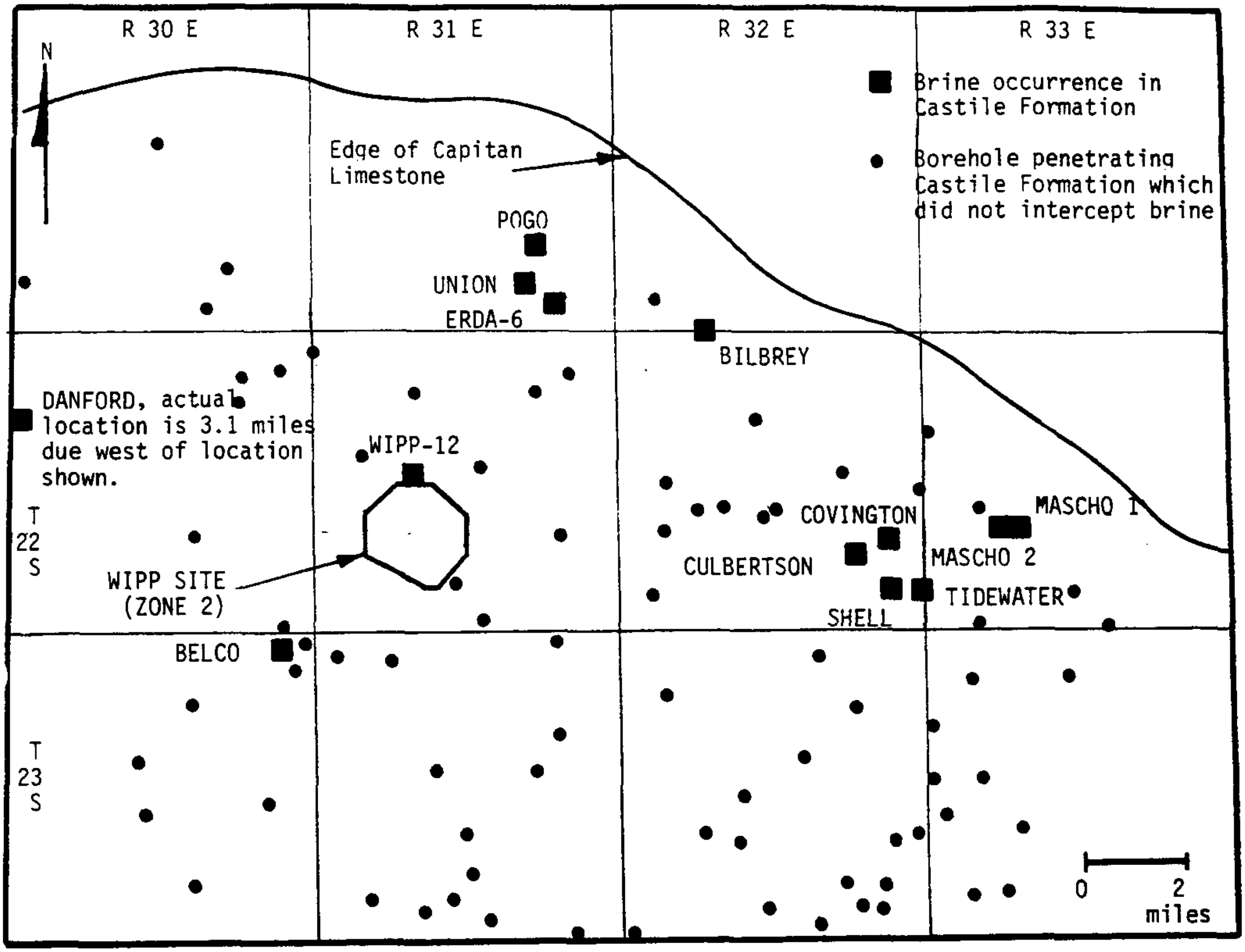


Figure 8. Location of brine encounters and deep boreholes penetrating the Castile Formation. Figure obtained from reference 1.

occurrence appears to be associated with structural features in the Castile. However, every drill hole into a structure has not encountered brine. The general consensus is that the brines occur within the fractured upper Castile anhydrite in areas of structural deformation.

3.0 Hydraulics

Extensive drill stem and flow testing of both ERDA-6 and WIPP-12 have yielded data on the permeability of the two reservoirs. In both wells heterogeneity of permeability was observed. Short tests produced high flows of brine and associated high permeabilities. The longer flow tests were characterized by smaller flows and smaller permeabilities.

The representative calculated permeabilities (Popielak et al, 1983; Spiegler, 1982) for the short and long tests in ERDA-6 and WIPP-12 are listed below.

	Long tests	Short tests
ERDA-6	1 - 3 md	10 - 13 md
WIPP-12	6 - 17 md	2000 - 5000 md

In each well, the brine was produced from fractures. Therefore, the calculated permeabilities based on porous media radial flow theory are rough approximations. In addition, the permeabilities were calculated from the permeability - thickness product, where the thickness was not the length of a fracture encountered, but rather the interval isolated by the packers. Although approximate, the data clearly indicate the greater permeability associated with the WIPP-12 encounter.

The hydraulic testing showed that the high initial flows from the two tested reservoirs are sustained for only a short time.

The wellhead pressures on March 19, 1983, at ERDA-6 and WIPP-12 were 552 and 162 psig, respectively. These pressures correspond to a column of brine extending above the wellhead for 1047 ft. and 307 ft., for ERDA-6 and WIPP-12, respectively.

4.0 Size

DOE (Popielak, et al., 1983) estimates the representative volumes of the ERDA-6 and WIPP-12 brines as 630,000 bbl and 17 x 10^6 bbl, respectively. Based on preliminary data EEG estimated the volumes to be between 60,000 bbl and 120,000 bbl for ERDA-6 and between 5 x 10^6 bbl and 10 x 10^6 bbl for WIPP-12 (Spiegler, 1982). Using the most recent data provided by DOE, EEG calculates the ERDA-6 brine volume to be between 170,000 bbl and 340,000 bbl. The WIPP-12 volume remains unchanged.

The volume is calculated by

$$V = \frac{\Delta V}{\Delta P \, C_t} = \frac{\Delta V}{\Delta P \, (\phi K)^{-1}}$$

where ΔV = volume of fluid discharged

ΔP = reservoir pressure depletion

C_t = total system compressibility which in most situations can be approximated by the pore-volume compressibility

$(\phi K)^{-1}$ = inverse porosity-rock bulk modulus product; used by DOE to calculate the pore-volume compressibility

The smaller EEG estimate for the ERDA-6 volume is due to the assumption of a larger compressibility. Compressibility will be discussed later. The smaller EEG estimate of the WIPP-12 volume is due to EEG's utilization of a subset of the WIPP-12 data and a larger compressibility. The volume discharged and pressure depletion used by EEG were those as of January, 1982 whereas DOE uses the data through March, 1983. Since the WIPP-12 brine encounter is closer to the site, larger in volume, and has a larger permeability than the ERDA-6 encounter, subsequent discussion will concentrate on WIPP-12.

The compressibilities used by both EEG and DOE are largely crude estimates. Figure 9 depicts the variation in DOE's calculated reservoir volume as a function of porosity (ϕ) and rock bulk modulus (K), where $C_t = (\phi K)^{-1}$. The representative volume presented by DOE falls near the center of the regions.

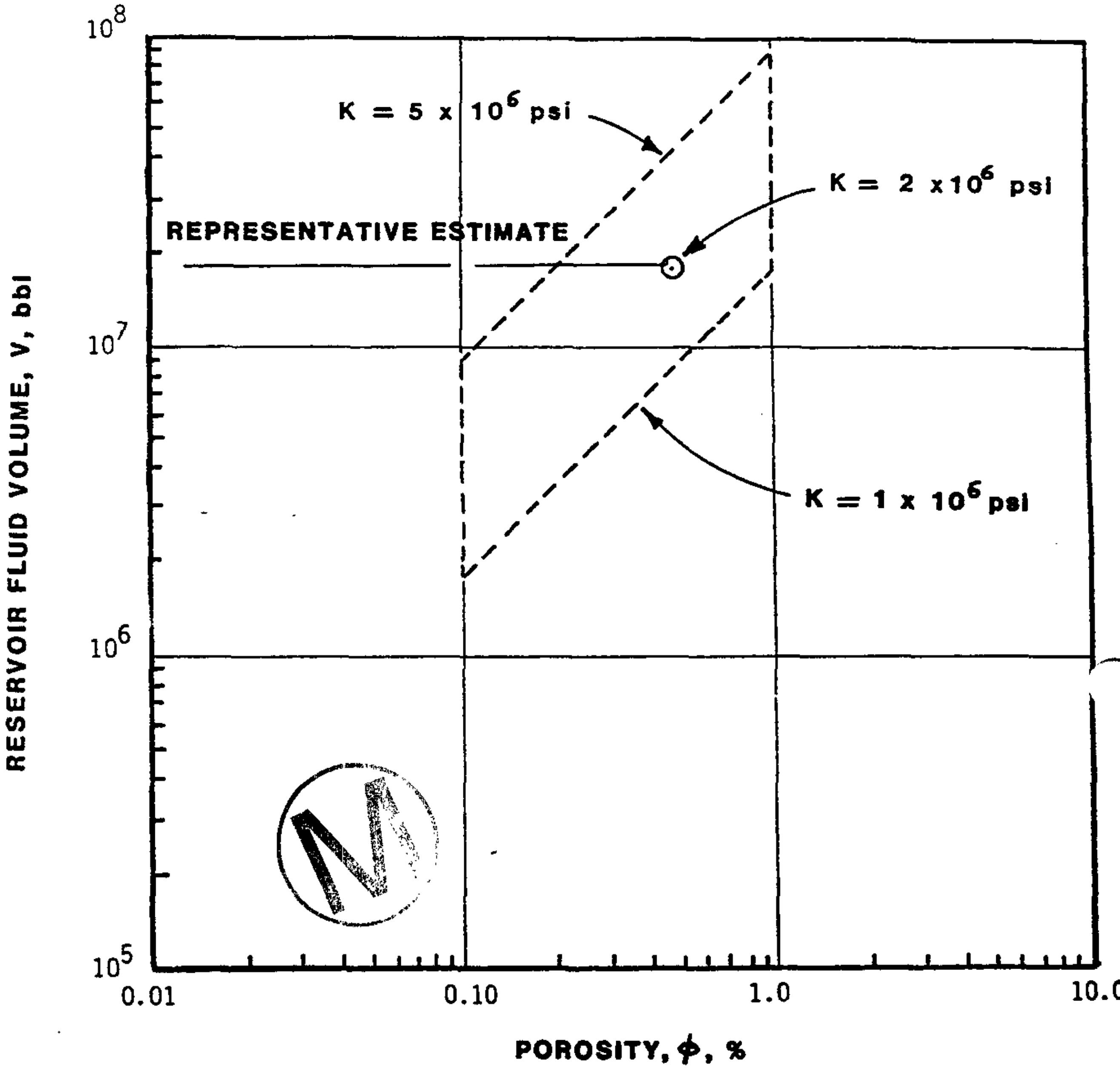


Figure 9. Total reservoir fluid volume WIPP-12
(from Popielak et al., 1983)

EEG has adopted the larger DOE estimates as reasonable, recognizing the approximate nature of the volume estimates.

Given an estimate of the brine volume, albeit a rough one, the next logical step is to estimate an area over which the brine is contained. The area is obtained from Popielak, et al. (1983), as,

$$A = \frac{V}{H\phi} = \frac{\Delta V \phi K}{\Delta P H \phi}$$

where A = area

V = volume of brine

H = thickness of anhydrite that contains brine

ϕ = porosity

It is interesting to note that because the total compressibility (C_t) is calculated as the porosity - rock bulk modulus product, the calculated area is independent of porosity. The only variable in the area calculation is the thickness of anhydrite that contains brine. The area of the WIPP-12 brine as a function of thickness and rock bulk modulus is presented in Figures 10.

Figure 11 is a map of the WIPP site showing the area of the WIPP-12 brine assuming the bulk modulus K = 2 x 10^6 psi for various reservoir thicknesses. Also included on Figure 11 is the seismic time structure on the middle of the Castile. The calculated areas for WIPP-12 all extend well beyond the limits of the apparent domal structure.

In summary it is apparent that any volume or areal extent estimate for the brine encounters is of limited accuracy. However, these estimates indicate that the WIPP-12 brine could extend beneath the repository.

5.0 Geochemical Data

Extensive chemical analyses (D'Appolonia, 1982) have produced a wealth of data. In addition to major and minor element chemical determinations, trace and isotopic chemical analyses were performed.

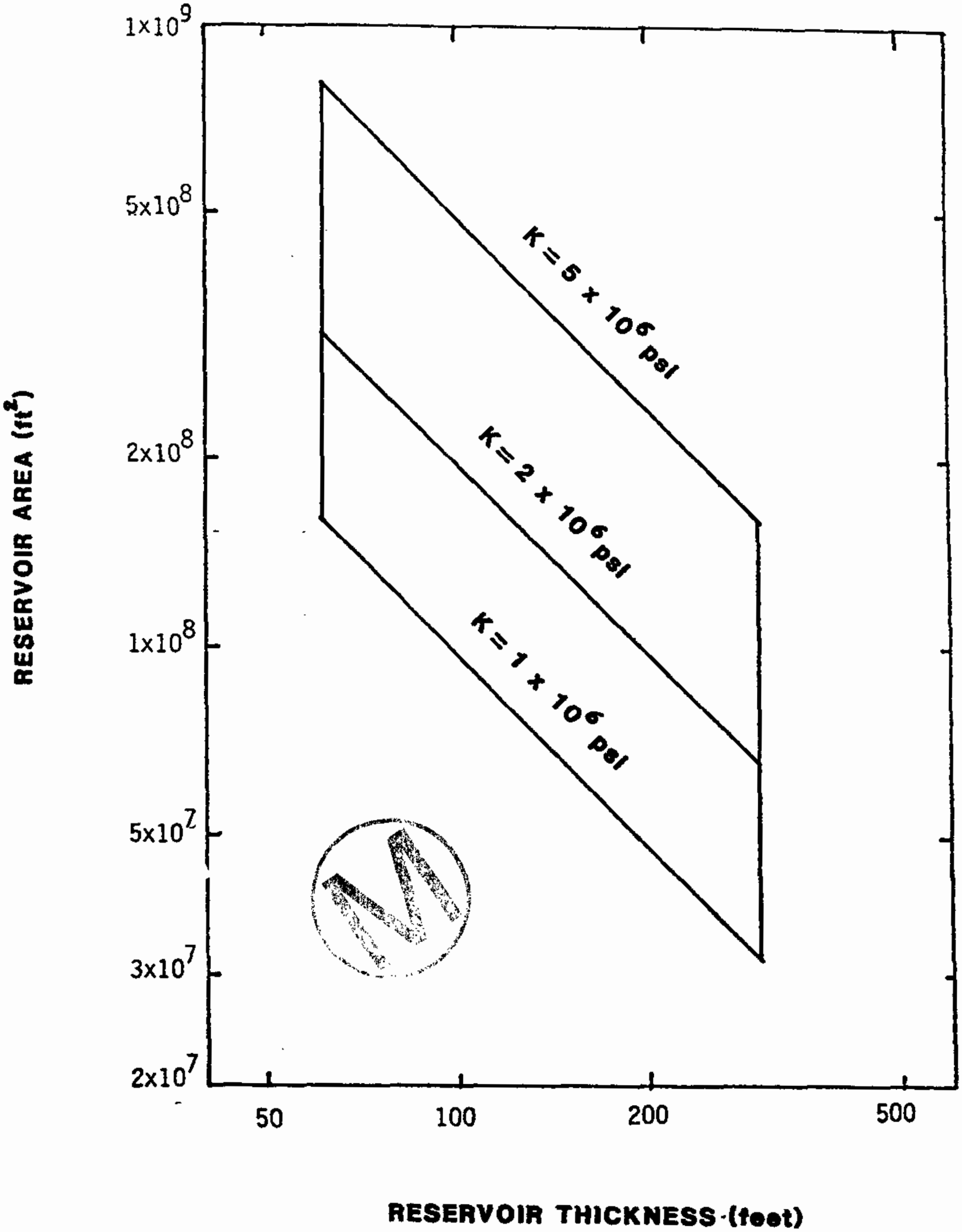


Figure 10. Reservoir area for the WIPP-12 brine as a function of reservoir thickness and rock bulk modulus.

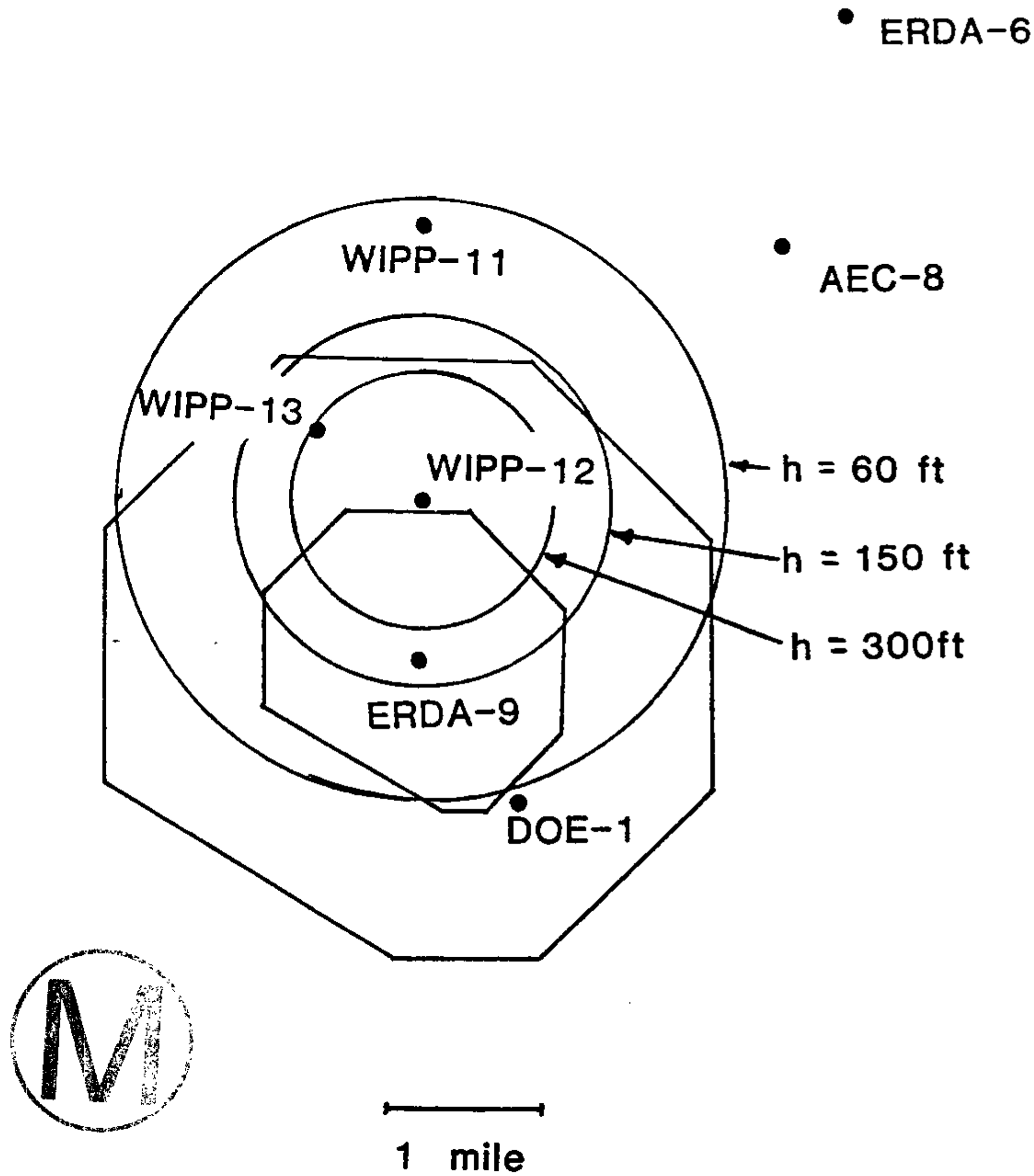


Figure 11. Aereal extent of the brines assuming a circle centered at the borehole for various reservoir thicknesses, $K = 2x10^6$ psi.

Interpretation of the major and minor element chemical data by EEG (Faith, et al., 1983) has led to the following conclusions.

- Small, yet statistically significant differences in the chemistry of the ERDA-6 and WIPP-12 brines are evident.

- Within the accuracy of thermodynamic equilibrium modeling, the ERDA-6 and WIPP-12 brines are saturated with calcite, anhydrite, glauberite and dolomite. The ERDA-6 brine is slightly undersaturated with halite and the WIPP-12 brine is nearly saturated with halite. The potential for dissolving additional halite or anhydrite is considered to be minimal.

- The relationship between the bromide content and the total dissolved solids in the brines indicates the brines are attributable to seawater evaporation and additional halite dissolution. The source of water for the halite dissolution is unclear.

The ERDA-6 and WIPP-12 brines appear to be nearly saturated with halite, therefore, the need to determine the original mechanism of halite dissolution may be of academic interest only. Suggested mechanisms for additional halite dissolution include: (1) dehydration of gypsum at depth, (2) introduction of meteorically derived water during Permian exposure, (3) mixing of groundwater from the underlying Bell Canyon aquifer with subsequent isolation by recrystallization or healing of fracture pathways, and (4) combinations of the above.

Interpretation of the isotopic data by EEG (Spiegler and Updegraff, 1983; Faith, et al., 1983) suggests the following conclusions:

- Many of the stable isotope fractionations indicate equilibrium. However, the calcite water fractionation, which does not indicate equilibrium, suggests that the water was not enriched in 18-oxygen by exchange with carbonates of the Castile formation. The fractionation of carbon between dolomite and calcite for WIPP-12 suggests that the dolomite and calcite are not cogenetic in the sense of having been precipitated from the same solution under the same conditions.

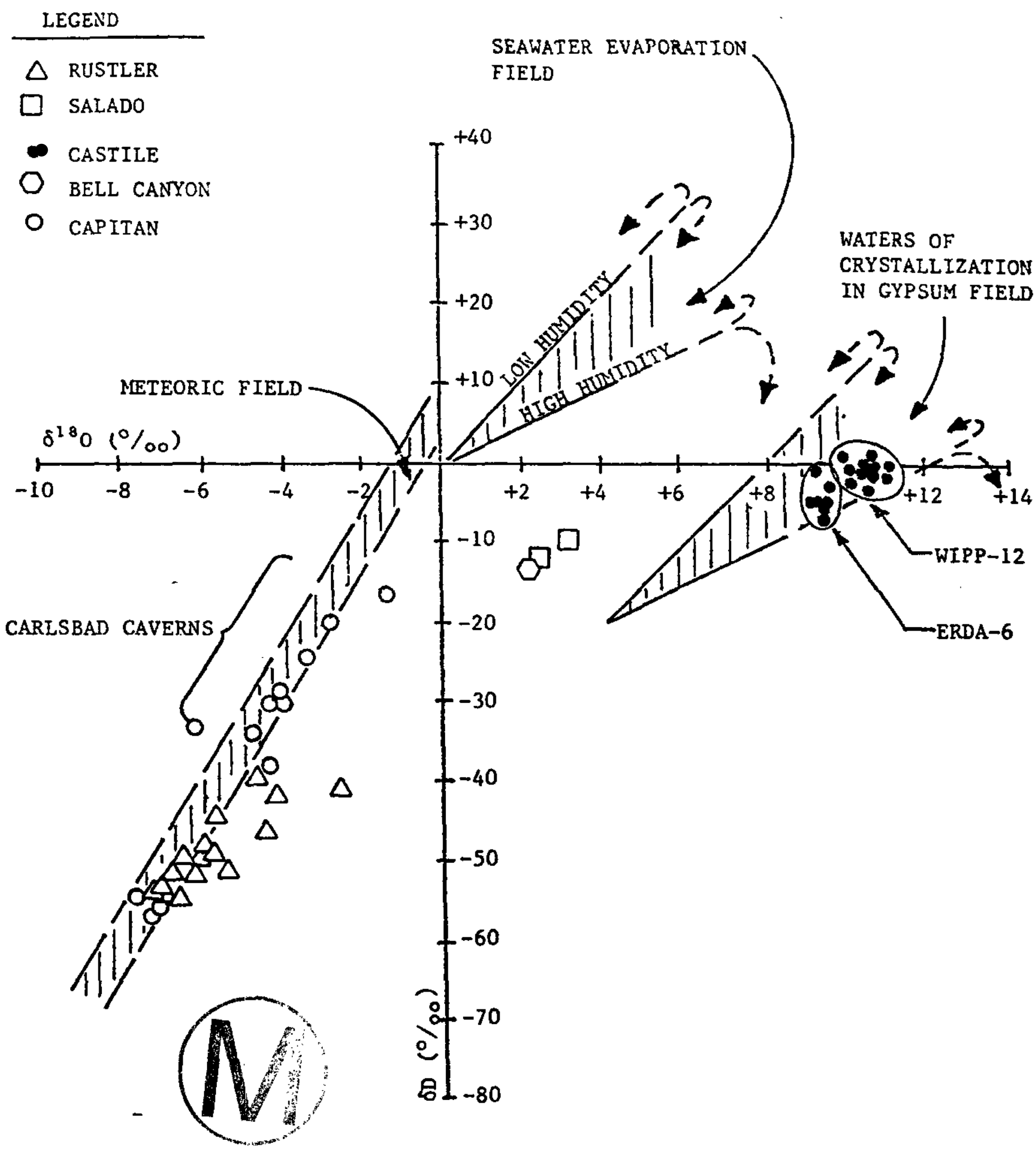


Figure 12. Isotopic compositions of the water/brine from the Delaware Basin (Spiegler and Updegraff, 1983)

- The oxygen-18 and deuterium concentration of the brines is unique compared to water in other nearby aquifers (Figure 12). A variety of source waters and isotope alteration pathways were considered. The hypotheses that the brines could have originated from waters of the Bell Canyon Formation or Capitan Reef in recent geologic time did not seem plausible. The ERDA-6 and WIPP-12 brines were probably derived from ancient ocean waters that have been isotopically enriched in oxygen-18 by exchange interaction with rock. The dehydration of gypsum as a process of brine origin cannot be ruled out.

- Analyses of uranium disequilibrium data yield only general conclusions. The ^{234}U in the ERDA-6 and WIPP-12 brines is not in secular equilibrium with ^{238}U. The disequilibrium probably results from the preferential leaching of ^{234}U from fractures in anhydrite. This leaching may be an ongoing process. Neither the true age of the brine, nor the age of fracturing is determinable with any degree of confidence.

6.0 Interconnection of Brine Occurrences

Based on the following evidence, the WIPP-12 and ERDA-6 brine occurrences are not likely to be connected to each other.

- The pressure potentials of the two encounters are significantly different. However, this in itself does not constitute proof of separation as pressure potential differences within reservoirs is an indication of fluid movement.

- The calculated areas, albeit approximate, for WIPP-12 and ERDA-6 do not overlap.

- The geochemical data suggest a lack of communication between the ERDA-6 and WIPP-12 reservoirs.

The lack of communication between the ERDA-6 and WIPP-12 brines does not imply that all brine encounters represent isolated brine pockets.

7.0 Origin of Brine

The tests performed on the brines of ERDA-6 and WIPP-12, which include hydrological tests, major and minor element chemistry analyses, isotope geochemical analyses, uranium disequilibrium measurements, and helium concentration in gases of brines, have yielded data which allow a discussion of the following possibilities of the origin.

Ancient seawater. Major and minor element geochemical data and stable isotope data favor this hypothesis.

Delaware Mountain Group aquifer water. Not likely because of geochemical and stable isotope data.

Capitan Reef water. Still implicated when estimating the age of brines using uranium disequilibrium data. Also implicated by proximity to a majority of brine encounters. Less likely based on geochemical and stable isotope data.

Water from dehydration of gypsum to anhydrite. Stable isotope composition of water in brines favors this hypothesis.

Meteoric water. Not likely because of geochemical and stable isotope data.

7.1 Age of Brine

There is no consensus on estimates of the age of the brine. The major and minor element chemistry data and the stable isotope data indicate ancient seawater. This hypothesis indicates that the water has been separated from the biosphere for tens of millions of years. The uranium disequilibrium age dating is very speculative since it requires numerous assumptions. With a range of parameters and initial conditions, The calculated brine "age" range from a negative age to 2 million years (Faith, et al, 1983).

8.0 Brine Reservoirs as a Threat to the Proposed Repository

The southern part of Zone II of the WIPP site appears to be more geologically predictable based on seismic and core hole data than the disturbed zone to the north. As no structure other than the WIPP-12 anticline is seen in the seismic profiles in zone II, the probability of the presence of brine in the southern part of Zone II appears to be low. Estimates of the area of brine include the zone beneath the proposed repository. Because there is no currently available method to prove a brine reservoir does not exist beneath the repository, other than by drilling boreholes into the Castile formation, EEG has taken the position of assuming a brine reservoir does exist beneath the repository and quantifying the consequences (Bard, 1982; Channell, 1982).

Human intrusion scenarios are believed to be the limiting cases because no plausible natural causes that will allow brine to bring wastes to the biosphere are envisioned. From its scenario analyses, EEG concludes that plausible radiation doses to the public (Bard, 1982; Channell, 1982) are below the limits that Protective Action Guides recommends for low probability accidents. DOE (Woolfolk, 1982) has reached similar conclusions.

9.0 Recommendations

In order to achieve more confidence and understanding of the subsurface below the repository, at least from an operational viewpoint, EEG recommends further evaluation and testing of the geophysical methods such as controlled source audio Magneto-Telluric (CSAMT) for the detection of brine in Zone II.

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1.0 Introduction

Knowledge of the regional hydrology near the WIPP is crucial because groundwater is the most likely path for radionuclide migration to the biosphere. In particular, modeling the solute transport characteristics of the water-bearing formations requires accurate determination of the direction and velocity of the groundwater flow.

The nearest perennial water course is the Pecos River, which at its nearest point is about 14 miles from the proposed repository. The only well developed ephemeral drainage is located about 4 miles west of the site at Nash Draw. The nearest surface water body, Laguna Grande de la Sal, is located within Nash Draw, about 10 miles southwest of the center of the site. The lake is fed by groundwater dicharging through springs, by local surface runoff following intense rainfall, and by discharge water from nearby mining operations (Geohydrology Associates, 1978).

Six water-bearing units have been identified near the proposed repository (Figures 13 and 14). Although defined as aquifers in this report, the units do not qualify as aquifers by strict definition. The three aquifers above the proposed repository (Figure 14) are contained in the Rustler-Salado contact, the Rustler Culebra Dolomite, and the Rustler Magenta Dolomite. Water is observed in two units underlying the level of the proposed repository; (Figure 13) as isolated brine occurrences in the upper anhydrite of the Castile Formation, probably anhydrite III, and in the Bell Canyon formation of the Delaware Mountain Group. The Capitan Reef aquifer which surrounds nearly the entire Delaware Basin, lies about 10 miles northeast of the site at its closest point.

2.0 Surface Water Hydrology

The nearest surface water body, Laguna Grande de la Sal, is located about 10 miles southwest of the center of the site (Figure 15). The lake is perennial and receives its water from precipitation, local surface runoff and from the

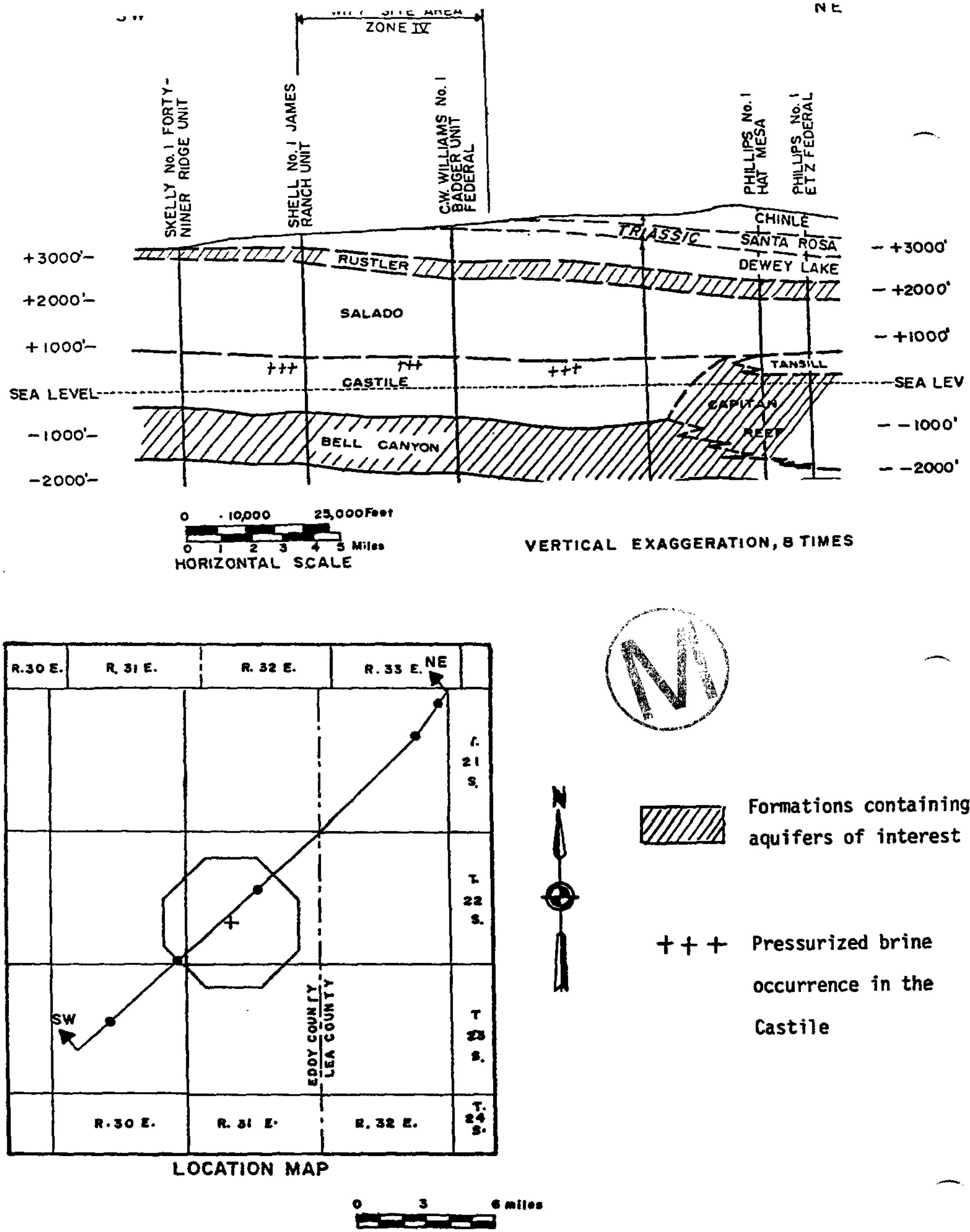


Figure 13. Generalized Site Stratigraphic Section
(from the Geological characterization Report, 1978)

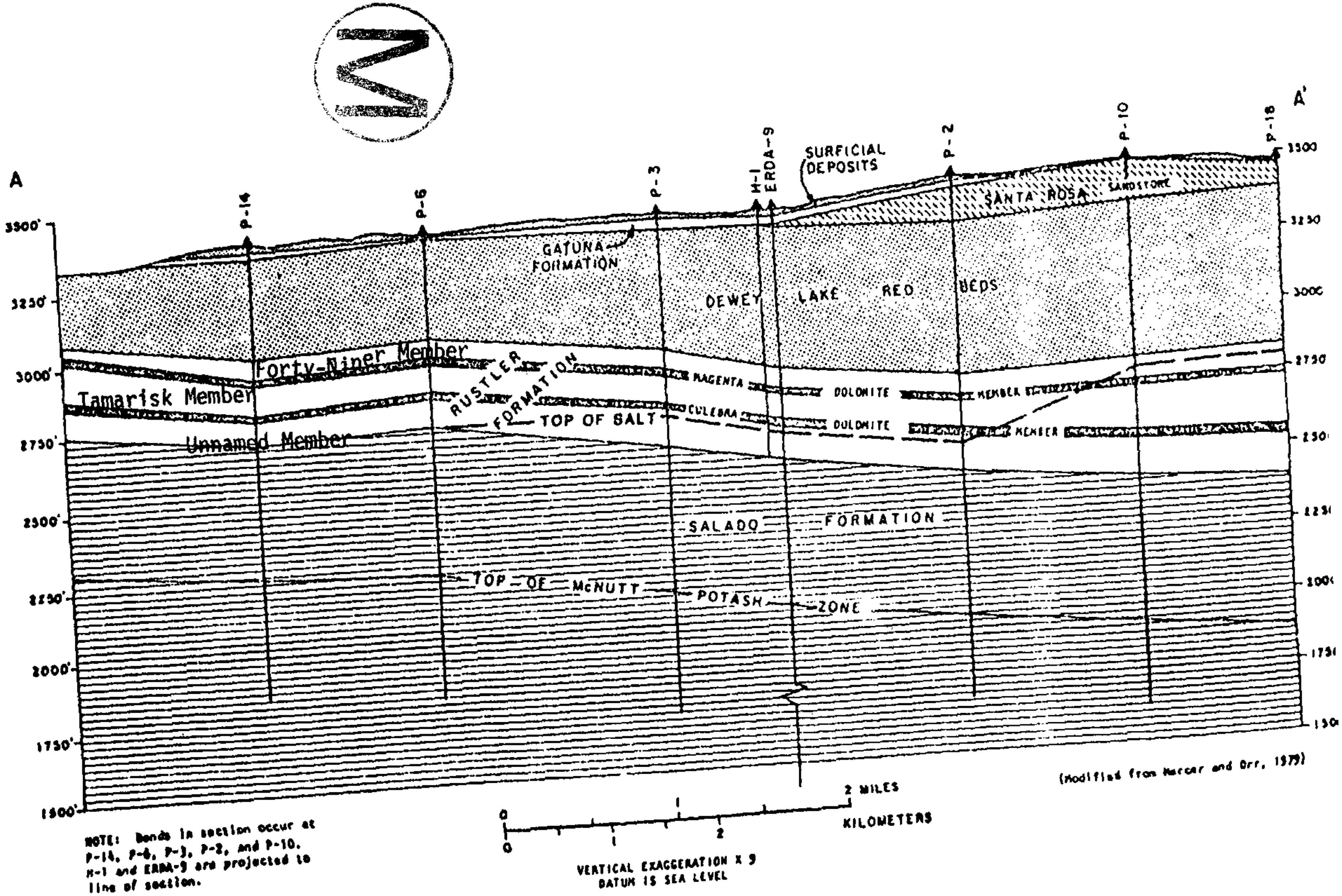


Figure 14. Geologic section across the proposed WIPP site (from Mercer, 1983)

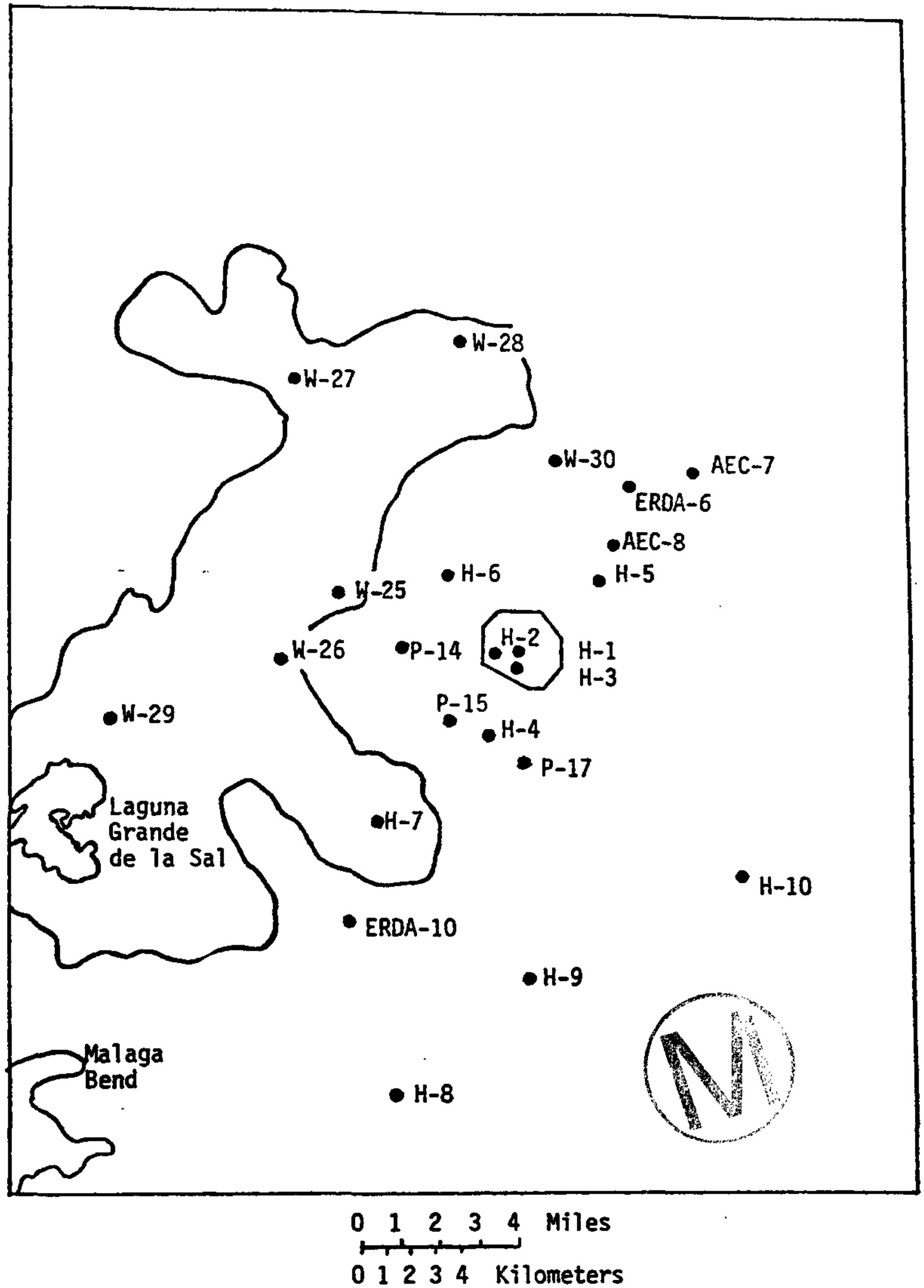


Figure 15. Location of test holes at and near the proposed WIPP site (from Mercer, 1983)

underlying Rustler formation, which may include discharge water from mining operations. The groundwater source is either the Culebra Dolomite, or an overlying anhydrite unit. The source is indeterminate at this time based on the limited chemical data available. However, on a piper diagram (Figure 16) two separate chemical analyses of water attributed to Surprise Spring are compared to Culebra water from selected surrounding wells (Mercer, 1983). One analysis (Geohydrology Associates, 1978) is similar to Culebra wells WIPP-27, WIPP 28, WIPP-29, WIPP-30, and P-17 while the second analysis (Lambert, 1983) is similar to wells P-14, WIPP-25, and WIPP-26.

The first chemical analysis of Surprise Spring (Geohydrology Associates, 1978) had a total dissolved solids content higher than any Culebra water sample. This may indicate that the sample was really from the lake and was not a representative sample of Surprise Spring. The second chemical analysis (Lambert, 1983), although similar to the Culebra waters, is dissimilar enough to make a postulated connection between the Culebra and Surprise Spring tenuous without further study. Surprise Spring is obviously not the only source of water to Laguna Grande de la Sal, but other specific locations of inflow to the lake are not identified.

Mercer (1983) states that at a drill hole in Laguna Grande de la Sal, the hydraulic head in the Culebra was 21 feet above the lake level. The Culebra was overlain by 40 feet of gypsum mud at that location. These data are an indication that some leakage of Culebra water into the Laguna Grande de la Sal is occurring, but the leakage rates are unknown. In any event, the lake is a potential discharge point of the Culebra Dolomite.

The other currently recognized surface discharge point for the Culebra, or Rustler water in general, is the Pecos River. The large brine springs near Malaga Bend are the likely Pecos discharge locations nearest the WIPP site.

3.0 Groundwater Flow in the Bell Canyon Aquifer

The Bell Canyon Formation is of interest in relation to deep dissolution and as a transport mode for bringing radioactive waste to the biosphere.

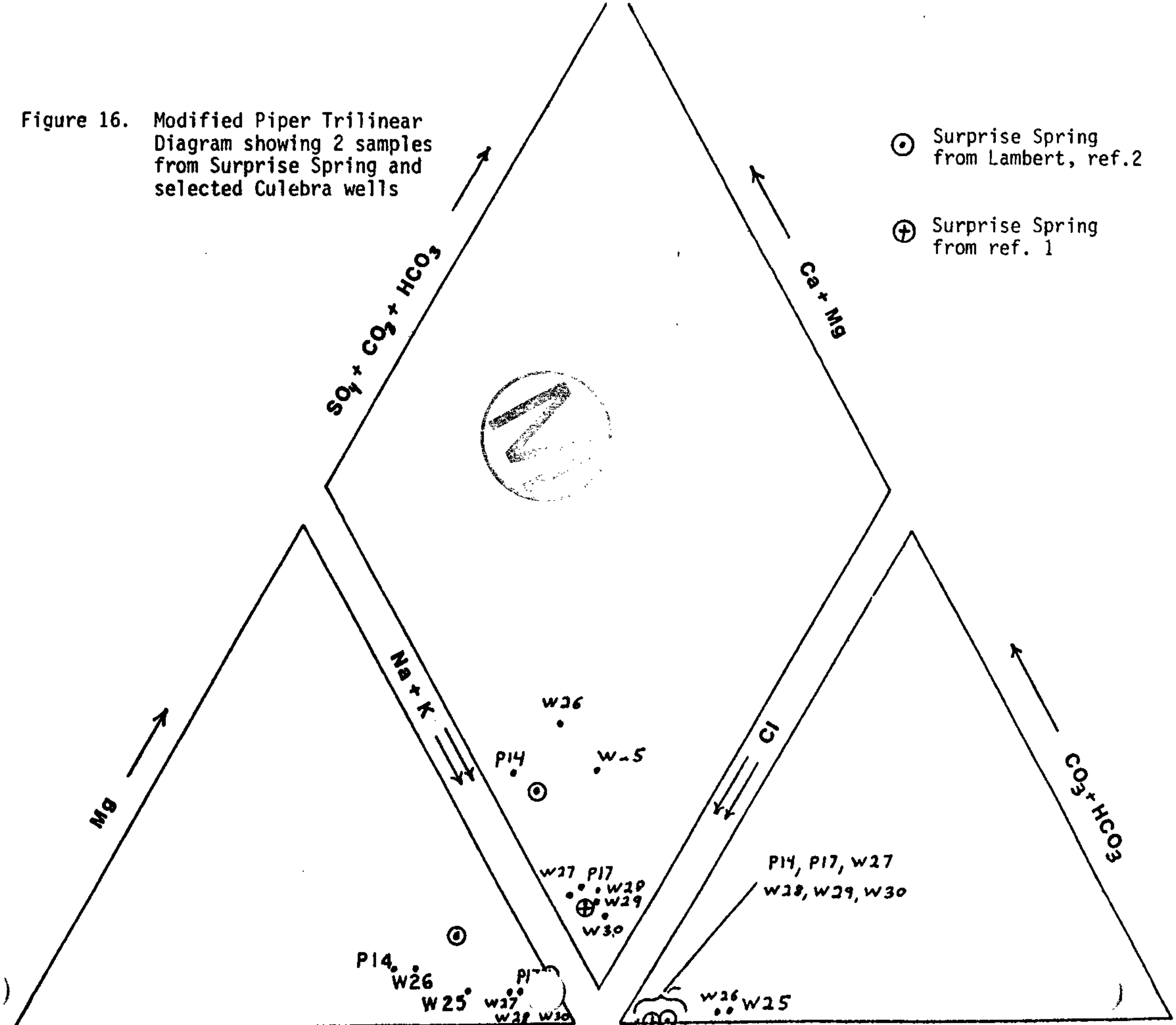


Figure 16. Modified Piper Trilinear Diagram showing 2 samples from Surprise Spring and selected Culebra wells

The question of dissolution has been addressed elsewhere in this report. Studies by EEG and Wood et al. (1982) indicate that groundwater flow in the Bell-Canyon is insufficient to remove enough salt to pose a threat to the repository. In the unlikely event that a local dissolution feature (such as a breccia pipe) rooted in the Bell Canyon below the site were to form, Spiegler (1982) has shown the radiological consequences to not be significant. Additional analyses by EEG indicate that the representative solute transport characteristics of the Bell Canyon are such that water transport times to the accessible environment, assumed to be the Capitan Reef, are in excess of 165,000 years. If the most conservative parameters (Williamson, 1979) are used, then travel time could be as low as 9000 years. Solute transport times would likely be much longer due to solute retardation.

A significant point is the hydraulic head (uncorrected for salinity) of the Bell Canyon. Mercer (1983) and Gonzalez (1983) present extrapolated static bottom hole pressures and fluid densities for petroleum drill tests conducted over various intervals in three test holes (Table 1). Mercer (1983) and Weart (1983) state that the head of the Bell Canyon is insufficient to cause an upward flow of water into the overlying Culebra Dolomite aquifer, should such a connection occured, based primarily on the data of the three deep test holes (AEC-7, AEC-8, ERDA-10). EEG questions the contention of insufficient head in the Bell Canyon based on the limited borehole test data for the following six reasons.

1. Measured hydraulic head is only available for test hole AEC-8. For test holes AEC-7 and ERDA-10 only downhole pressure and fluid density are available from which hydraulic head can be calculated.

2. When calculating the hydraulic head based on bottom hole pressure and fluid density, the resulting heads are very sensitive to changes in density or pressure. At test hole ERDA-10, test number 10, a change in fluid specific gravity from 1.165 to 1.164 results in a 3 foot calculated head increase. A change in static downhole pressure from 1820 psig to 1821 psig yields an increase in calculated head of two feet. Therefore, if the measured fluid densities and pressures are not an accurate representation of the in-situ conditions, substantial errors in calculated hydraulic head may result.

Table 1. Summary of drill-stem tests at test holes AEC-7, AEC-8, and ERDA-10, upper Bell Canyon Formation, in the vicinity of the WIPP site (from Mercer, 1983).

Test number	Date of test	Tested interval, in feet below	Type of test	Hydrostatic pressure, in pounds per square inch (gage) Initial	Hydrostatic pressure (gage) Final	Flow period in minutes	Bottom hole flowing pressure, in pounds per square inch (gage) Initial	Bottom hole flowing pressure (gage) Final	Shut-in period, in minutes	Bottom hole shut-in pressure, in pounds per square inch (gage) Initial	Bottom hole shut-in pressure (gage) Final	Calculated hydraulic conductivity, in feet per day	Static bottom hole pressure (extrapolated), in pounds per square inch (gage)	Fluid density, in grams per cubic centimeter
Test Hole AEC-7														
1	4-23-79	4520-4583 (Lamar)	Standard	2,841	2,462	30 120 360	30 23 25	23 23 21	60 360 480	23 23 21	23 25 23	Insufficient Data to Make Calculation	-	-
2	4-27-79	4609-4714 (Ramsey)	Standard	2,547	2,531	25 60 120	127 460 861	395 804 1,270	60 120 335	395 804 1,270	1,814 1,808 1,839	4×10^{-2}	1,883	1.130
3	4-28-79	4493-4714 (Upper Bell Canyon)	Standard	2,479	2,466	10 60 120	120 352 770	314 717 1,188	60 120 350	314 717 1,188	1,764 1,737 1,768	4×10^{-2}	1,811	1.130
Test Hole AEC-8														
1	8-15-77	4844-4800 (pre Ramsey lower sand)	Modified	-	-	-	-	-	-	-	-	2×10^{-2}	2,037	1.147
2	9-27-77	4821-4827 (upper sand)	Modified	-	-	-	-	-	-	-	-	7×10^{-3}	2,044	1.060
7	7-24-76	4304-4405 (Lamar)	Standard	2,445	-	30 58	13 24	18 32	121 748	18 32	1,761 1,788	2×10^{-6}	1,813	-
Test Hole ERDA-10														
9	9-19-77	3860-3927 (Lamar)	Standard	2,083	2,054	30 120 480	51 [illegible]	58 106 215	120 360 240	58 106 215	1,708 1,684 1,511	4×10^{-4}	1,783	-
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	-	5×10^{-2}	[illegible]	1.165

3. Large variations in reported fluid densities are observed. For test hole AEC-8, test number 1, two different fluid densities are reported; 1.147 g/cm^3 (Mercer, 1983) and 1.11 g/cm^3 (Mercer and Orr, 1979). For test number 2, the densities are 1.060 g/cm^3 (Mercer, 1983) and 1.12 g/cm^3 (Mercer and Orr, 1979). The measured hydraulic head for test number 1 is 2979 feet (Mercer, 1983); the calculated heads are 2807 feet and 2944 feet., for densities 1.147 g/cm^3 and 1.11 g/cm^3, respectively. For test number 2 the measured head is 2964 feet (Mercer, 1983). The calculated heads are 3186 feet and 2948 feet for densities 1.060 g/cm^3 and 1.12 g/cm^3, respectively.

4. There are large variations reported for static bottom hole pressure. For test hole AEC-8, test number 7, extrapolated static bottom hole pressures of 1813 psig and 1962 psig are presented in the Basic Data Report for AEC-8 (SAND 79-0269). For test hole ERDA-10, test number 9 extrapolated static bottom hole pressures of 1783 psig and 1816 psig are recorded in the Basic Data Report for ERDA-10 (SAND 79-0271). For both test holes, only the lower pressure is presented by Mercer (1983) and Gonzalez (1983). Fluid densities are not available, so hydraulic heads cannot be calculated.

5. The calculated freshwater head in ERDA-10 is not consistent with previous studies (Hiss, 1976; McNeal, 1965). The freshwater head relative to mean sea level is defined by

$$h_f = \frac{P \cdot 144}{\gamma_f} + sg\ (e_s)$$

where h_f = freshwater head (feet above sea level datum)

e_s = elevation of the pressure measurement (feet)

sg = fluid specific gravity; assumed numerically equal to fluid density

P = measured pressure (lb/in^2)

γ_w = the weight density of the water (lb/ft^3)

γ_f = 62.4 lb/ft^3 for fresh water

The calculated fresh water hydraulic head, pressure measurement elevation, pressure, and specific gravity for well tests in the Bell Canyon sandstones in the three test holes are presented in Table 2.

Table 2. Calculated Fresh Water Hydraulic Head in the Bell Canyon Sandstones at Test Wells AEC-7, AEC-8 and ERDA-10 Using Published Static Bottom Hole Pressures and Densities.

Test Hole	Test Number	Pressure Measurement Elevation (msl datum) (feet)	Static bottom hole pressure (psig)	Fluid specific gravity	Fresh water head (feet above msl) Calculated	Fresh water head (feet above msl) Ref. 11
AEC-7	2	-941.6*	1883	1.130	3281	3280
AEC-7	3	-827.6*	1811	1.130	3244	
AEC-8	1	-1291.3[1]	2037	1.147-	3220	
AEC-8	2	-1264.0[1]	2044	1.060[2]	3377	3310
AEC-8	1	-1291.3[1]	2037	1.11[1]	3267	
AEC-8	2	-1264.0[1]	2044	1.12[1]	3301	
ERDA-10	10	-742.8*	1820	1.165	3335	3490

*Pressure measurement elevation is assumed to be the top of the tested interval given in Table 1.

[1]from Mercer and Orr (1979)

[2]from Table 1

[3]interpolated from Figure 22 of Hiss (1976)

The calculated fresh water heads for AEC-7 and AEC-8 are generally consistent with the work of Hiss (1976). The calculated fresh water head for test hole ERDA-10 appears to be too low compared to Hiss (1976). Errors in fluid density or bottom hole pressure of the magnitude observed in reasons 3 and 4 could easily account for the unusually low freshwater head in test hole ERDA-10.

6. The intervals tested in test hole AEC-8 appear to completely bypass the Ramsey sandstone member. Geophysical logs of the upper Bell Canyon including the 2 tested intervals are presented in Figure 17. The two sand units were chosen for testing because "The natural gamma log indicated that the two units were predominantly sandstone and the porosity log indicated that they

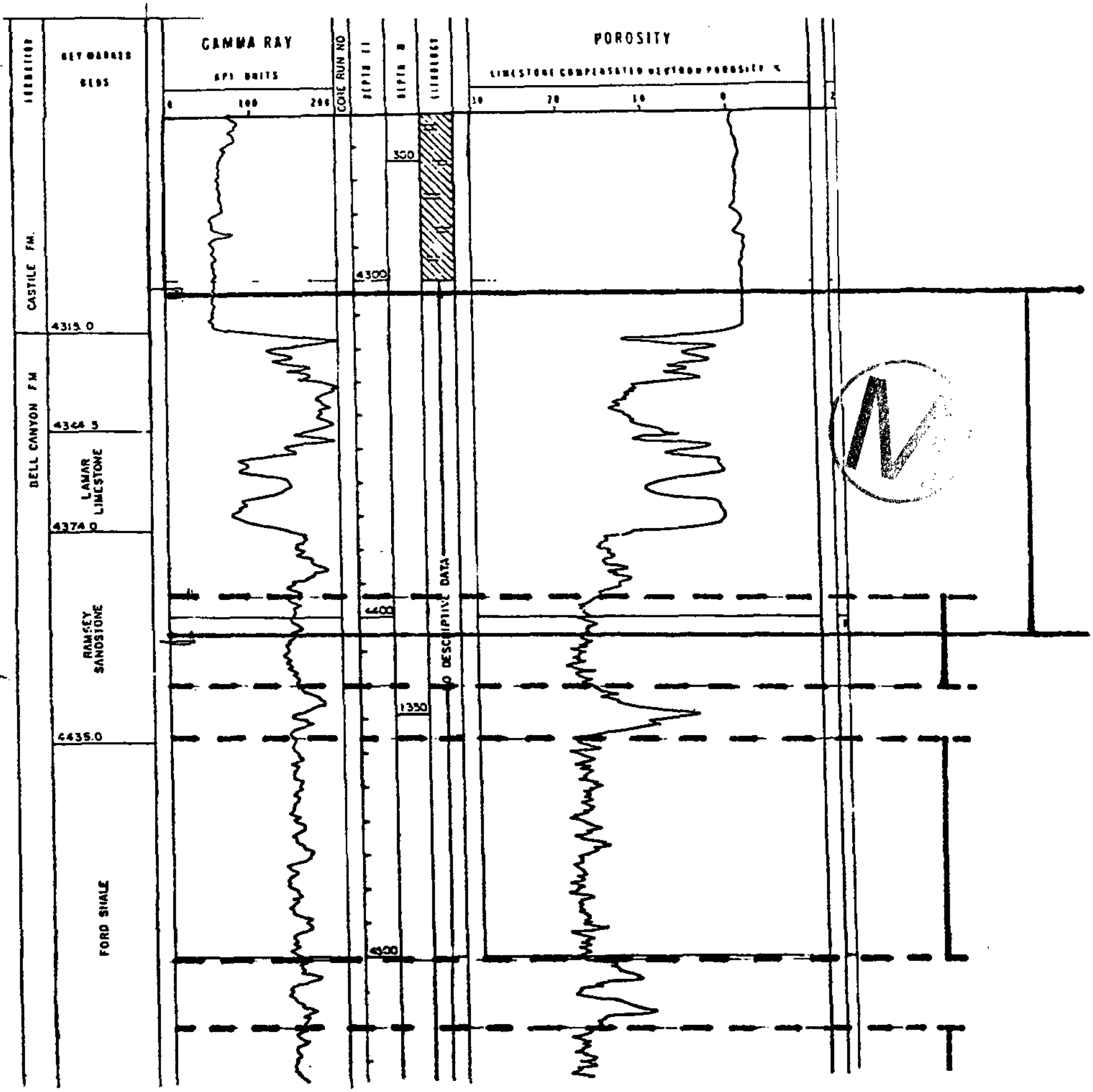


Figure 17a. Geophysical logs of borehole AEC-8 and intervals that EEG contends should have been tested (logs adapted from SAND79-0269, 1983)

intervals tested by DOE

intervals EEG contends should been tested

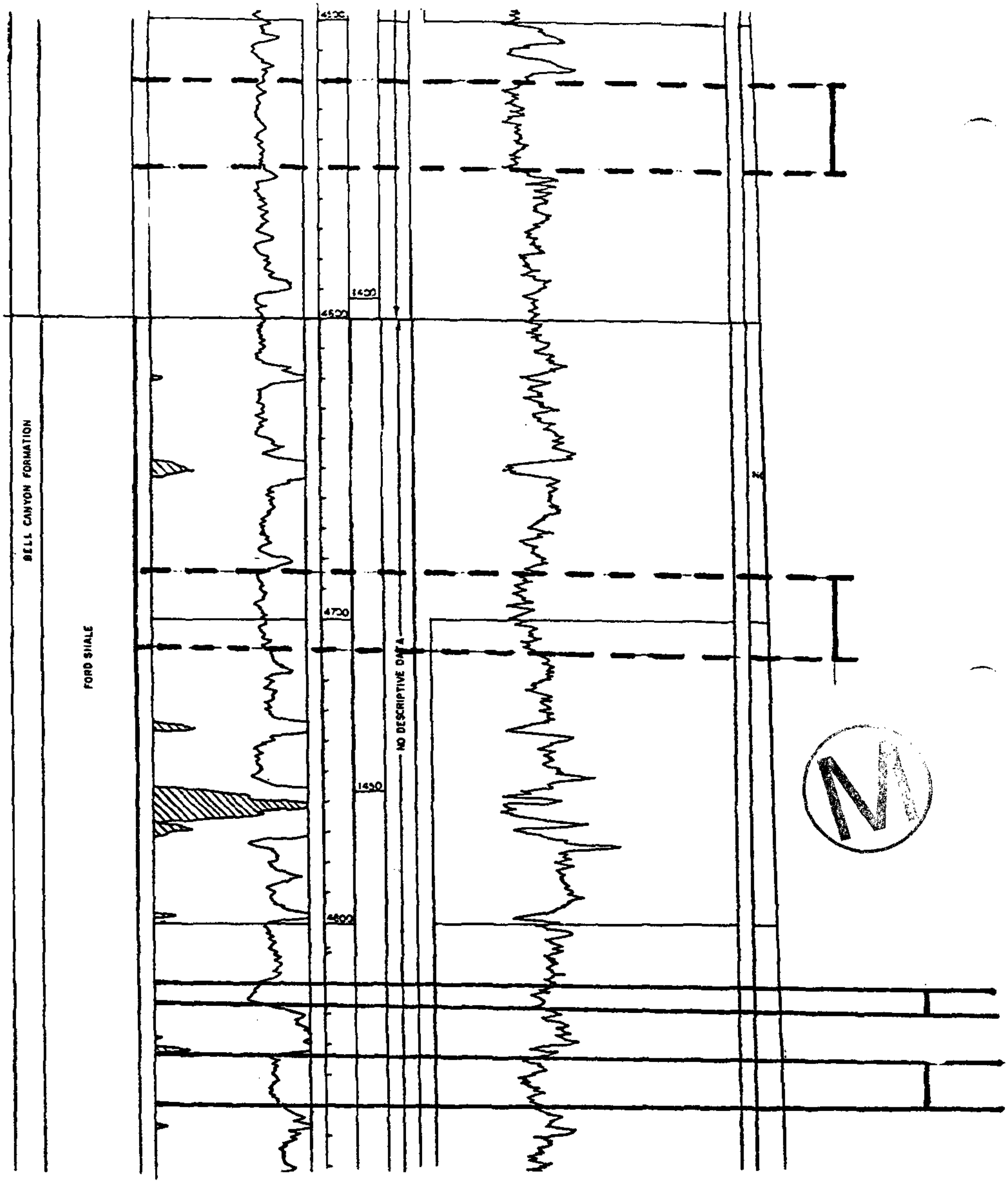


Figure 17b. Geophysical logs of borehole AEC-8 and intervals that EEG contends should have been tested (logs adapted from SAND79-0269, 1983)

intervals tested by DOE

intervals EEG contends should have been tested had greater porosities than other Bell Canyon sand units." (Mercer and Orr, 1979, p. 127). Four other sand units, not tested, which possess very similar geophysical log signatures as the intervals tested are indicated on Figure 17. These other untested sand units with a combined thickness of 150 feet, are stratigraphically closer to the repository and would have been logical intervals to test.

The calculated hydraulic head data for AEC-7 and ERDA-10 appear unreliable. From reason 2, a 5 foot error in hydraulic head results from a 1 psig error in pressure and a 0.001 g/cm^3 error in fluid density. From reasons 3 and 4, inconsistencies in both fluid density and pressure can be quite large. In addition, the intervals tested in AEC-8 do not appear to be representative of the upper Bell Canyon because from reason 5 it appears that 150 ft. of stratigraphically higher sands should have been tested.

In summary although EEG disagrees with some details presented by DOE concerning the salt removal and transport characteristics of the Bell Canyon, it does not appear to pose a threat to the repository either through the dissolution of salt or as a medium of radionuclide transport to the accessible environment.

Knowledge of the true hydraulic head in the Bell Canyon is essential to determining the direction of groundwater flow between the Culebra Dolomite and the Bell Canyon should such a connection occur in the future. If the flow is downward into the Bell Canyon, the radiological consequences of a repository breach would probably be much less than if the flow is upward into the Culebra.

The most conservative scenario modeling of a connection between the Bell Canyon and Culebra aquifers assumes the flow to be from the Bell Canyon to the Culebra. If DOE insists on establishing a downward flow from the Culebra to the Bell Canyon, the water level in at least one other well in addition to AEC-8 should be monitored. The well could be any borehole of opportunity located southwest, south, or southeast of the proposed repository. In addition, AEC-8 should be perforated in sandstones above the currently monitored intervals.

4.0 Castile Formation

Scattered occurrences of artesian and flowing artesian brines in the upper anhydrite layer of the Castile formation are recorded in the Northern Delaware Basin (see the section on Brine Reservoirs for more detail). To date, there is no evidence to suggest that a brine aquifer exists in the Castile Formation east of the Pecos River. In fact, the existence of highly pressurized brines provides evidence that an aquifer does not exist because the hydraulic head associated with such an aquifer should be consistent with the hydraulic head in the other aquifers, namely the Bell Canyon and the Capitan Reef. The observed hydraulic heads of the highly pressurized brines are much above the hydraulic heads in either the Capitan Reef or the Bell Canyon. Also, the geochemical data of the ERDA-6 and WIPP-12 brines indicate that the brines are immobile and not part of an aquifer system.

In the outcrop area west of the Pecos River, localized flow systems containing relatively fresh water are observed in the Castile Formation. The eastern extension of these fresh water systems is unknown, but it is assumed to be limited to the area west of the Pecos River.

Aquifers have not been observed near the WIPP site in the Castile Formation and consequently it is not considered a viable mode of radionuclide transport. The observation of only brines in the Castile near the WIPP would indicate that salt dissolution by the water in the Castile is not likely.

5.0 Groundwater Flow in the Rustler Formation

Groundwater in the Rustler Formation is observed in 3 distinct units: the Rustler Salado contact, the Culebra Dolomite, and the Magenta Dolomite (Figure 14). At the site the three aquifers are distinct and separate, but in Nash Draw, the distinction is less apparent to the southwest toward the Pecos River. Table 3 contains measured transmissivities for the Rustler aquifers.

5.1 Rustler-Salado Contact

The Rustler-Salado contact aquifer exists in solution residuum at the top of the Salado formation. From the site, the groundwater in the Rustler-Salado residuum

Table 3. Values of transmissivity and storage coefficient for water-bearing zones in the Rustler Formation penetrated by selected test holes at and near the WIPP site (from Mercer, 1983)

(Tansmissivity is expressed in feet squared per day)

Test hole	Magenta Dolomite Member		Culebra Dolomite Member		Rustler-Salado Contact	
	Transmissivity	Storage	Transmissivity	Storage	Transmissivity	Storage
H-1	0.05	–	0.07	10^{-4}	0.0003	–
H-2a	.01	10^{-4}				
H-2b			0.4	10^{-9}		
H-2c					0.0001	–
H-3	.1	10^{-5}	19.0	–	0.0003	10^{-4}
H-4a	.06	10^{-6}				
H-4b			0.9	10^{-9}		
H-4c					0.0006	10^{-4}
H-5a	.1	10^{-5}				
H-5b			0.2	10^{-5}		
H-5c					.00003	10^{-3}
H-6a	.3	10^{-5}				
H-6b			73.0	–		
H-6c					.003	10^{-6}
H-7a	Dry	–				
H-7b			1000+	–		
H-7c					0.73	–
H-8a	.006	10^{-5}				
H-8b			16.0	–		
H-8c					0.003	–
H-9a	1.0	10^{-9}				
H-9b			231	–		
H-9c					0.0002	–
H-10a	0.01	10^{-3}				
H-10b			0.07	10^{-4}		
H-10c					0.00009	–
P-14			140	–	0.05	–
P-15			0.07	10^{-4}	0.0004	–
P-17			1.0	10^{-6}	0.0002	10^{-4}
P-18			0.001	–	0.00003	10^{-5}
W-25	375	–	270	–	5.0	10^{-3}
W-26	Dry	–	1250	–	0.4	–
W-27	53	–	650	–	0.0002	–
W-28	Dry	–	18	–	0.87	–
W-29	Not present		1000	–	8	–
W-30	0.004	–	0.3	10^{-4}	0.2	10^{-4}

flows generally southwest with a possible discharge at Laguna Grande de la Sal, but the major discharge point nearest the WIPP site is the Pecos River near Malaga Bend. In Nash Draw, the Rustler-Salado contact is an aquifer with a transmissivity as high as 8000 ft^2/day. The transmissivity of the aquifer is very small (less than 3 x $10^{-4} ft^2$/day) within 2 miles of the center of the site.

The water in the aquifer is characterized by extremely high total dissolved solids, the lowest being around 70,000 mg/l. In, and near Nash Draw the TDS is dominated by NaCl indicating flowing groundwater and active dissolution. Within zone II and most of zone III, the Rustler-Salado aquifer is very thin, has an extremely high TDS concentration and a disproportionately high potassium and magnesium concentration (Mercer, 1983). The extremely small transmissivity east of the western edge of zone II, in conjunction with the high magnesium and potassium concentration indicates a very restricted flow system at the Rustler-Salado contact at the site. Therefore, the Rustler-Salado contact residuum aquifer does not appear to be an important consideration for waste transport following a repository breach.

5.2 Culebra Dolomite Aquifer

The Culebra Dolomite aquifer is the most hydraulically conductive of the Rustler-water bearing units. As such, the Culebra may represent the bounding transport mode for contaminated water following a repository breach and subsequent water movement upward into the Rustler. In this section, the general hydrogeological characteristics of the Culebra are presented. Maps of the Culebra potentiometric surface and major chemical constituents are presented in Figures 18 and 19. The inferred direction of flow from the center of the site is from north to south and then west to Malaga Bend passing somewhere near to the Project Gnome site. Determinations of anisotropy of hydraulic conductivity at H-4, H-5, and H-6 by Gonzalez (1983), when incorporated into the flow analysis, indicate an initial southeasterly direction of flow from the WIPP site center before turning west to Malaga Bend. No data on anisotropy are available at the center of the site or to the southeast. In any event, the discharge point of Culebra water at the site would appear to be Malaga Bend.

The above picture of flow from the site passing in the vicinity of the Project Gnome site and discharging into the Pecos River is inconsistent with the observed

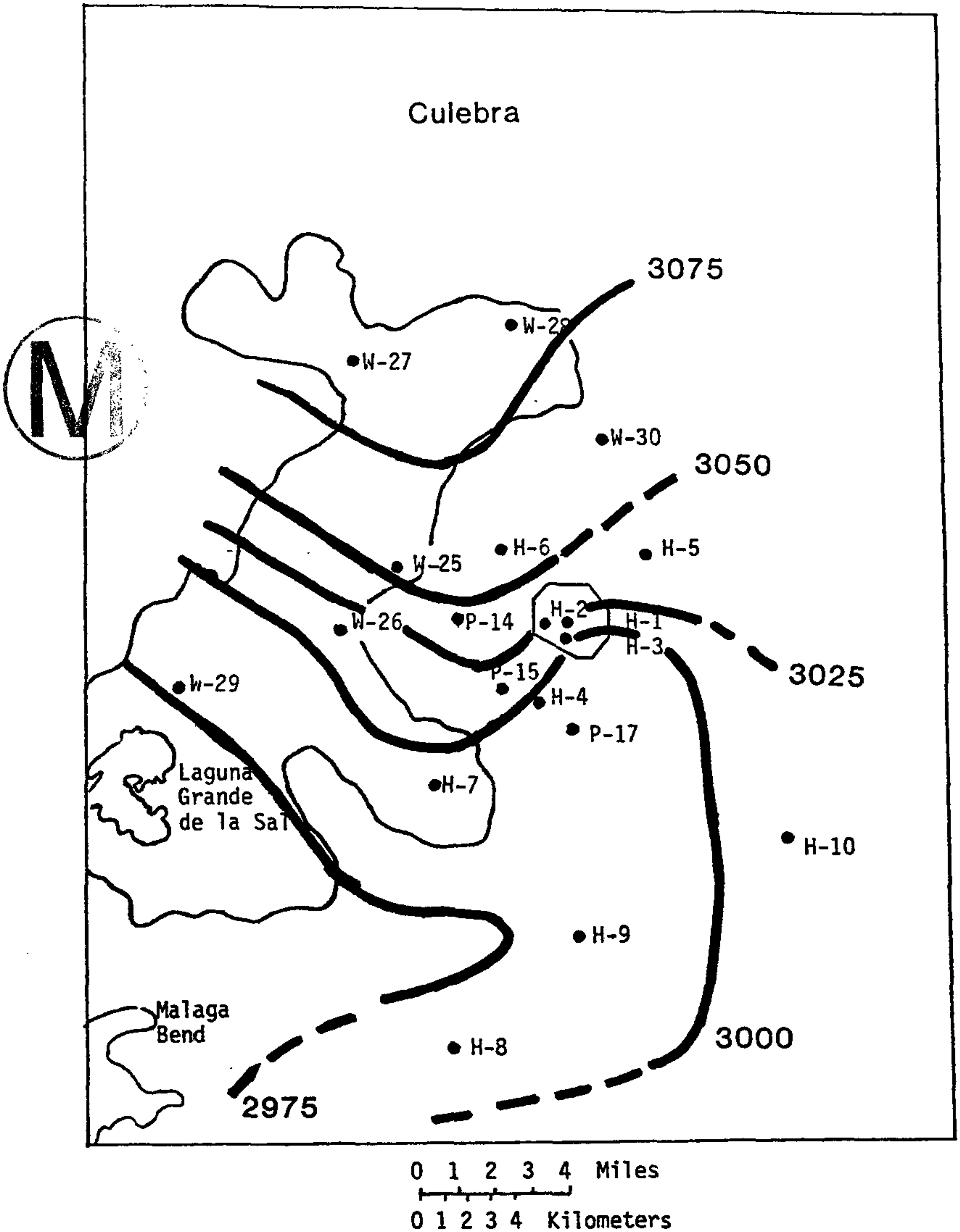


Figure 18. Adjusted potentiometric surface of the Culebra Dolomite Member of the Rustler Formation (1982) at and near the proposed WIPP site (from Mercer, 1983)

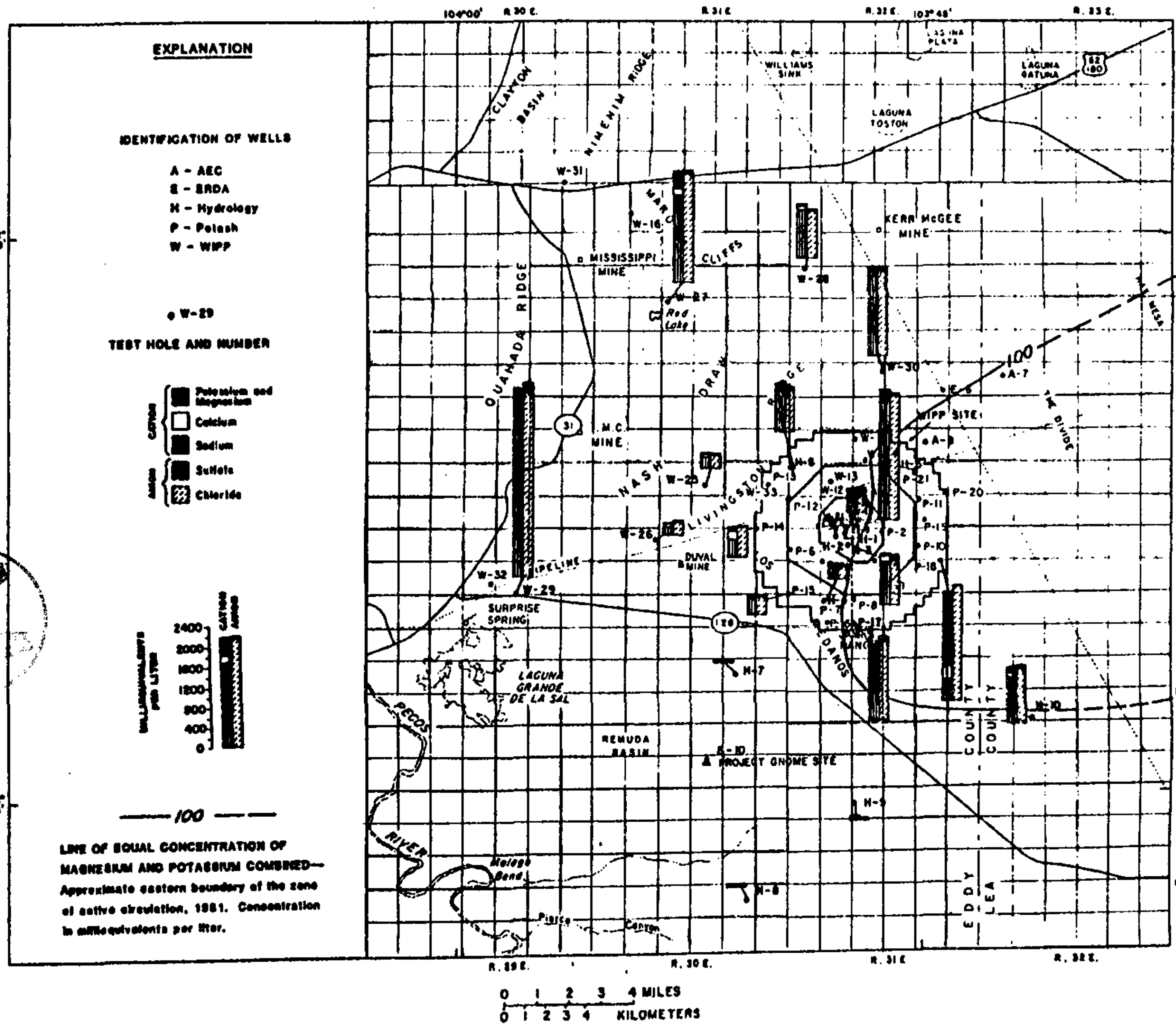


Figure 19. Concentration of major chemical constituents in water from the Culebra Dolomite Member of the Rustler Formation at and near the proposed WIPP site (from Mercer, 1983)

water chemistry in the Culebra. Figure 20 is a modified Piper Trilinear plot of all the Culebra water chemistry data. From the plot, the chemical constituents of wells at the center of the site H-1, H-2, H-3 are predominantly Na and Cl and have total dissolved solids concentrations (TDS) of 30,100 mg/l, 9700 mg/l and 62,000 mg/l respectively. The chemical constituents of wells down flow, H-7, H-8, H-9 are predominantly Ca, Mg and SO and have total dissolved solids concentrations of 3610 mg/l, 3200 mg/l and 3590 mg/l respectively. There is no credible mechanism, other than mixing, to account for a decrease in TDS and a change in chemical constituents from Na and Cl to Mg, Ca and SO in the direction of apparent flow. Mixing with the overlying Magenta aquifer appears unlikely because the TDS in the Magenta is everywhere greater than the TDS in H-7, H-8 and H-9 of the Culebra. Continued investigation into the hydrology of the Culebra Dolomite by Sandia National Laboratories will hopefully clarify the current inconsistency between the apparent water flow direction and water chemistry.

EEG's tentative conclusion is that there is insufficient well data south and southeast of the site to accurately estimate the direction of groundwater flow from the site. As additional information is made available, EEG will modify its conclusions accordingly.

5.3 Magenta Dolomite Aquifer

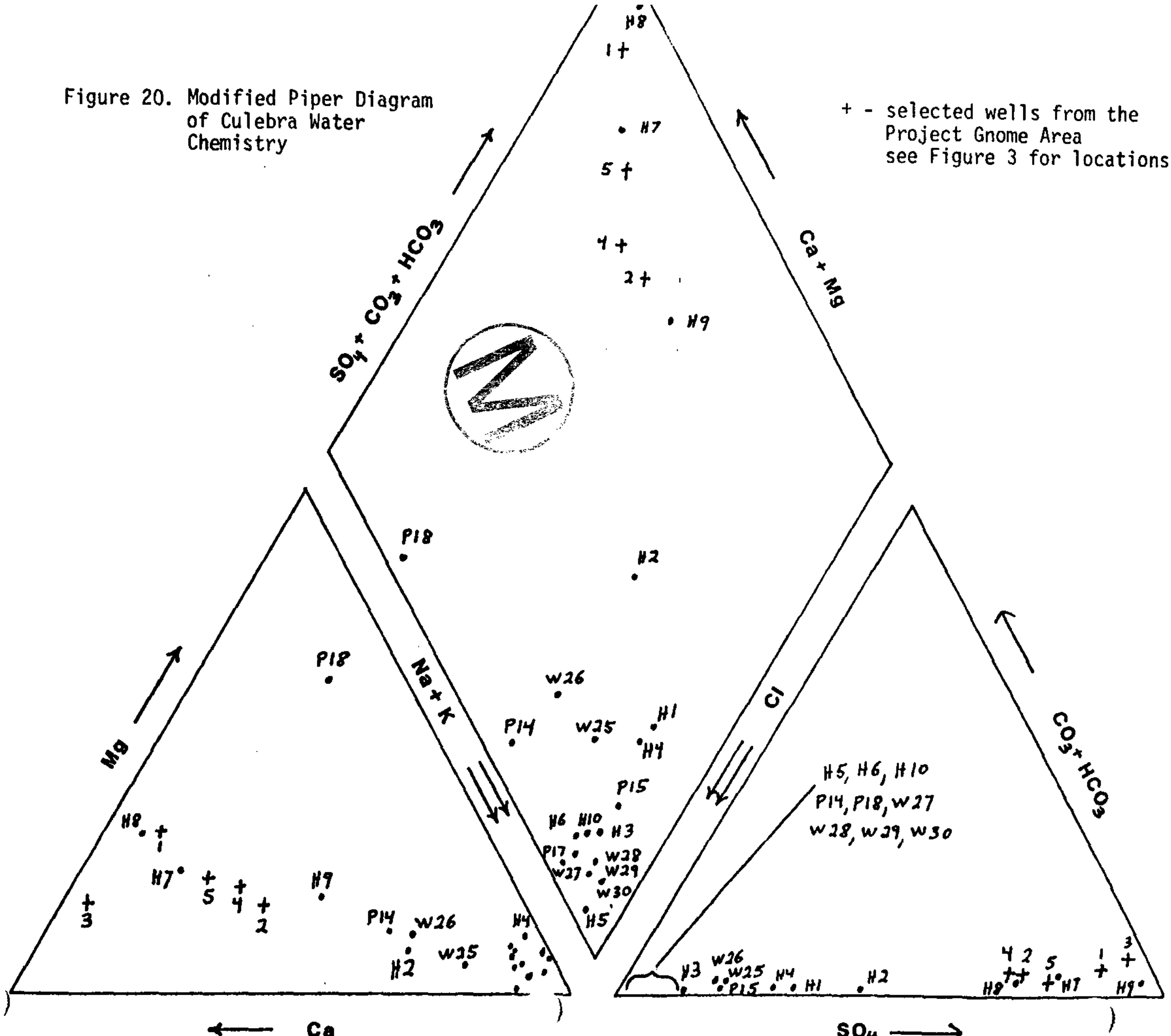
The Magenta Dolomite aquifer lies stratigraphically above the Culebra Dolomite. Figures 21 and 22 show the potentiometric surface and major chemical constituents for the Magenta. In general, water in the Magenta at the center of the WIPP site will flow westward to Nash Draw where it likely discharges into underlying units. The Magenta has been largely ignored by DOE for solute transport scenarios because of the small transmissivities associated with that aquifer. However, due to the uncertainty associated with the direction of flow in the Culebra, the possible transport of contaminants in the Magenta should be given consideration. This will be discussed in detail in the section on "Hydrologic Transport Characteristics in the Rustler Formation."

6.0 Capitan Reef Aquifer

The Capitan reef aquifer, one of the most productive freshwater aquifers in southeastern SE New Mexico, extends in an arcuate band around most of the

Figure 20. Modified Piper Diagram of Culebra Water Chemistry

+ - selected wells from the Project Gnome Area see Figure 3 for locations



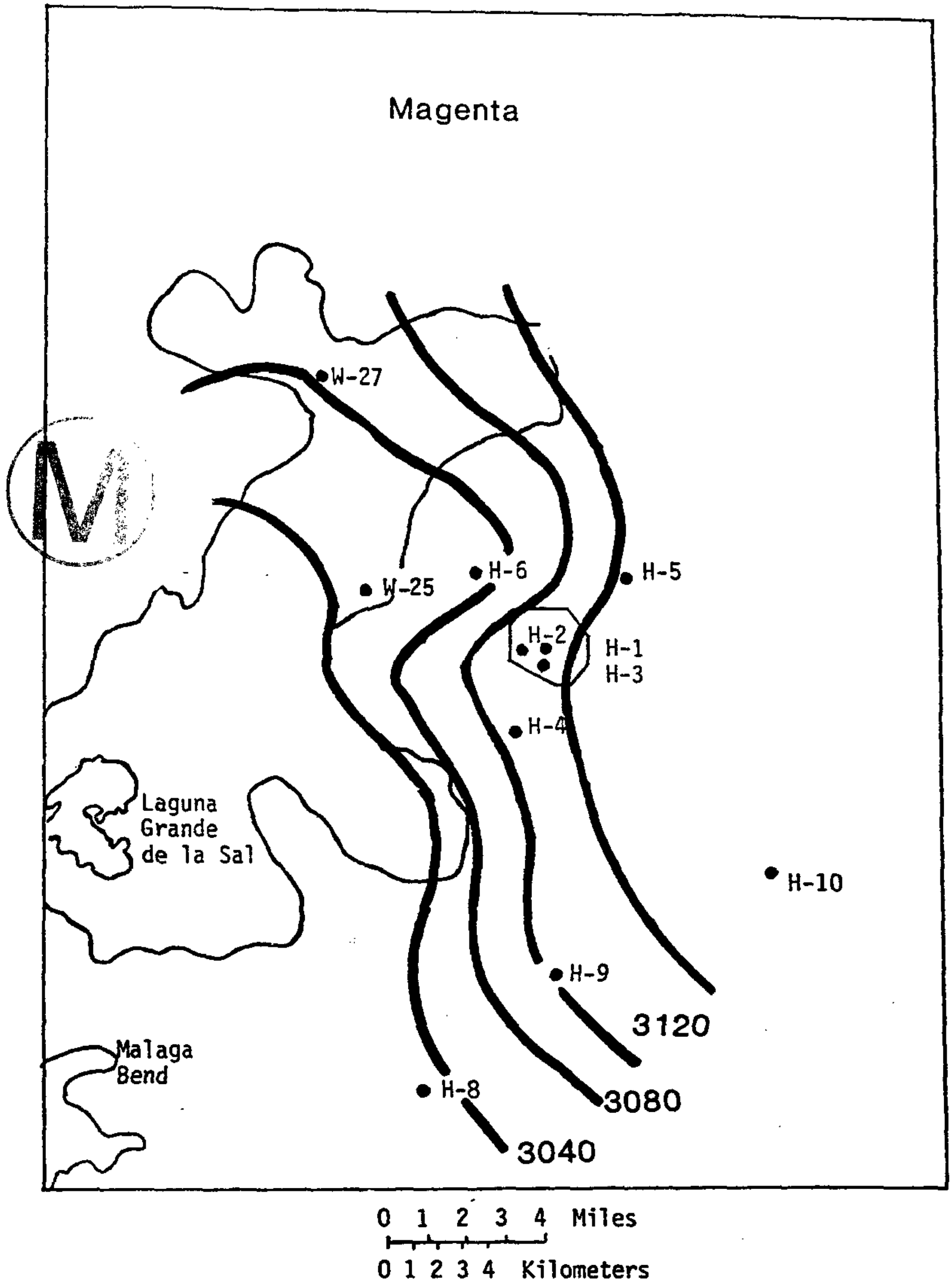


Figure 21. Adjusted potentionmetric surface of the Magenta Dolomite Member of the Rustler Formation (1982), at and near the proposed Waste Isolation Pilot Plant (WIPP) site (from Mercer, 1983)

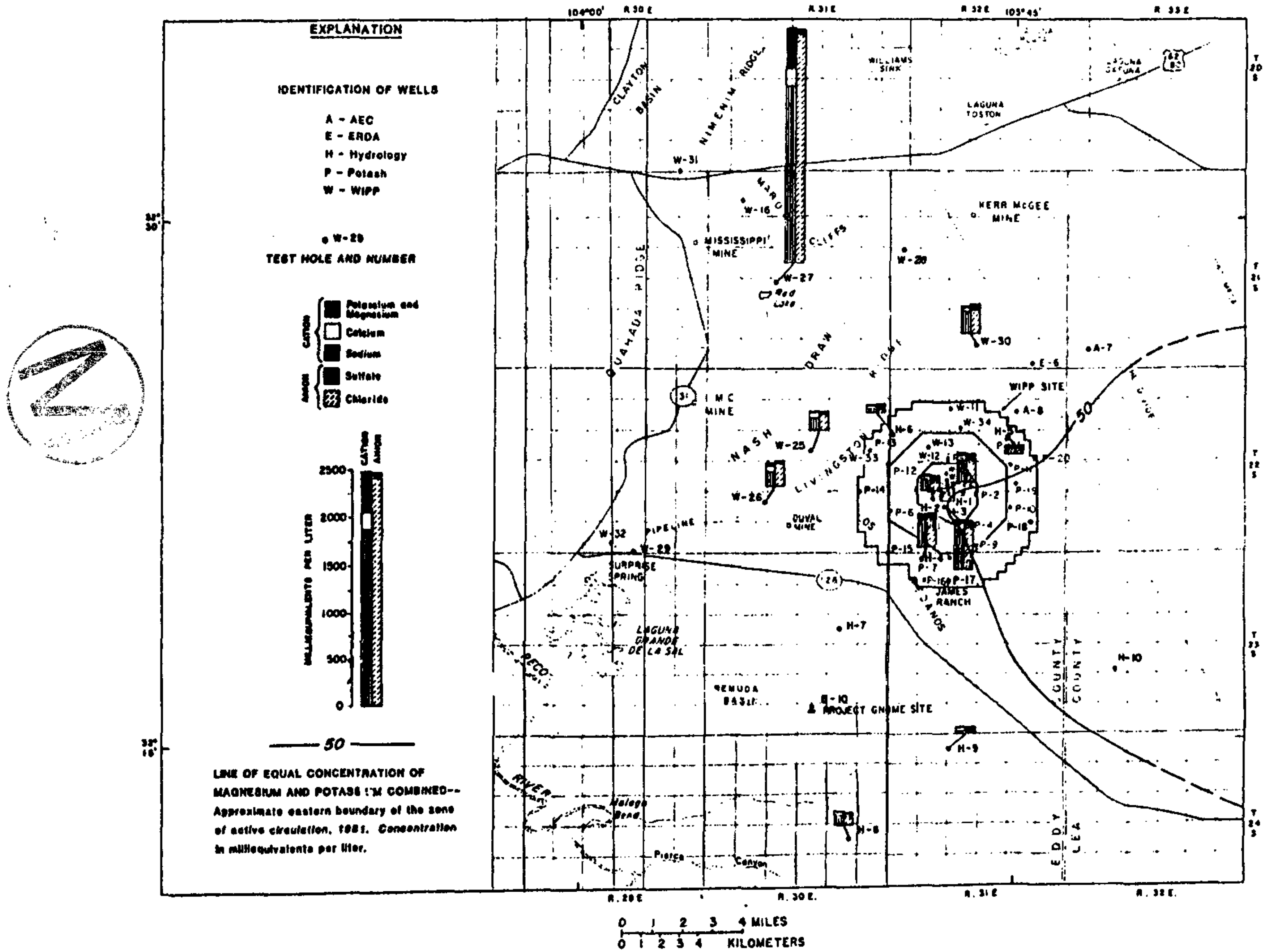


Figure 22. Concentrations of major chemica[illegible] constituents in water from the Magenta Dolomite Member of the Rustler Formation [illegible] near the proposed [illegible] site (from Mercer, 1983)

Delaware Basin and lies at its closest point about 10 miles north of the WIPP. The hydraulic head in the Capitan Reef aquifer is less than that in the Bell Canyon (Hiss, 1976) indicating a flow into the reef if the two aquifers are connected. The relatively impermeable anhydrites of the Castile Formation restrict the lateral movement of freshwater away from the reef (Mercer, 1983). Numerous collapse phenomena are associated with the Capitan Reef and some near reef salt dissolution is probably attributable to the Capitan Reef aquifer (see the section on Dissolution). However, salt dissolution associated with the reef does not appear to pose a threat to the repository. The solute transport characteristics of the Bell Canyon are such that a minimal radiological hazard would result from a repository breach and subsequent transport of radionuclides to the Capitan Reef by the Bell Canyon aquifer.

7.0 Summary of Conclusions

The degree of understanding of the regional hydrology, although far from complete, is sufficient to reach some general conclusions.

7.1 Waters in the Bell Canyon formation and the Castile formation do not pose a significant threat to the repository. The salt removal potential is too low and the radionuclide transport time is too long.
However, both formations may be a source of water for some breach scenarios that result in the injection of radionuclides into the Rustler.

7.2 The Capitan Reef Aquifer is at its nearest point about 10 miles from the site. Water in the aquifer is largely prevented from moving laterally into the basin. Although there is some localized dissolution associated with the reef, the basinward dissolution north of the site appears small. Therefore, the Capitan Reef Aquifer poses a minimal threat to the repository.

7.3 The groundwater in the Rustler Formation is the likely bounding conduit following a repository breach for radionuclides to reach the accessible environment. Within the Rustler, the Culebra aquifer is of most concern, because of higher transmissivities. However, there are insufficient data to characterize the flow system in the Culebra south of the site and hence additional experiments are needed. EEG hopes the solution will come from ongoing hydrologic studies concentrated in the Culebra.

7.4 The various nuclear waste repository criteria that relate to groundwater generally are directed toward solute transport characteristics of the aquifers. How well WIPP meets these criteria is discussed in the section on hydrologic transport in the Rustler.

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THE DISTURBED ZONE

1.0 Definition

The northern part of the WIPP site is an area of poor seismic reflections. The first direct evidence of the structural complexity of this area was obtained in 1975 when ERDA-6 encountered very high dips of the upper Castile anhydrite beds and pressurized brine. On the basis of seismic reflection data then available, Long and Associates (1977), showed a "highly disturbed area (Castile)" in the northern part of the WIPP site (Fig. 23). Several more seismic reflection surveys were conducted in 1978 and 1979 and the boundary of the disturbed zone was broadened to include the northern part of Zone III in a "zone of Anomalous Seismic Reflection Data" (SAR, 1980, Fig. 2.7-23). The same figure (Fig. 23) also shows a "Line indicating steepening of dip of Castile strata to the north" More recently, Borns et al, (1983) have delineated the "Disturbed Zone" (DZ) on the "combined basis of structure exhibited in boreholes and by the chaotic seismic reflection data in the northern part of the site" (p. 10). This figure, reproduced here as Fig. 24, shows a band of DZ bordering the Capitan Reef and passing through the northern part of the WIPP site. Since the zone of WIPP is not identified in this figure and there is no scale, it is difficult to estimate the part of WIPP covered by this band of DZ. The text of Borns et al., (1983, p. 11) however, explains that the southern boundary of DZ approximately coincides with the "line indicating steepening of dip of Castile strata to the north," which is about 2/3 mile north of ERDA-9. Of more interest are the two other areas identified as DZ in this figure. The circular area to the southwest appears to be based on the structure observed in the Belco-Hudson Well. The other oblong area, south of the highway, appears to include the Poker Lake anticline. The report (Borns et al 1983) does not contain an explanation for the inclusion of these two areas in the "Disturbed Zone."

Other than being an area of poor seismic reflections, the Disturbed Zone has never been properly defined. Borns et al (1983) have variously defined it

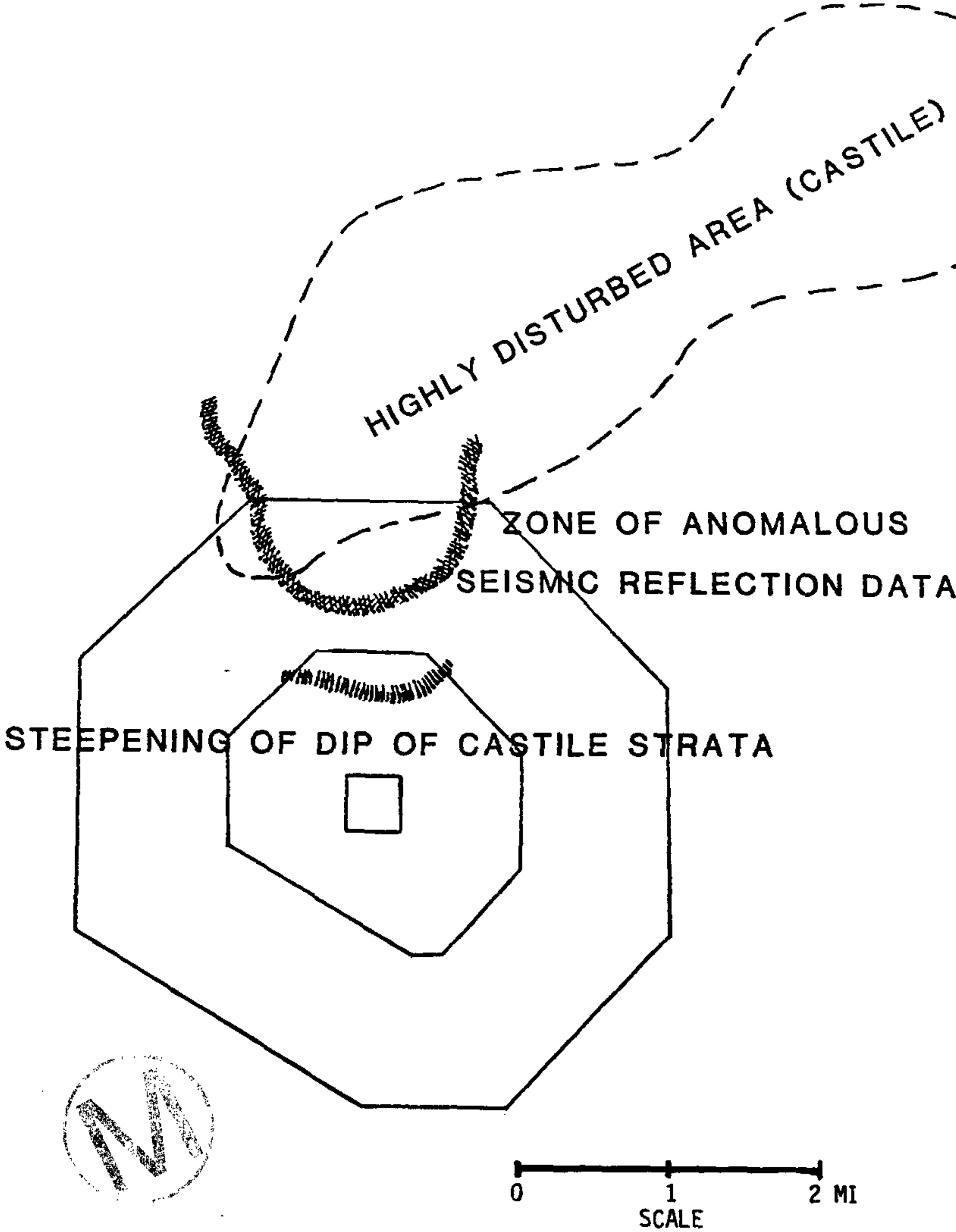

Figure 23. WIPP Site and the southern limits of the "Highly Disturbed Area" (GCR), the "Zone of Anomalous Seismic Reflection Data" and the "Steepening of Dip of Castile Strata" (SAR).

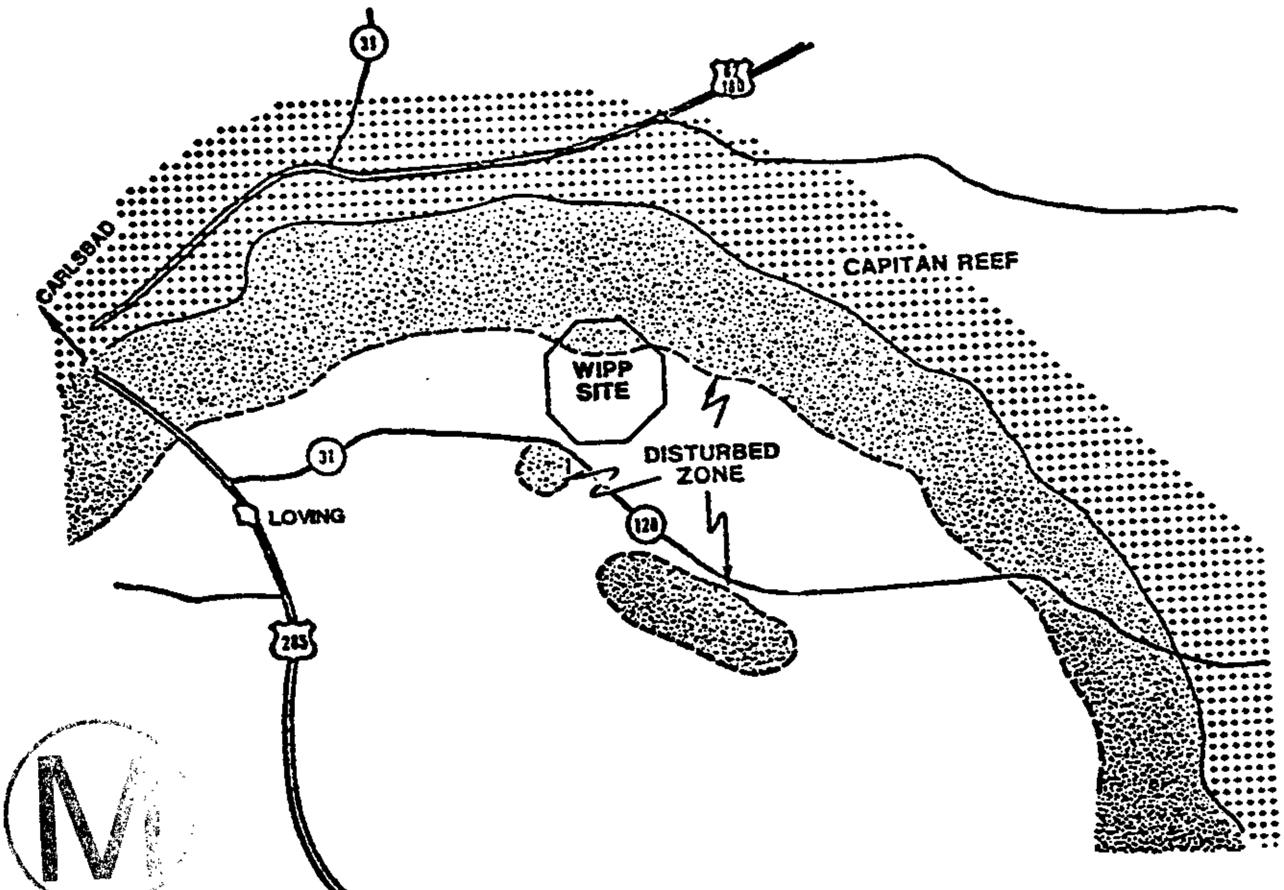

Figure 24. Aereal extent of the disturbed zone, northern Delaware Basin (from Borns et al., 1983)

as, "the area where the Castile/lower Salado departs from generally parallel beds with slight dip" (p. 11) and "The outer edge of the mapped flow structures is here taken as the limit of the DZ. This definition is necessarily ambiguous. It includes the anticline at WIPP-12, and may or may not include the anticline in Sec. 19" (p. 69).

2.0 Areal Extent

In earlier DOE publications, e.g. Powers et al (1978) and Register (1981)*, the disturbed zone was presented as a zone bordering the Capitan Reef. Borns et al (1983) have widened this zone to include the WIPP-12 structure where brine was encountered. In addition, they have shown two more areas, to the southwest and south of the WIPP site (Fig. 23), as part of DZ. No rational explanation has been provided for separating these two areas from the band bordering the reef. The seismic profiles do show structures between WIPP-12 and Belco-Hudson well, but there are no wells penetrating the Castile formation between these two and, therefore, the boundary of the circular DZ shown southwest of the site in Figure 23 is arbitrary.

Concerning the explanation for the limited areal distribution of the disturbed zone, Borns et al (1983) state, "no hypothesis adequately answers why the deformation has a limited areal distribution" (p. 4). However, a hypothesis has been offered by them (on p. 87-88) to explain this phenomenon. It concerns the difference in the yield strength of the rock due to anomalously high water content which would facilitate grain boundary pressure solution.

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*Register (1981) showed the DZ as a 6 mile wide "Deformation Front" bordering the reef. Popielak et al (1983) simply refer to it as, "this band or belt extends underneath the WIPP site" (p. G-38) and avoid assigning a southern limit to it.

Because of the absence of identifiable boundaries of DZ and the lack of an adequate explanation for a limited areal extent, it seems logical to conclude that some structural complexity in the Castile formation may exist to varying degrees anywhere in the northern Delaware Basin including the WIPP site.

3.0 Geophysical Data

3.1 Seismic Reflection

The disturbed zone has been delineated primarily on the basis of seismic reflection data. The seismic data indicate a "blocky structure with abrupt dip changes and offsets (faults) between units" and "the seismic character (wiggle shape) changes, which indicates variations in thicknesses and/or acoustic properties." (Borns, et al, 1983, p. 69). The seismic data at the disturbed zone shows that the geologic structures within the Castile formation are too complex to map with the seismic technique. It is this complexity of geologic structures within the Castile that identifies the DZ from the "undisturbed" strata. The interpretations from the seismic profile are supported by "the steep lamination dips, variable stratigraphic thicknesses and petrographic features (e.g. recumbent folds, shear zones) exhibited by core" (Borns, et al 1983).

Since most of the deformation in the disturbed zone is restricted to the Castile formation and involves a redistribution of the massive anhydrite and halite beds within this formation, it was thought that the gravity survey should pick out the lateral density variations resulting from the deformation. The interpretation of the gravity survey is described in Chapter 3 of Borns, et al (1983). According to this interpretation, "the (gravity) anomalies are much too sharp (shorter double half-width) to originate within the Castile formation. They extend into areas that are indicated by the seismic profiles as undeformed. The negative gravity anomalies were established by drilling to originate from lateral density variations within relatively flat strata." (p.73).

The only explanation of lateral density variations within a shallow zone as interpreted from the gravity survey, provided by Borns et al (1983) is that the negative anomalies represent, "decreased rock densities near karst channels, primarily in the Rustler formation" (p. 73). The question of karst hydrology in the Rustler formation is discussed in the section on "Rustler Hydrology".

4.0 The Origin of the Disturbed Zone

Borns et al (1983) discusses the following hypotheses of origin for the disturbed zone:

- Gravity Foundering
- Dissolution
- Gravity Slides
- Gypsum Dehydration
- Depositional Processes

Out of these, they appear to favor the gravity foundering and, to a lesser extent, gravity sliding, as the mechanisms which are most consistent with the available observations. As far as the movement of salt within the Castile formation is concerned, gravity foundering appears to be a reasonable hypothesis to explain the phenomenon. The difficulty with this hypothesis is, of course, in explaining the areas which remained undeformed, adjacent to the deformed or "disturbed" areas.

5.0 The Age of Deformation

The geological time during which the deformation in the DZ occurred has been a question of debate in the literature. The following account provides a summary of various approaches to answer this question.

Kirkland and Anderson (1970) studied the microfolding in the Castile strata exposed in the western part of the basin. By noticing the relationship between the orientation of microfolds and the larger folds, which in turn correspond with the basic Cenozoic structural grain of the basin, they concluded that the Castile microfolds postdate the late Cenozoic regional tilting. Anderson (in

Chaturvedi, 1980) showed that the ERDA-6 core has a similar stretching of microfolds as seen at the stateline Castile outcrop, and inferred from this, that the deformation in the DZ would also be post Cenozoic-tilting of the basin.

Borns et al (1983) have examined the possibility of dating the deformation by applying the axiom that the deformation must predate deposition of the oldest underformed strata. However, this axiom cannot be applied to a situation where the deformation is clearly stratabound in Castile and becomes dampened upward and downward in the section.

Consideration of the mechanism of gravity foundering, the preferred hypothesis for the deformation in the DZ, led Barrows (1983) to the conclusion that the deformation would remain active until all the anhydrite has settled beneath the halite. Since this has not yet happened in the DZ, the implication is that the deformation in the DZ is an active, ongoing process.

6.0 The Rate of Deformation

Barrows (1983) has calculated that the time required for the deformation in the Castile through the process of isostatic movement of salt would range from 10^4 to 10^7 years. Borns et al (1983) have calculated that, by this mechanism, a structure of the size of WIPP-12 anticline could develop at the WIPP site in a time frame of approximately 10,000 years to 250,000 years. Such a structure, developing in the Castile anhydrite, would produce fractures and may result in the development of a brine reservoir. Although theoretically possible, Borns et al (1983) argue that the development of a structure directly under the site would be a random event and given that the conditions for such an event have existed for the past several millions of years, it would be very unlikely for a structure to develop directly under the site during the next 250,000 years.

Borns et al (1983) have calculated the effect of the "deformation front" progressing toward the site. By assuming an average width of 10 km of the DZ adjacent to the reef and 30 m.y. as the time since basin tilted and the deformation began, they calculate that the belt has grown at a rate of 0.3 mm/yr and "At this rate 4.6 m.y. would be required for the deformation front to progress over the site."

The assumptions made in this calculation may not be valid. Fig. 1 of Borns et al shows the width of DZ bordering the reef, near the WIPP site, to be about 16 km (≈10 miles). The main phase of the uplift occurred in late Pliocene to early Pleistocene time (King, 1948; Hayes, 1964) or about 2 to 6 m.y. ago. Therefore, a more realistic assumption would be that the deformation has progressed 16 km in 2 to 6 m.y., or 2.7 to 8 Km per million years. The edge of the WIPP-12 structure is about 1 Km north of the center of the site. Using these assumptions, the deformation front would reach the center of the site in 125,000 years to 375,000 years.

7.0 Conclusions

It is clear that the structural deformation is most pronounced within the Castile formation and near the Capitan Reef. However, there is no rational basis to assume a 10 km band of deformation bordering the Capitan Reef. The WIPP-12 structure clearly shows that the "front" extends to at least the northern part of the WIPP Zone II. A more conservative approach would be to assume that the entire WIPP site is within the zone where the Castile beds have been deformed to varying degrees and include the Belco-Hudson structure within this zone. Further, the interpretation of the structure at WIPP-11 shows that the involvement of the Delaware Mountain Group formation with the deformation in Castile, at least locally, is possible, and at this drill hole the Castile structural deformations appear to extend into the lower Salado as well.

The gravity foundering hypothesis provides a reasonable explanation for the style of deformation present in the Castile formation in the northern Delaware Basin. By using this hypothesis, Borns et al (1983) have calculated that if the deformation is progressing towards the WIPP repository area, it would take 4.6 m.y. for the deformation front to reach the area directly under the WIPP repository. EEG's calculations show that this may happen in 125,000 to 375,000 years. The progression of a structure such as that located at WIPP-12, however, requires conditions which facilitate the gravity foundering mechanism and these conditions (e.g. high trapped fluid in rock, low yield strength, etc.) may not exist under the southern part of Zone II of the WIPP site. The borehole DOE-1 drilled just outside the Zone II, to the southeast, certainly does not exhibit the Castile deformation structures except some minor lateral flow textures in the Castile halites. Further, with the reorientation of the WIPP repository to the south within Zone II, the repository would now be in a relatively undeformed region as interpreted from the seismic reflection data. EEG, therefore, concludes that the proposed WIPP repository in the southern part of Zone II is located in a relatively undeformed area.

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HYDROLOGIC TRANSPORT CHARACTERISTICS OF THE RUSTLER AQUIFERS

The site validation report (DOE, 1983) concluded that the Culebra and Magenta Dolomite aquifers of the Rustler Formation are the only aquifers of significance at the WIPP site. Of the two, the Culebra is considered the most important and is the target of DOE's detailed hydrologic transport studies. Recent modeling studies (Barr et al., 1983), cited by Weart (1983) indicate that water will move less than 2 miles in 1000 years in the region near the site but the document (Barr et al, 1983) was unavailable for review by EEG on May 25, 1983.

While the general hydrogeology of the Rustler aquifers has been presented in the section on Regional Hydrology, specific aspects relating to a repository breach and the transport of radionuclides to the biosphere are discussed in this section. Neither the breach mechanism nor the mechanism to move radioactive material 1400 feet from the repository to the Rustler are addressed in the following discussion.

Figure 25 shows the WIPP site, the pertinent test holes, the location of Laguna Grande de la Sal, the Pecos River at Malaga Bend, and the approximate boundaries of Nash Draw. The three Rustler aquifers in ascending order are the Rustler-Salado interface residuum, the Culebra Dolomite, and the Magenta Dolomite.

1.0 Rustler-Salado Residuum

Groundwater in the Rustler-Salado residuum flows southwest from the site with a possible discharge at Laguna Grande de la Sal, but the major discharge point is the Pecos River near Malaga Bend. In Nash Draw the transmissivity is as high as 8000 ft /day (Hale et al, 1958), but it is less than 3 x 10^{-} ft /day within 2 miles of the center of the site. In addition, the high magnesium and potassium concentration of the water (Mercer, 1983) in zone II would indicate a very restricted flow system. Therefore, the Rustler-Salado contact residuum is not considered to be a major avenue for the transport of radionuclides to the accessible environment.

2.0 Culebra Dolomite

Where hydraulic conductivity has been measured in the Rustler, the Culebra has been the most conductive layer. Hence DOE has concluded that the Culebra is the limiting aquifer for modeling studies.

The potentiometric surface map of the Culebra is presented in Figure 18. From these data one might conclude that the direction of flow from the site is due south to about the center of T 23S, R. 31E, and then southwest to a discharge point at Malaga Bend. Recent work by Gonzalez (1983) to define the anisotropy of hydraulic conductivity (Figure 25) has led to the conclusion by DOE that the flow from the site will be southeast and then westerly to Malaga Bend. The decrease in TDS and the change in water chemistry from sodium and chloride to calcium, magnesium and sulfate south of the site has been discussed in the Regional Hydrology section. Until the chemical inconsistencies are explained, the hydraulic head distribution shown in Figure 18 does not definitively show that the direction of groundwater flow is other than along a straight line to Malaga Bend. To date, the anisotropy of conductivity has been determined at only three locations; H-4, H-5, and H-6. The direction of the principal component of the transmissivity tensor is nearly identical at test pads H-5 and H-6. At H-4, the direction of the principal component of the transmissivity tensor is rotated about 50° counterclockwise in relation to H-5 and H-6. No data on anisotropy are available at the center of the site or to the southeast. Additional anisotropy tests are needed to accurately predict the direction of groundwater flow in the fractured Culebra Dolomite.

When the direction of groundwater flow and specific discharge are firmly established, the speed at which the solutes will travel is dependent on the effective porosity and the distribution coefficient. Gonzalez (1983) has performed a number of tracer tests to estimate effective porosity. The results of two tracer tests, at test pads H-2 and H-6 yield different results.

The recirculating tracer test at test pad H-2 yielded an effective porosity of 18 percent. The convergent tracer test at test pad H-6 yields effective porosities of 0.7 and 11 percent. These results point out some very interesting aspects of solute transport in the Culebra.

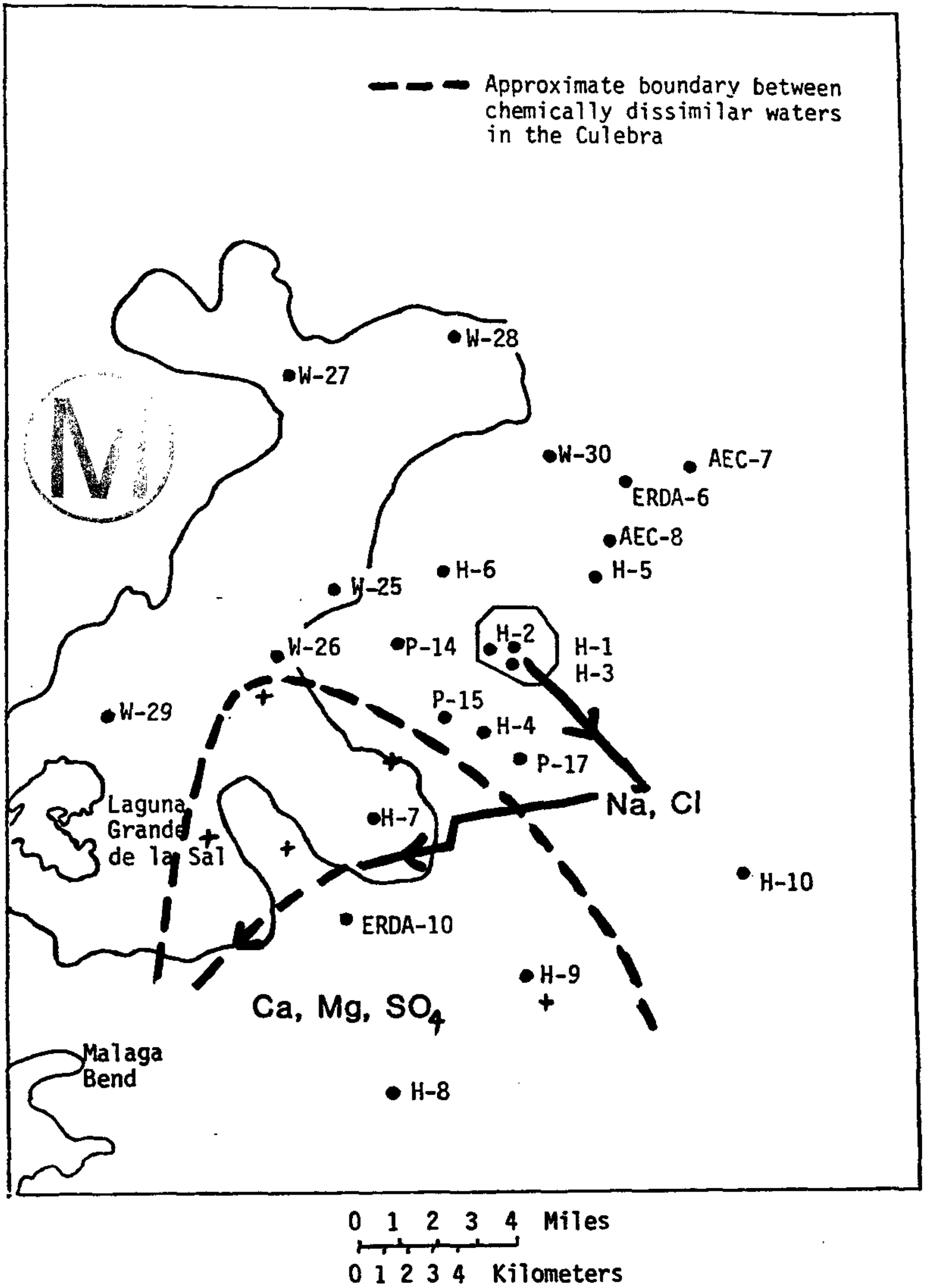

Figure 25. Particle flow path estimates 1983 in the vicinity of the WIPP site. Major chemical constituents of the Culebra water are indicated (based on Gonzalez, 1983)

Groundwater flow in the Culebra through fractures (Gonzalez, 1983; Weart, 1983; Mercer, 1983) is dramatically displayed by the H-6 tracer test. The three well configuration (labeled a, b and c) was an equilateral triangle, 100 feet on each side, with pumping from well "c" and tracer injection into the other two. The peak concentration in the b-c direction was 10 times greater and arrived 30 times faster than the peak concentration in the a-c direction. As the hydraulic conductivity in the b-c direction is at most 2.1 times greater than the hydraulic conductivity in the a-c direction, the travel time differences were attributed to differences in effective porosity. This assumption implies an equal flow path length, but this may be a poor assumption in fractured media.

While the b-c well pair may have intersected the same fracture, the a-c well pair may not. The b-c flow path would have been nearly a straight line whereas the a-c path could have been extremely tortuous thereby causing a long flow path. This interpretation would not be inconsistent with the hydraulic conductivity data. The water level response in well "a" due to pumping in "c" is a pressure response in the confined Culebra aquifer and does not signify the movement of large amounts of water.

Because the tracer tests force the groundwater and tracer to flow in a specific direction, the flow may or may not coincide with the preferred natural flow direction. Parameters derived from an artificial flow test may not be the appropriate parameters to use in a natural flow situation. The apparent variability of effective porosity in the H-6 tracer experiments is significant because effective porosity exhibits such a strong influence on calculated water velocities.

Although water transit times in Nash Draw are rapid, the controlling times are associated with the relatively small permeabilities observed near the center of the site. If the hydraulic conductivity at H-1 (0.003 ft/d) and an effective porosity of 0.18 (from the H-2 tracer test) are representative of the site, then transit times are long. If the hydraulic conductivity at H-3 (0.86 ft/d) and an effective porosity of 0.007 (from the H-6 tracer test) are representative, transit times are short.

The lack of anisotropy data at the site severely limits the confidence one can place in any model results. In fractured media, such as the Culebra, the hydraulic gradient does not necessarily indicate the direction of groundwater flow. In fact, the flow direction could be nearly parallel to the hydraulic head contours. The unexplained decrease in TDS and a change in the general chemical nature of the Culebra water from sodium and chloride at the site to magnesium, calcium, and sulfate south of the site indicates that insufficient data are presently available to adequately characterize the flow system south of the site. The anisotropy of hydraulic conductivity at the site must be determined before the flow direction can be postulated. The tracer tests provide information on the transport of conservative solutes, but these tests generate artificial flow systems. In fractured media, these tracer tests may not provide the proper data to use in modeling the transport of water and solutes in a natural flow system. However, the tracer tests are the only means currently available to estimate the solute transport parameters in a reasonable amount of time.

The hydologic testing program conducted by Sandia National Laboratories is ongoing. Future testing is planned at the site and to the south and southeast. These additional tests will hopefully provide adequate data to confidently model the groundwater flow direction and velocity at the site.

Until the Culebra groundwater flow system is adequately understood, consequence analysis scenarios that assume essentially a straight line connection between the site and the nearest probable discharge point, Malaga Bend are valid. EEG has modeled the consequences of 3 scenarios in which a repository breach injects radioactivity into the Culebra aquifer (Greenfield, 1979; Wofsy, 1980; Spiegler, 1981). In two scenarios transport is assumed to be straight from the site to Malaga Bend with discharge into the Pecos River. Both analyses are conservative, but may not be bounding. The largest calculated one year exposure for an adult drinking Pecos River water containing radionuclides is less than 10 mrem to the bone (Greenfield, 1979). This scenario is conservative in that a large rate of waste dissolution was assumed, but it is not conservative in terms of groundwater velocity. The second scenario (Wofsy, 1980) is a sensitivity analysis which examined the consequences of plutonium transport only. The maximum exposure for the adult whole body 50-year dose commitment from drinking Pecos River water is less than 1 mrem. Neither scenario uses concentration (pCi/ℓ) as an input initial condition, but rather uses rates (pCi/sec). Concentration scenarios m… be more appropriate for some scenario analyses.

The third scenario examined the consequences of using contaminated water from a well located three miles from the site. Accounting for desalinization, radioactive decay, secondary water treatment, and solute retardation in the aquifer, the 50-year bone dose commitments from one year of drinking treated water contaminated with U-233 or Pu-239 and Pu-240 were found to be 132 mrem for an adult and 217 mrem for a child.

These doses are not significant when one considers that doses from natural background radiation are between 60 and 100 mrem per year. The dose calculated from scenario 1 (Greenfield, 1979) could be slightly higher than 10 mrem if faster travel times are used. In any event, precise knowledge of the groundwater flow regime in the Culebra Dolomite is needed to insure that the scenarios are bounding. If the flow from the site is to the southeast then the consequences at a Pecos River discharge point should be less than those obtained from the above scenarios. If, however, the fracture network at the site directs flow t… the southwest into Nash Draw, rapid transport times could result in larger doses than indicated by the scenarios.

3.0 Magenta Dolomite

The potentiometric surface map for the Magenta is presented in Figure 21. This aquifer has not been considered as a major vehicle for solute transport by DOE largely because of its relatively low hydraulic conductivity (Gonzalez, 1983).

There are no data for the Magenta on effective porosity, anisotropy of hydraulic conductivity, or dispersivity near the site. It appears that fracture flow in the Magenta is less prominant than in the Culebra (Mercer, 1983). Therefore, the Magenta may be best represented by porous media flow analyses. Magenta water at the site appears to discharge into underlying units near Nash Draw (Mercer, 1983), however, there are no direct observations of such discharge.

The Magenta is not the major avenue for radionuclide transport in the Rustler based on the currently available data. However, if ongoing studies of the Culebra lead to extremely long radionuclide travel times to the accessible environment then hydrologic transport in the Magenta should be considered.

4.0 Solute Retardation

Many radionuclides do not travel at the same velocity as the water, but move at a slower, retarded velocity. The low radiation doses calculated for the hydrologic breach scenarios (ref. Greenfield, 1979; Spiegler, 1981) result in part from the fact that the K_d value greatly retards the rate at which plutonium travels. A sensitivity analysis (Wofsy, 1980) showed that if K_d of plutonium were greater than 10, the effective porosity had little effect on the radiation doses at the Pecos River.

The laboratory measurements are generally performed on powdered rock samples thereby greatly inceasing the rock surface area (Dosch and Lynch, 1978; Dosch, 1980; Lynch and Dosch, 1980)). K_d is generally reported as the mass of solute on the solid phase per unit mass of solid phase divided by the concentration of solute in solution. In fractured media it is better to report the distribution coefficient on a per-unit-surface-area basis (Freeze and Cherry, 1979). Porous secondary material filling some fractures in the Culebra may justify the use of K_d on a per-unit-mass-basis. Laboratory measurements of K_d values may not reflect field conditions. For example, small amounts of plutonium or other elements will decrease the capacity of the rocks to adsorb more plutonium; thus a "loading effect" can reduce K_d values. Chelating agents like EDTA can also reduce K_d values, as can temperature, pH and other physical and chemical factors. The appropriate K_d to use for scenario analyses is not established. Therefore, until in-situ K_d data are available, the smallest reported K_d value should be used to have truly conservative scenarios.

5.0 Possibility of Karst Hydrology in Rustler

A gravity survey was carried out at the WIPP site by Sandia National Laboratories, during 1981-82, with a primary purpose of delineating the "Disturbed Zone" structures within the Castile formation. The field parameters for this study were selected to resolve low-amplitude, broad-wavelength anomalies originating from structures within the Castile formation, more than 3000 ft. below the surface at WIPP (Barrows, 1982). Instead of the anticipated signals, the survey revealed a complex pattern of high-amplitude and short-wavelength negative anomalies. Barrows (1982) interpreted these anomalies as resulting from density (and acoustic velocity) alterations in the vicinity of karst channels. Borns et al. (1983) have presented this as the only interpretation of the gravity data with a disclaimer that the other authors of that report do not necessarily agree with it and it also does not imply endorsement by Sandia National Laboratories. The discussion presented in Borns et al. (1983, p. 3-9) rules out the possibility that the lateral density variations interpreted from the gravity data are caused by facies variations. Weart (1983) states that the negative gravity anomalies might be caused by low-density channel fillings in the Dewey Lake Redbeds.

5.1 Observations Supporting the Presence of Karst

Barrows (1983) compiled other observations besides the negative gravity anomalies to support his conclusion that karst channels exist in the Rustler formation. His observations are summarized below.

5.1.1 Rustler Thinning: The Rustler formation is about 475 feet thick in the southeast corner and about 300 feet thick in the northwest corner of the WIPP site (GCR, Fig. 4.3-8 and Snyder 1983, Fig. 2.25). Barrows cites this "thinning" of Rustler as an example of, "a complex interstratal blanket karst involving halite, anhydrite-gypsum, and, to a lesser extent, dolomite." According to him, if the thinning were caused by dissolution by confined water, it should have proceeded in the direction of flow of the aquifers, which is to the southwest. Therefore, he argues, that "a more likely process involves easterly progressing karst development with downward infiltration of fresh water through feeders in the overlying Dewey Lake formation to karst channels in the Rustler formation.

5.1.2 Closed Depressions: There are a large number of depressions at the WIPP site. The smaller ones may be due to wind deflation but the larger ones can only be reasonably attributed to alluvial dolines, which form when loose surficial material is washed into solution cavities in the underlying rocks. The WIPP-3 depression is a good example of such a doline.

5.1.3 The WIPP 33 Cavities: The borehole WIPP 33, located in Zone IV in the northwest part of the WIPP site, encountered four cavities totaling slightly over 20 feet in the forty-niner and Magenta Dolomite members of the Rustler formation. According to Barrows, these cavities are direct evidence of karst and they demonstrate the relation between alluvial dolines, negative gravity anomalies and karst channels in the Rustler formation.

5.1.4 Lack of Surface Runoff and the Water Balance: Barrows points out that there are about 12 inches of annual rainfall at the WIPP site, most of which falls between May and October. Since the WIPP site has almost no visible surface runoff, Barrows claims that the precipitation collects in the small topographic depressions and rapidly soaks into the ground.

5.2 Observations Doubting the Presence of Karst

Weart (1983, p.20) gives several reasons to doubt the existence of karst conditions over the WIPP site. These are briefly discussed below.

5.2.1 Lateral Movement of Water: The alteration in the Rustler formation is carried out by lateral movement of water along beds of fractured (permeable) anhydrite and should not be ascribed to vertically downward moving waters.

5.2.2 The WIPP-33 Cavities: Features such as WIPP-33 sink is a manifestation of the eastward growth of dissolution along fingers extending from Nash Draw.

5.2.3 Closed Depressions: The depressions interpreted as dolines by Barrows (1982) may have resulted by wind deflation.

5.2.4 Hydrologic Tests: The data from pump tests shows no indication of karst channels underlying the site.

5.2.5 Water Table: There is no free water-table at WIPP and karst development usually requires this condition.

5.2.6 Gravity Anomalies: The negative gravity anomalies might be caused by low-density channel fillings in the Dewey Lake Redbeds.

5.3 Implications of Karst Hydrology

Calculations based on the hydrologic parameters measured in boreholes and tracer tests yield extremely long (5000 years to 40,000 years) travel times of water through the Rustler formation at the WIPP site to the Pecos River at Malaga Bend (Gonzalez, 1983). If karst channels exist in the Rustler formation, the travel time for the tranport of radionuclides in the Rustler formation might be drastically reduced if a breach occurred that would bring radioactive material up into the Rustler.

5.4 Discussion

EEG organized a field trip on May 11, 1983 to afford Larry Barrows an opportunity to point out the field evidence for the presence of karst at the WIPP site. The field trip was attended by 20 geologists and geohydrologists including some of the well known experts in this area. In addition, Harry Legrand has written two brief reports for EEG on this question. The following discussion is based on the views expressed by LeGrand and others in writing, during the field trip on May 11 and during the discussions at the meeting in Carlsbad on May 12 and 13, 1983.

The most direct evidence for karst features near the WIPP site is the sink hole at WIPP-33, approximately 3 miles northwest of the center of the site. The few closed depressions near the site seem to be too conspicuous to have been caused by wind deflation, yet do not show features of typical sinkholes. The hydrologic tests may not detect the presence of fine karst. Even though the Rustler aquifers are under artesian conditions, there are examples at several locations worldwide where karst can develop under such conditions. The gravity anomalies at the site can be interpreted in more than one way. There is sufficient sand and vegetation at the site that very little, if any, water may percolate down into the fractured rock, although careful water balance studies have not yet been conducted. The unconsolidated sand deposits at the surface of the site would facilitate rapid infiltration of precipitation. The depth of infiltration will determine whether the water returns to the atmosphere by evaporation or recharges the groundwater. Most of the hydrologic testing in Zones III and IV of the WIPP site shows the Rustler aquifers to be extremely tight with very low hydraulic conductivities, but the Well H-3, in Zone II shows an anomalously high hydraulic conductivity compared to H-1 and H-2. However, preliminary flow net analyses by EEG indicate that the H-3 hydraulic conductivity is consistent with the potentiometric surface and that the H-1 and H-2 data are anomalous. Finally, the mechanics of removal of halite from the Rustler formation, without invoking vertical infiltration of water at the WIPP site, should be understood.

EEG concludes that although there is very little evidence for the presence of karst conditions east of the western margin of Zone III of the WIPP site, some additional work should be done to completely settle this issue. Recommendations for the additional work include the water balance study, the understanding of the mechanics of salt removal from the Rustler formation, exploration of at least one depression e.g. in Sec. 30, about two miles SW of the center of the site and continued evaluation of the Rustler aquifer hydrology. These recommendations are outlined in more detail at the end of this chapter.

6.0 Dispersion

Dispersion in groundwater flow is a spreading phenomenon that leads to a dilution of the solute. This generally leads to reduction of the peak concentration in comparison to models where dispersion is ignored. An additional phenomenon of dispersion is that a portion of the solute travels faster than the mean velocity. This may be important in situations where first arrivals, rather than peak concentrations, are of paramount concern.

Dispersion is generally ignored in scenario analyses as a means of making the analyses more conservative. If more realistic results are desired, the dispersivity is required. It is not clear, however, that dispersivities obtained from tracer tests which create an artificial flow system are accurate estimates of the parameters applicable to natural flow systems.

7.0 Site Qualification Criteria

It is important for EEG to evaluate how well the WIPP satisfies proposed criteria for nuclear waste repositories. Of concern in this discussion are the criteria that specifically relate to groundwater.

7.1 DOE WIPP Site Qualification Factors (Criteria)

Weart (1982) lists four Site Qualifiction Criteria pertaining to groundwater. The criteria and EEG's determination of how well the WIPP satisfied the criteria are presented below.

Criterion 11.1:

> "Facility and related shafts must not adversely affect existing aquifers which are, or could be, sources of water supply for humans or animals."

Only two aquifers could be affected by the shafts; the Culebra and the Magenta. Perched groundwater, although present in scattered locations near the site, was not encountered during the sinking of either shaft. At the site, neither the Culebra nor the Magenta are likely to be sources of water to humans or animals. Irrespective of that, the sealing of the Rustler in the 12 foot exploratory shaft suggests that in the short term the aquifers will be unaffected. The WIPP appears to satisfy criterion 11.1.

Criterion 11.2:

> "The underground facility must be able to be isolated from waterbearing strata and must not, itself, be located in a water-bearing stratum (stratum which will yield water to a drillhole under the influence of gravity alone)."

The repository level is separated by about 1300 ft. of bedded halite from the overlying Rustler Formation. There is about 1900 feet of interbedded halite and anhydrite between the repository horizon and the top of the Bell Canyon Formation. If the borehole and shaft plugging programs are successful, the respository will be isolated from the water-bearing strata.

Potash mining operations have encountered relatively small pockets of brine in the Salado formation approximately 400 ft. above the level of the repository. These pockets would yield water to a drill hole under the influence of gravity, but to date no brine pockets are observed at the repository level. In any event, a small brine pocket or two would not define the repository horizon as water-bearing. The WIPP appears to satisfy criterion 11.2.

Criterion 11.3:

> "The hydraulic conductivity of the facility stratum must be sufficiently low (10^{-6} cm/sec or less) to prevent the flow of water through that stratum from any source which could develop after facility construction."

Some of the layers in the repository horizon exhibit hydraulic conductivities of near 10^{-6} cm/sec under light loading (Black et al., 1983). Under loadings consistent with in situ conditions, the hydraulic conductivities were much less than 10^{-6} cm/sec. The WIPP appears to satisfy Criterion 11.3.

Criterion 11.4:

> "Calculated hydrologic transport of radionuclides through the waste disposal facility and overlying strata must be slow enough that a significant hazard to humans would not exist even if the disposal stratum were breached."

Under some repository-breach scenarios, the transport of waste from the repository to the Rustler is rapid. Therefore, radionuclide transport in the Rustler aquifers is the critical factor to consider in determining whether a significant hazard to humans would exist if the disposal stratum were breached.

To adequately predict the radiological hazard to humans following a breach and transport of radionuclides in the Rustler, knowledge of the groundwater flow direction, anisotropy of hydraulic conductivity, effective porosity, and solute distribution coefficients are required.

There are no data on the anisotropy of hydraulic conductivity within 2 miles of the center of the site. These data are critical to determining the direction of groundwater flow in the fractured Culebra Dolomite. At present, the nearest observation well southeast of the site (H-10) is 8 miles away. Additional observation wells are planned. The proposed flow path in the Culebra southeast of the site and then west to Malaga Bend (Gonzalez, 1983) is based on insufficient data. Therefore, the WIPP has not yet been shown to satisfy criterion 11.4.

7.2 NRC Criterion on Travel Time to the Accessible Environment

The NRC is proposing criteria for the Disposal of High-Level Radioactive Wastes in Geological Repositories (10 CFR Part 60). One of their requirements concerns water travel time from a repository to the accessible environment. The proposed wording in a late draft (December 1982) of this regulation is:

> "The geologic repository shall be located so that pre-waste emplacement groundwater travel time along the fastest path of likely radionuclide travel from the disturbed zone to the accessible environment shall be at least 1,000 years or such travel time as may be approved or specified by the Commission."

Definitions pertinent to an understanding of the above requirement are:

1) The "disturbed zone means that portion of the controlled area whose physical or chemical properties have changed as a result of underground facility construction or heat generated by the emplaced radioactive wastes...."

2) "Accessible environment means (1) the atmosphere, (2) the land surface, surface water, (4) oceans, and (5) the portion of the lithosphere that is outside the controlled area."

3) "Controlled area means a surface location, to be marked by suitable monuments, extending horizontally no more than 10 kilometers in any direction from the underground facility, and the underlying subsurface, which area has been committed to use as a geologic repository and from which incompatible activities would be restricted following permanent closure."

The intent of this requirement is to have groundwater flow time as one of the multiple barriers to "act independent of overall repository performance to provide confidence that the wastes will be isolated at least for as long as they are most hazardous" (preamble to proposed rule, July 8, 1981). It is recognzied there are uncertainties concerning this proposed NRC requirement. For example: (1) it may be changed before promulgation of 10CFR60; (2) the manner in which dispersion should be included in the travel time; (3) the interpretation of the requirement that should be applied to a bedded salt repository where circulating groundwater is not expected in the host rock; and (4) to what extent it should be applicable to a transuranic waste repository. However, it is worthwhile considering whether aquifers at the WIPP site would meet this criteria.

First it is apparent from the definition that travel time from the repository to the Rustler aquifer would be included in the 1,000 year transport time unless it is interpreted that the disturbed zone includes shafts that penetrate the aquifer. The travel time from breach to arrival at the Rustler aquifer would be greater than 1,000 years itself in several of the scenarios that have been considered. However, with a direct hydraulic connection such as Scenario #2 in the FEIS, the travel time to the Rustler aquifer would be minimal.

Weart (1983) states that recent modeling results indicate that water will move less than 2 miles in 1000 years. The minimal distance from waste emplacement to the edge of Zone III is now estimated to be about 6900 feet due south or 9700 feet in a southeasterly direction. WIPP may not meet the proposed NRC criteria.

8.0 Conclusions

The regional hydrology appears to be adequately understood except for the Rustler Formation aquifers. Of the three aquifers recognized in the Rustler formation, the Culebra represents the bounding transport mode to the accessible environment should the repository be breached and radioactive material brought into the Rustler aquifers.

The work done so far indicates a lack of a clear understanding concerning the direction of flow and the velocity of groundwater in the Culebra aquifer at the site. Additional work is recommended to better define groundwater flow in the Culebra Dolomite aquifer. The question of karst is embodied in the need to better define the groundwater system. The karst phenomenon of concern is the development of open channels in the Culebra aquifer. The channels would greatly increase the groundwater velocity and hence reduce the groundwater travel time. Groundwater travel time refers to the time required for water to flow from the site to a discharge point at Malaga Bend. The time following emplacement that waste enters the groundwater system is the breach time.

The question of breach and radionuclide travel time is important because of the presence of short-lived radionuclides in the WIPP repository. The relative radiological ingestion toxicity hazard of the inventory decreases from approximately 1.00 at 100 years to 0.023 at 1000 years, and to 0.014 at 10,000 years. Therefore if breach and travel times to the accessible environment were only a few hundred years there would be a need to calculate the effect of the short-lived radionuclides on the dose received in the water transport scenarios.

The probability of human intrusion within 250 years after closure is low. In addition, groundwater travel times are currently estimated to be greater than 5000 years. However, the existence of karst channels could reduce groundwater travel times to less than 500 years. The probability of channeling at the WIPP site is also low, but there is still enough doubt to warrant additional testing as outlined below. The expected result of this testing will be to provide greater assurance that channeling does not exist in Zone II and, thereby, improve the confidence that the present scenarios are conservative.

9.0 RECOMMENDATIONS

9.1 Analysis of drawdown data in test holes H-1, H-2, H-3 caused by the open vent shaft. These data can be interpreted as a large scale pumping test and may yield estimates of average aquifer parameters. In addition, the presence of large karst channels should be detectable from the data. Small channels, however, will likely not be detected.

9.2 *Computer modeling of groundwater flow in the Rustler Aquifers.* This will help determine if the measured aquifer parameters through well testing represent the larger area. In addition, the model will help identify recharge to and discharge from aquifers, and leakage between aquifers.

9.3 Publish the results of transport modeling using concentration as an input.

9.4 Long duration pumping at test well H-3, in conjunction with careful monitoring of groundwater levels in H-3 and surrounding wells. This will indicate whether the relatively high hydraulic conductivity at H-3 is of limited areal extent or whether it represents a zone of high hydraulic conductivity extending over a large area.

9.5 Measure the anisotropy of the hydraulic conductivity at test pads H-1, H-2 and H-3.

9.6 Perform convergence tracer tests at H-1, H-3 and H-4. Items 9.4 and 9.5 will yield valuable data for the radionuclide transport modeling. In the March, 1983, Project progress Report (WIPP-DOE-156), DOE states that a tracer test at H-4 is in progress, but no data are yet available.

9.7 Perform tracer test (convergence) at H-6 using sorbing tracers. The K_d of such tracers from the H-6 field test will then be compared to laborator derived K_d using the same tracer and Culebra rock to determine if laboratory derived values are applicable to the field situation.

9.8 Analyze for environmental isotopes (Carbon-14, Chlorine-36, Uranium-234, and Uranium-238) to aid in understanding the groundwater flow direction an relative velocity.

9.9 Drill the planned additional hydrologic testing wells, viz. H-11 and H-12. Obtain the cores while drilling these wells and examine the cores to determine the extent of fracturing and solution residues, which may indicate possible movement of water through zones other than the two dolomite aquifers.

9.10 Conduct a water balance study for the WIPP site.

9.11 Study the mechanics of removal of salt from the Rustler formation at and near the site.

9.12 Drill a shallow hole in the depression in Sec. 30 (SW 1/4) using an auger to determine the depth of soil and the presence of the caliche layer. This would help answer whether it is a sink hole or a wind deflation feature.

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NATURAL RESOURCES AT WIPP

1.0 Introduction

This review discusses the extent of natural resources at the WIPP site, and the results of EEG's analysis of the potential effect of removal of certain of these resources on the integrity of the repository. To ensure consideration of all important aspects of the question of resources, the subject will be divided as follows:

- The nature and extent of resources at WIPP;
- Provisions of important criteria and standards which relate to resources;
- The U.S. Department of Energy's (DOE) Interim Policy on Resource Recovery at WIPP;
- The potential effect of exploration for or removal of resources on the integrity of the repository;
- Summary and conclusions.

The presence of scarce or easily accessible resources at a site under consideration for a nuclear waste repository is undesirable for two reasons: a) efforts at exploration or removal of the resources could lead to structural alterations of the site which over the long term would increase the potential for breach and release of the radioactive nuclides to the biosphere; or b) there is a possibility that it would be necessary to permanently prohibit access through institutional controls and therefore they represent an additional cost consideration. The question of resources is fraught with uncertainty because of the difficulty of assigning values to the resources and degree of technical sophistication to populations thousands of years into the future. Indeed, it may well be that the waste itself will prove to be a resource of the future. For this reason, it is not reasonable to conclude that any site is without resources or is free from the potential for human intrusion or damage.

2.0 Nature and Extent of Resources at WIPP

The known resources at WIPP include caliche, gypsum, halite, potash, possibly lithium, and hydrocarbons. (Most of the hydrocarbons are natural gas and distillate). Several contractors, both private and government, were involved in the evaluation of resources at the site. These are listed in Table 4, and the reports are further described in the references. Table 5 provides a summary of the known resources and the estimated quantities.

2.1 Caliche

Large quantities of caliche are used in New Mexico for road surfacing, however because of extensive deposits in the region, and since it is near the surface and about 2000 feet from the repository horizon, it is not considered to be of potential consequence to the repository.

2.2 Gypsum

Gypsum is found mostly in the Rustler formation, but the quality and bed thickness is inferior to those deposits found west of the site, where it is readily mined by open pit methods. Very large deposits of gypsum are also found in California, Michigan, Iowa, and Oklahoma. These sources account for 62% of the U.S. production. Most of New Mexico's gypsum production is from mines located in Sandoval and Santa Fe counties (about 250,000 tons/yr.). Therefore, it is not likely that gypsum from the WIPP area will ever be of commercial interest, and because of its location in the Rustler, it could be removed without imposing a threat to the repository horizon.

2.3 Halite

Halite in the Salado underlies the entire area of the WIPP site from about 170 meters down to 870 meters below the surface. It is from 90 to 98% pure sodium chloride, but an even purer grade is found in portions of the Castile formation. The Salado salt is interbedded with anhydrite, polyhalite, sandstone and claystone in a regular succession, and in discrete layers that range from 2 cm. to several meters in thickness. The Salado at the WIPP site also includes a zone of potassium minerals, sylvite and langbeinite as discussed below. The total thickness of the Castile salt is about 170 meters at the WIPP site. The leading producers of salt are in Louisiana, Texas, New York, Ohio, and Indiana. About 80% of the annual production is used in chemical manufacturing, and from 12 to 25% for highway deicing. It has been estimated that as much as 61 trillion tons (Klingman, 1975) exist underground in the U.S. as rock salt or as brine. Also, sea water represents an almost inexhaustible source of salt. The U.S., therefore, has unlimited salt resources. There is some salt production in southeastern New Mexico, mostly from the Salt Lake Mine (about 108,000 tons/yr.). Salt is also produced from the Zuni Salt Lake in west central New Mexico. It is likely that brine lakes and potash tailing piles could meet New Mexico's salt needs indefinitely, and that bedded salt at the WIPP site probably will not become economically attractive for several reasons:

- These resources are more than 165 meters below the surface;
- There are plentiful surface supplies of salt in New Mexico;
- At the regional and national level there are virtually unlimited salt reserves which are more economically attractive;
- Water supplies for processing the rock salt are not readily available in the area.

2.4 Potash

The potash resources within the WIPP site are summarized in Table 6 and Fig. 26. Reserves are those resources which are economically recoverable at current prices and removable with existing technology. Most of the potassium ore at the WIPP site lies between 420 and 550 meters below the surface. The estimates of these resources have been reported by John, et al, (1978) of the U.S. Geological Survey (USGS) and are based on a total of 61 holes drilled by industry and 21 by DOE in the vicinity of the site. The U.S. Bureau of Mines (1977) evaluated the extent to which the resources defined by USGS could be classified as reserves.

Resources were considered to be ore zones of at least 4 feet and with sylvite (KCL) and langbeinite ($K_2Mg_2(SO_4)_3$) of at least 8% and 3% richness respectively in K_2O equivalent. Reserves are those deposits having at least 14 and 8% richness in K_2O equivalent. On this basis, the total potash resources within the four zones of WIPP was estimated to be 484 million tons. Of these resources, 132 million tons were considered reserves. Sixty-seven percent of the potash resources are within Zone IV. Sixty-eight percent of the langbeinite and 82% of the sylvite reserves are recoverable from Zone IV. Because of limited water in the area, and solubility considerations, the more likely method of removal would be by underground (room and pillar) mining.

In summary, the nonretrievable potash resources within Zones I, II and III is estimated as 38 million tons of sylvite and 122 million tons of langbeinite. The non-retrievable langbeinite represents 7% of the known U.S. resources of this mineral.

2.5. *Lithium*

Powers, et al, (1978), in the WIPP Geological Characterization Report (GCR), recognized the existence of brine reservoirs containing potentially economic concentrations of lithium (at that time thought to be 140 mg/l at ERDA-6 well, 6 miles northeast of the center of the site). Brine reservoirs have been encountered in the Castile formation on several occasions around the WIPP site (DOE, 1983). The DOE in the GCR concluded on the basis of seismic data that no brine pockets existed within the WIPP site, and therefore stated that lithium is not a potential resource at WIPP. In 1981, however, a brine reservoir was encountered at the northern boundary of Zone II and following extensive studies of the reservoir, it was estimated to contain 17 million barrels of saturated brine having a lithium content of 280 mg/l. ERDA-6 brine pocket was reassayed and found to contain 240 mg/l, and the brine pocket at Union Well (about 3/4 mile northwest of ERDA-6) contained 360 mg/l (DOE, 1983). On this basis, one might conclude that lithium is a potential resource and considering only the WIPP-12 reservoir, the extent of the lithium resources may be as high as 800 tons. It is also of interest to note that the lithium contents of the brine are not nearly as high as in Searles Lake and other non-marine evaporite areas. The United States has reserves in excess of 400 times the amount consumed (as of 1975), much of this Li is from brines in which the average Li content is well over 0.1 percent (as compared to the 0.03% in Delaware Basin brines). The U.S. also supplies about 60% of the World Common Market lithium as well. It is unlikely that the Li content of the Delaware Basin brines will be able to compete with other reserves. It also is likely that removal of the brine at WIPP-12 would not lead to a breach of the WIPP repository with transport of the waste to the accessible environment at a substantially accelerated rate. Therefore, the consequences of this resource recovery are bounded by scenarios already considered.

Because of restrictions on deep drill holes within the site to preserve a buffer zone around the repository, the evaluation of the potential hydrocarbon resources was based on a statistical area survey around the site (Foster, 1974). The economic evaluation of these potential resources was then conducted by Keesy (1976). He concluded that there is a high potential for natural gas in the Morrow unit, but too much of an economic risk for other hydrocarbons. These results are summarized in Table 7. Of course, since Foster's study used a regional statistical approach, there may be considerably more or less than the average quantity of hydrocarbons if the site were actually drilled. Therefore, it is possible that significant reserves of oil also exist within the site.

3.0 Criteria and Standards

Although there are numerous criteria, regulations and guidelines which bear on the subject of site suitability, this report will examine only those which relate to the question of natural resources at a site under consideration for high-level or transuranic waste.

3.1 EPA Proposed Standards

On December 29, 1982, the Environmental Protection Agency (EPA) published proposed "Environmental Standards for the Management and Disposal of Nuclear Fuel, High-Level and Transuranic Radioactive Wastes" (47 FR 58196). These standards apply "to radiation doses received by members of the public as a result of the management (except for transportation) and storage of spent nuclear fuel, high-level, or transuranic radioactive wastes to the extent that these operations are not subject to the provision of Part 190 of Title 40." (Part 190 of Title 40 applies to environmental protection for nuclear power operations.) Section 191.14(f) of these standards states that.

> "Disposal systems shall not be located where there has been mining for resources or where there is a reasonable expectation of exploration for scarce or easily accessible resources in the future. Furthermore, disposal systems shall not be located where there is a significant concentration of any material which is not widely available from other sources."

Furthermore, there is no provision for a variance from this subpart of the proposed regulation. The above provision also is not as explicit as one might like, certain passages from the published preamble add to the uncertainty of the intended meaning:

> "This requirement (section 191.14(f)) would discourage the use of geologic formations which are often associated with resources or mining activity. For example, the frequent mining of salt domes either for their relatively pure salt or for use as storage caverns would argue against locating a repository in this type of structure. However, this same concern would generally not apply to bedded salt deposits because they are much more common." (Certain words are underlined for emphasis.)

Thus, one would conclude that EPA did not intend to prohibit use of geologic formations which are associated with resources, but only discourage such use. Also, the EPA either was not aware of the resources frequently associated with bedded salt (potash, hydrocarbons, etc.) or did not consider these resources to be as threatening to a repository as the commercial activities associated with salt domes.

3.2 NRC Proposed HLW Regulations.

The Nuclear Regulatory Commission (NRC) published on July 8, 1981 its proposed regulations for "Disposal of High-Level Radioactive Wastes in Geologic Repositories" (48 FR 35280). Subsection 60.122 (c)(18) of Siting Criteria of a draft of the final NRC regulation defines as one of several "potentially adverse conditions":

> "(18) The presence of naturally occurring materials, whether identified or undiscovered, within the site, in such form that: (i) economic extraction is currently feasible or potentially feasible during the foreseeable future; or (ii) such materials have greater gross value, or net value, than the average for other areas of similar size that are representative of and located in the geologic setting."

Although WIPP is exempt from NRC licensure and the NRC regulations, if the site were evaluated against these criteria, one would conclude that the WIPP site has adverse conditions as described with respect to natural resources and when adverse conditions exist, the NRC regulations would require additional analysis, specific site characterization or identification of compensating or mitigating factors before qualifying the site.

A comparison of the WIPP site to the two standards discussed above is summarized in Table 8. In conclusion, the WIPP site appears to have adverse conditions by virtue of the of the natural resources. It was on this basis that EEG recommended that DOE indicate its plans for control of exploration and recovery of the resources, and analyze the consequences of such exploration and recovery.

4.0 DOE Interim Policy on Resource Recovery at WIPP

By letter of January 6, 1983, from the Project Manager, WIPP Project Office, DOE provided EEG its revised Interim Policy Statement. This policy authorizes resource recovery from Zone IV (see Figure 26), but would prohibit mining or drilling within Zones I, II, or III. The policy also allows hydrocarbon recovery from Zone I, II, or III by deviated drilling from Zone IV provided the planes formed by the downwara vertical projections of the Control Zone III boundary are not penetrated above 6000 feet.

The policy would also allow solution mining for potash in Zone IV, but is silent on whether castile brine reservoirs under Zone I, II, or III could be accessed from outside of Zone III (eg. to obtain brine for extraction of lithium). One would infer that the 6000 foot restriction would prohibit removal of brine from Zones I, II or III, but if the brine extends into Zone IV, it may be accessible without violating that restriction.

The EEG asked DOE to notify EEG of any requests for mining within one mile of the zone III boundary, but DOE replied that they would notify EEG of any unusual or advance technology planned resource recovery activities which are made known to them by Bureau of Land Management, Department of Interior (BLM).

For this reason, the State intends to negotiate with BLM to obtain notification from BLM of any applications for mining activity within 1 mile of the Zone III boundary. Upon notification, EEG plans to evaluate such proposals and provide appropriate comments, if any, to BLM and DOE, concerning the potential effects on the repository horizon.

5.0 The potential effects of exploration for or removal of resources on the integrity of the repository.

The DOE has considered the consequences of several breach and release events including some which may occur long after the repository is sealed and controls are discontinued and records lost (DOE, 1980, Woolfolk, 1982). Several of these scenarios could occur as a result of drilling activities associated with exploration or mining of resources. In all cases, it was concluded that the resultant radiation doses would be only a small fraction of that from natural

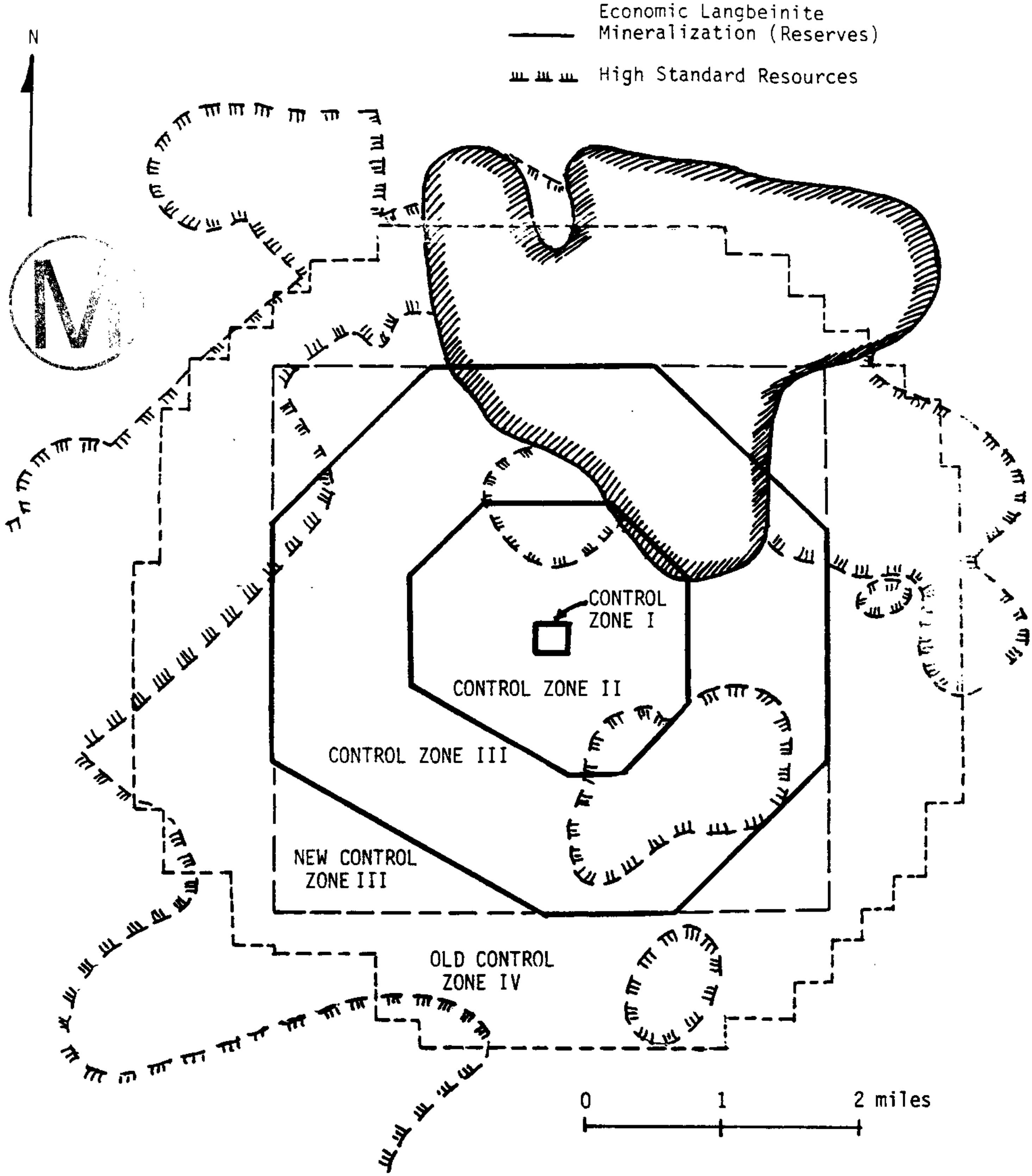

Figure 26. Potash deposits at the WIPP site.

background radiation. The proposed permanent TRU waste inventory (with no high level waste) was used for all such calculations. The EEG has evaluated certain of the models used in these scenarios (EEG-3), and independently considered several other hypothetical breach events associated with human intrusion (EEG-11, 12, 15, and 16). All of these involve low probability events, each associated with considerable uncertainty. Because of the differing assumptions used, the doses are not comparable, but they do suggest that even with conservative assumptions the associated long-term radiation risks of releases associated with natural resource recovery are generally only a small fraction of normal background radiation.

In compliance with one of the terms of the Stipulated Agreement between the DOE and New Mexico (Civil Action of the U. S. District Court for the District of New Mexico, 81-0363, July 1, 1981), the DOE has provided an analysis of the effects of resource recovery if carried out in accordance with the DOE Interim Policy (DOE, 1982). An earlier draft of this report was reviewed by EEG and the revised report (DOE, 1982) was responsive to the EEG comments and recommended changes. The report did not address the effects of brine removal from the WIPP-12 reservoir because at the time of this report, lithium was not recognized as a potential resource. It is likely, however, that such resource recovery is bounded by events already considered. The report also failed to consider bedded salt as a resource. Although EEG agrees that the probability of solution mining of halite from the WIPP site is unlikely, for reasons previously discussed, the potential consequences of such a conservative scenario were considered (EEG-12), and it was concluded that the associated risk is quite small.

Table 4*

Organizations Responsible for Resource Evaluation and Key Reports Concerning Resources

Organization	Responsibility	Reports
U.S. Geol Surv.	Potash Resources as related to ore grade and volume	John et al. (1978) Jones (1978)
U.S. Bur. of Mines	Determination as to what extent the potash resources reported by U.S.G.S. could be economically mined and refined under today's technology and market	USBM (1977)
N.M. Bur. of Mines	Definition of resources and economics for caliche, salt, gypsum, brine, sulfur and uranium	Siemers et al. (1978)
N.M. Bur. of Mines	Oil and gas resources of a four township area which includes the WIPP site	Foster (1974)
Sipes, Williams and Aycock, Inc.	Determination of the economic viability of hydrocarbons under the WIPP site	Keesey (1976)
G.J. Long & Assoc. Inc., Permain Exploration Co.	Interpretation of structure of Paleozoic sediments beneath Ochoan evaporites. These studies were useful in evaluation of hydrocarbons	Long (1976), McMillan (1976)

*From Powers, D. W., et al, 1978.

Table 5. Total Mineral Resources at the WIPP Site*

Resource	Quantity	Depth (ft)	Richness
Caliche[a]	185 million tons	At surface	21-69% insoluble
Gypsum[a]	1.3 billion tons	300-1500	Pure to mixed
Salt[a]	198 billion tons	500-4000	Pure to mixed
Sylvite ore[b]	133.2 million tons	1600	8% K_2O, 4-ft thickness
Langbeinite ore[b]	351.0 million tons	1800	3% K_2O, 4-ft thickness
Lithium[e]	800 tons	3050	240 mg/ℓ brine
Crude oil[c]	37.50 million bbl	4000-20,000	31-46° API[d]
Natural gas[c]	490.12 billion ft^3	4000-20,000	1100 Btu/ft^3
Distillate[c]	5.72 million bbl	4000-20,000	53° API[d]

[a]Data from Siemers et al. (1978).

[b]Low-grade resource and better. Data from John et al. (1978).

[c]Data from Foster (1974).

[d]The degrees API unit has been adopted by the American Petroleum Institute as a measure of the specific gravity of hydrocarbons.

[e]This resource is based on DOE (1983).

*DOE, 1980.

Table 6. Potash Within WIPP Site*

Deposit	Resources (million tons)	Reserves (million tons)	of Resources recoverable in Zone IV	% of Reserves recoverable in zone IV
Sylvite	133	54	71	82
Langbeinite	351	78	65	68

*This table was prepared from data in Johns (1978)

Table 7.* Potential Natural Gas Within WIPP Site

	Total BCF**	In Zones I,II,III BCF**	In Zone IV BCF**
Resources	490 (100%)	211 (43%)	279 (57%)
100%			
Reserves	44.6	21 (47%)	23.6 (53%)

* Based on data from U. S. DOE (1980)

**BCF = billion cubic feet

At a value of $4.40/1000 cubic feet, the total surface value of the natural gas reserves is about $200 million.

Table 8

The WIPP Site Natural Resources and

Federal Standards and Criteria

Standard	DOE Conclusion	EEG Conclusion	Remaining Question
DOE			
a) Site criteria	Site meets.	Natural resources at site create adverse condition.	Lithium not considered.
b) NRC proposed regulations (10CFR60)	No opinion expressed.	Natural resources at site create adverse condition.	Lithium not considered.
c) EPA proposed standard (40CFR191)	No opinion expressed.	Natural resources would render site unqualified.	Language of standard not consistent with preamble. Clarification needed.

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SPDV RESULTS

1.0 Introduction

The Site and Preliminary Design Validation (SPDV) program consists of two phases: Site Validation and preliminary design validation.

The results of the site validation phase were released on 3/31/83 in TME 3177, Results of Site Validation Experiments (ref. 1) which has been reviewed by the Environmental Evaluation Group (EEG) since it comprises item 7 of Appendix B of the Stipulated Agreement. The objectives and activities of the site validation phase are summarized in Table 9 and were intended by DOE to raise the level of satisfaction from "partially" or "adequately" to "complete" of nine WIPP site qualification criteria. The WIPP site qualification criteria are described in WIPP-DOE-116 Rev. 1 (ref. 2).

The results of the preliminary design validation phase were also released on 3/31/83 in a report entitled Preliminary Design Validation Report. Waste Isolation Pilot Plant (WIPP) (ref. 3). The document has been reviewed by EEG since it comprises item 9 of Appendix B of the Stipulated Agreement. The objectives of the preliminary design validation phase are summarized in Table 10. They are intended to demonstrate that the WIPP can be operated safely over its projected lifetime of 25 years and to insure that the waste can be retrieved should such a step be necessary.

2.0 Background of SPDV Program

The first justification for the SPDV program is contained in WIPP-DOE-049 (ref. 4) as follows:

"During the Title I design efforts on WIPP (1979), it has become increasingly obvious that the earlier research and development activities performed primarily by Sandia Laboratories, which were limited by the prohibition of penetrating the salt with drill holes, must be extended to include additional site verification studies and studies to support critical design assumptions

Table 9 SPDV Site Validation Activities

Objective (To Determine:)	Activity
Thickness of Facility Horizon	Map and Log Shafts, Excavations, Horizontal and Vertical Drillholes
Lateral Extent, Continuity, Inclination of Facility	992-m Exploratory Drift to the South Visual and Geophysical Logs, Map Excavations, High-Resolution Gravity Surveys, Correlation With Drillhole Logs
Brine and Gas Content	TGA, Miscellaneous Analysis of Samples Fluid Probe
Mineralogical Content	X-Ray Fluorescence and Diffraction and Microprobe Analysis of Samples
Interbed Characterization	Constituent Analysis, Mechanical Tests, Permeability
Aquifer Characterization	Fluid Inflow to Shaft, Piezometers in Shaft, Water Samples
Fluid Potential of Facility Level	Inflow of Excavation, Solution Composition
Permeability of Facility Level	Tests on Laboratory Samples

Table 10 Preliminary Design Validation Objectives

- To validate the design for the WIPP access shafts and TRU waste disposal demonstration rooms.
- To evaluate the amount and rate of shaft convergence and room creep deformation and to correlate these data with model predictions.
- To perform a preliminary evaluation of creep in salt and of the steady-state creep model.
- To evaluate instrumentation systems for accuracy and the reliability of measurements made with them in rock salt and to document the suitability of the system for future measurements.
- To evaluate the response of in situ formations such as clay seams and other material layers in addition to the salt.
- To collect large numbers of samples of rock salt and other materials and to conduct laboratory and bench-scale tests to determine the mechanical properties of these samples.

associated with the stability of the underground openings. The rationale and support for the proposed DOE actions has come from three primary sources:

The Nuclear Regulatory Commission, in testimony before the Runnels Oversight Committee, stated that their new proposed licensing process for HLW repositories will include the necessity of any repository applicant for license to have conducted early, detailed site exploration and evaluation at depth (i.e., exploratory shaft).

The Panel on the WIPP of the Committee on Radioactive Waste Management of the National Academy of Science advised that continuing efforts to acquire the necessary additional information solely by means of surface exploration, including boreholes, have reached the point of diminishing returns and recommended that:

a. An exploratory shaft be sunk at the site of one of the proposed shafts as soon as practicable, to the depth of the proposed repository horizon,

and that

b. Drilling be done, and tunnels developed in the salt as necessary to conduct the measurements and observations needed to resolve remaining site-specific geotechnical uncertainties and to ascertain the degree to which the site is suitable for the excavation of a repository.

The USGS, in testimony before the Runnels Oversight Committee, stated that their position on the suitability of the proposed site for WIPP could not be provided until observations taken during shaft sinking, and the results of in situ tests at the candidate horizon, were available."

The SPDV program was designed by Sandia National Laboratories (SNL) to satisfy the above demands. It was categorized into three general areas with the following headings: 1) Site Acceptability Program; 2) Measurement for Design Verification and Repository Boundary Determination; 3) Early Non-Waste Experimental Program. Although there have been changes in the experiments, the three categories have remained and are known today as: 1) Site Validation Program; 2) Preliminary Design Validation Program, and 3) WIPP Research and Development Program (R & D). However, only items 1 and 2 have been retained the current SPDV program; the WIPP R & D program has become a separate program. An environmental assessment (ref. 5) and a terse description of the SPDV program (ref. 6) were published in October 1980. The WIPP R & D program, which had already become a separate program was not included in the description.

A detailed description of the Site Validation Program, TME 2975, was published in April 1981 (ref. 7). It linked the experiments of the SPDV program with the WIPP site qualification criteria drafted by SNL and published in the Geological Characterization Report (GCR) (ref. 8). TME 2975 cross-referenced the WIPP site qualification criteria with the Office of Nuclear Waste (ONWI)'s criteria for high level waste (HLW) repositories (ref. 9). EEG commented on TME 2975, and these comments led to the issuance of a revised document (ref. 10). Another revision was published in October 1982 (ref. 2). This revision included the studies required under the Stipulated Agreement and the replacement of five proposed horizontal core holes at the repository horizon by an exploratory drift. EEG had taken the position that the horizontal core holes should be replaced by drifts in order to obtain more information than could be obtained from coreholes. The suggestion had first been made in the Golder Associates Report (ref. 11), an independent review of WIPP-DOE-049 commissioned by the Nuclear Regulatory Commission.

A detailed description of the Preliminary Design Validation Program first became available with the publishing of the draft report SAND 81-2628 (ref. 12) in March 1982. A report entitled Preliminary Design Validation Plan (ref. 13) was issued in January 1983; it was required as item 8 of the Stipulated Agreement. EEG commented on the drafts of this report.

3.0 SPDV Configuration and Instrumentation

Two shafts have been drilled and an underground experimental area has been mined. The layout of the experimental facility and the boundaries of zone 2 are shown in Figure 27. The 3.66-m in diameter shaft, the exploratory shaft, which was drilled to a depth of 702-m (2300 ft.), was outfitted to provide the

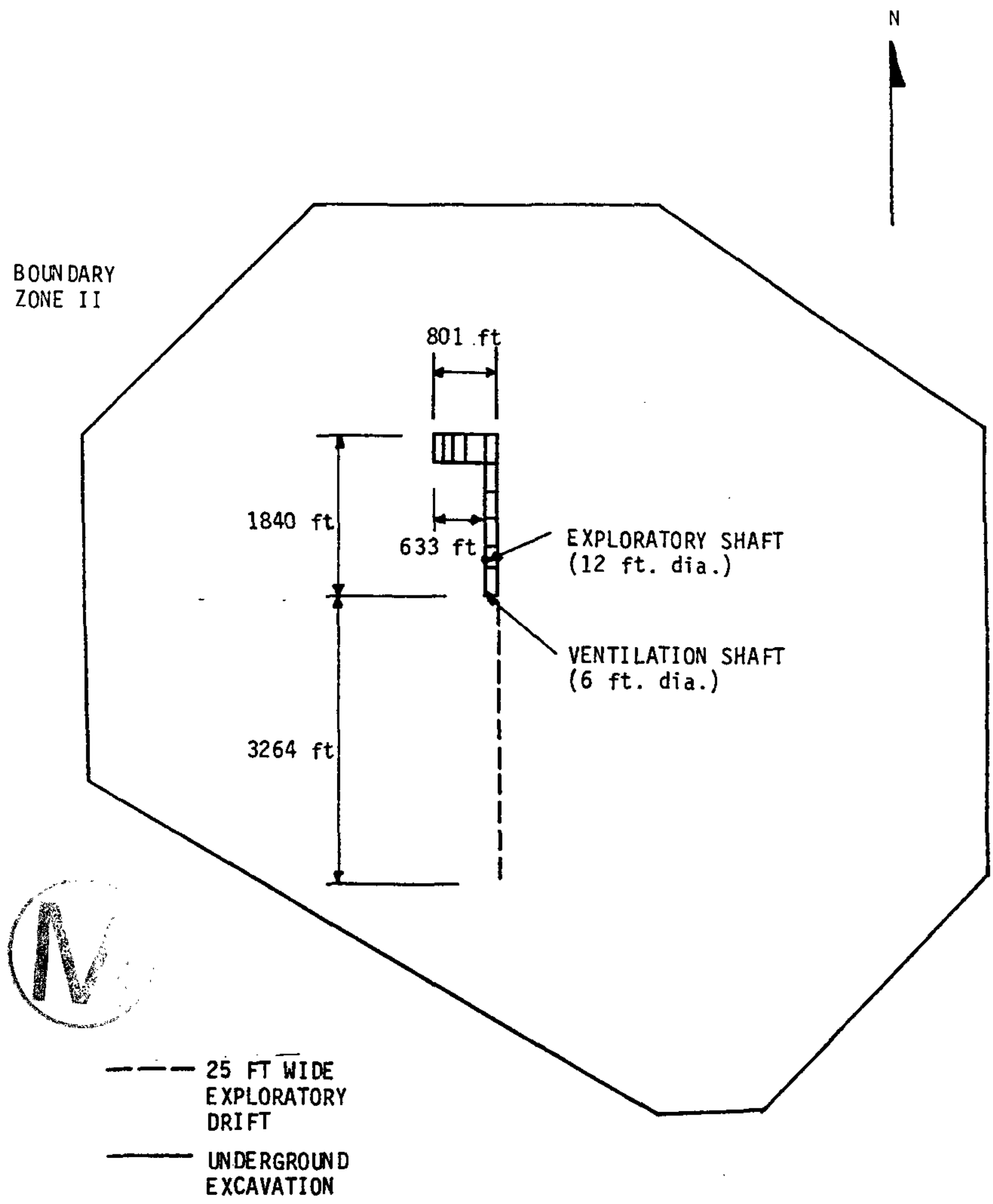


Figure 27. The SPDV layout.

main access to the underground and to bring the mined salt to the surface . The exploratory shaft has three testing areas: the upper part, which has a grouted steel liner from the surface down to the Salado formation (247-m, 850 ft.) is instrumented with piezometers for gathering hydrological data from the Rustlerformation, and with strain gages for gathering data on liner deformation; the shaft liner key, which seals the liner bottom from seapage, is instrumented with piezometers for obtaining hydrological data and with strain gages for obtaining strain data; the unlined portion of the shaft is instrumented for obtaining data on shaft closure and salt deformation. Figure 28 shows the instrumentation locations in the exploratory shaft. The 1.83-m diameter ventilation shaft is unlined except for about 100 ft. of surface conductor. It provides an outlet for the ventilation system and an escape way. It will be transformed into the 20 ft-diameter waste shaft later. The two shafts also provided mappings of the strata from the surface down to the repository horizon.

The underground facility consists of a 995-m (3264 ft.) drift to the south and a network of drifts to a design validation test panel in the north. The drift to the south was excavated to obtain data on the salt and to map the geology in the area of the repository. The design validation test panel consists of four 10 x 3.96-m rooms separated by 30.48-m pillars. The drifts and the test panel are instrumented to obtain data on room stability and room closure. Figure 29 shows the instrumentation of the underground facility.

For completeness, Figure 30 shows the entire WIPP underground layout.

4.0 Results of Site Validation Program

The results of the Site Validation Program are summarized below.

The host rock interval exhibits acceptable thickness and lithologic characteristics as projected from surface-based studies. All principal marker beds and intervening strata are consistent in thickness within the host rock interval throughout the extent of potential underground workings. The average apparent dip of rock strata is less than one degree. These statements are based on geologic profiles from deep boreholes, in-drift coreholes, geologic

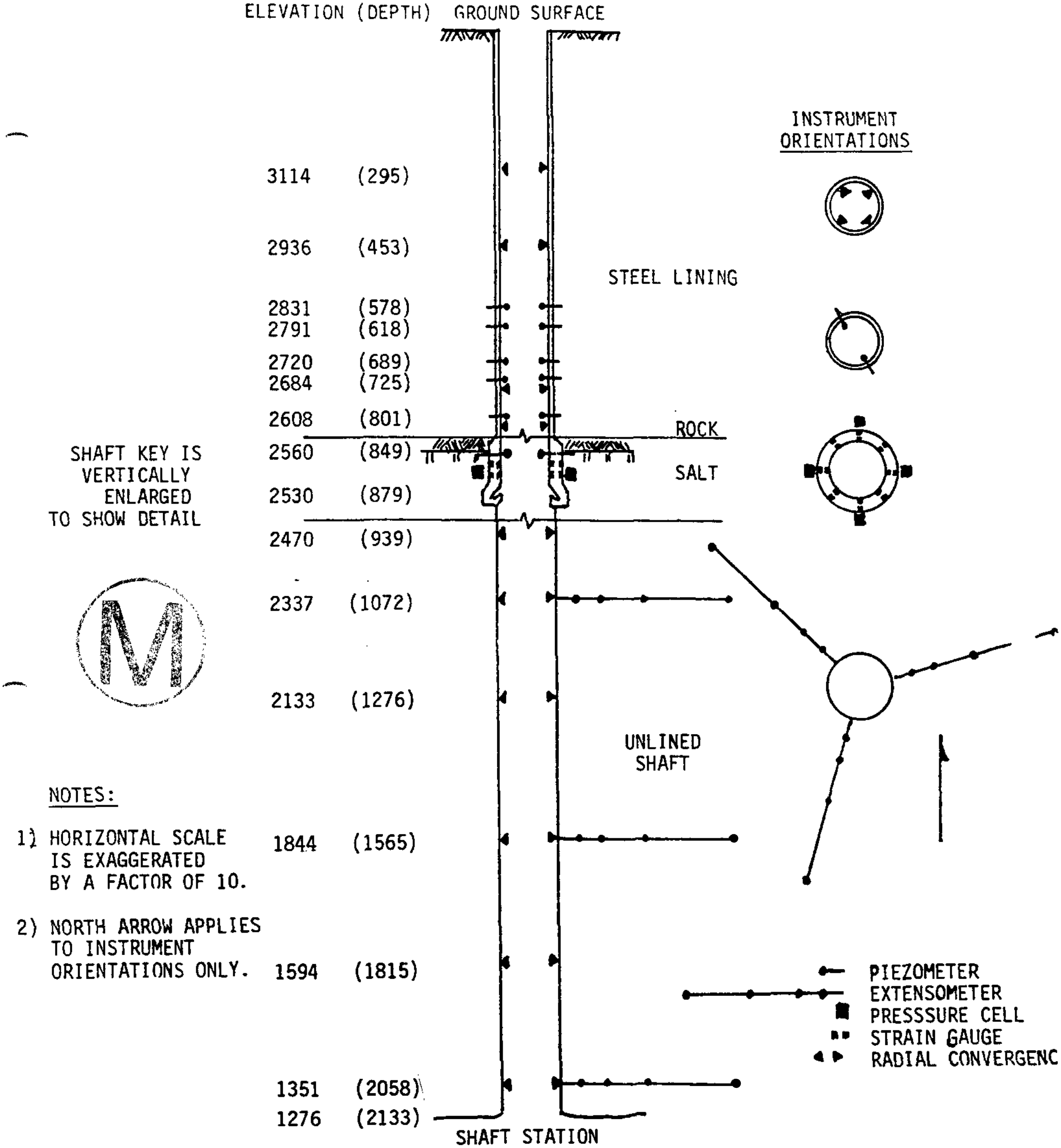


Figure 28. Instrumentation in the exploratory shaft.

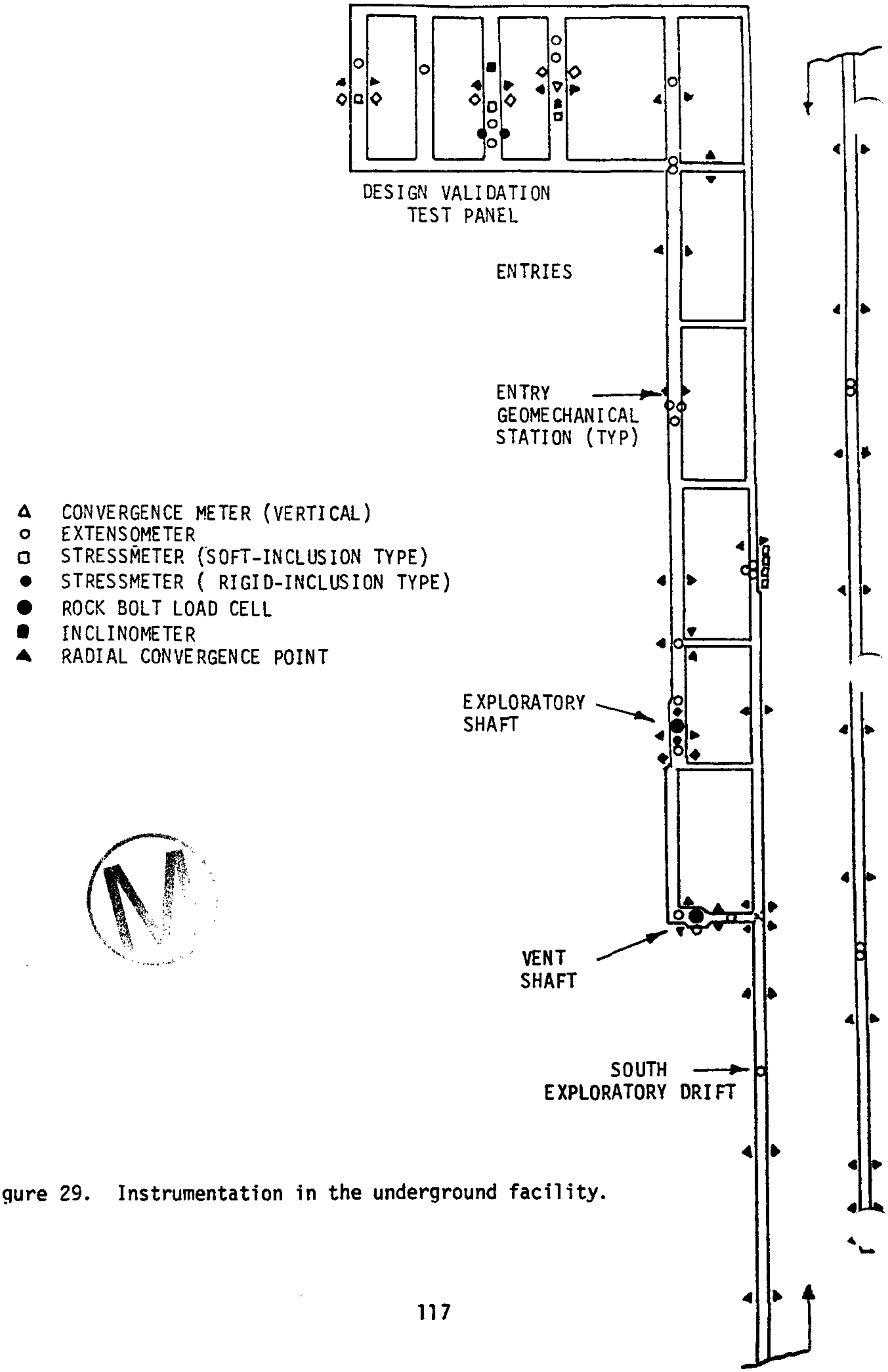


Figure 29. Instrumentation in the underground facility.

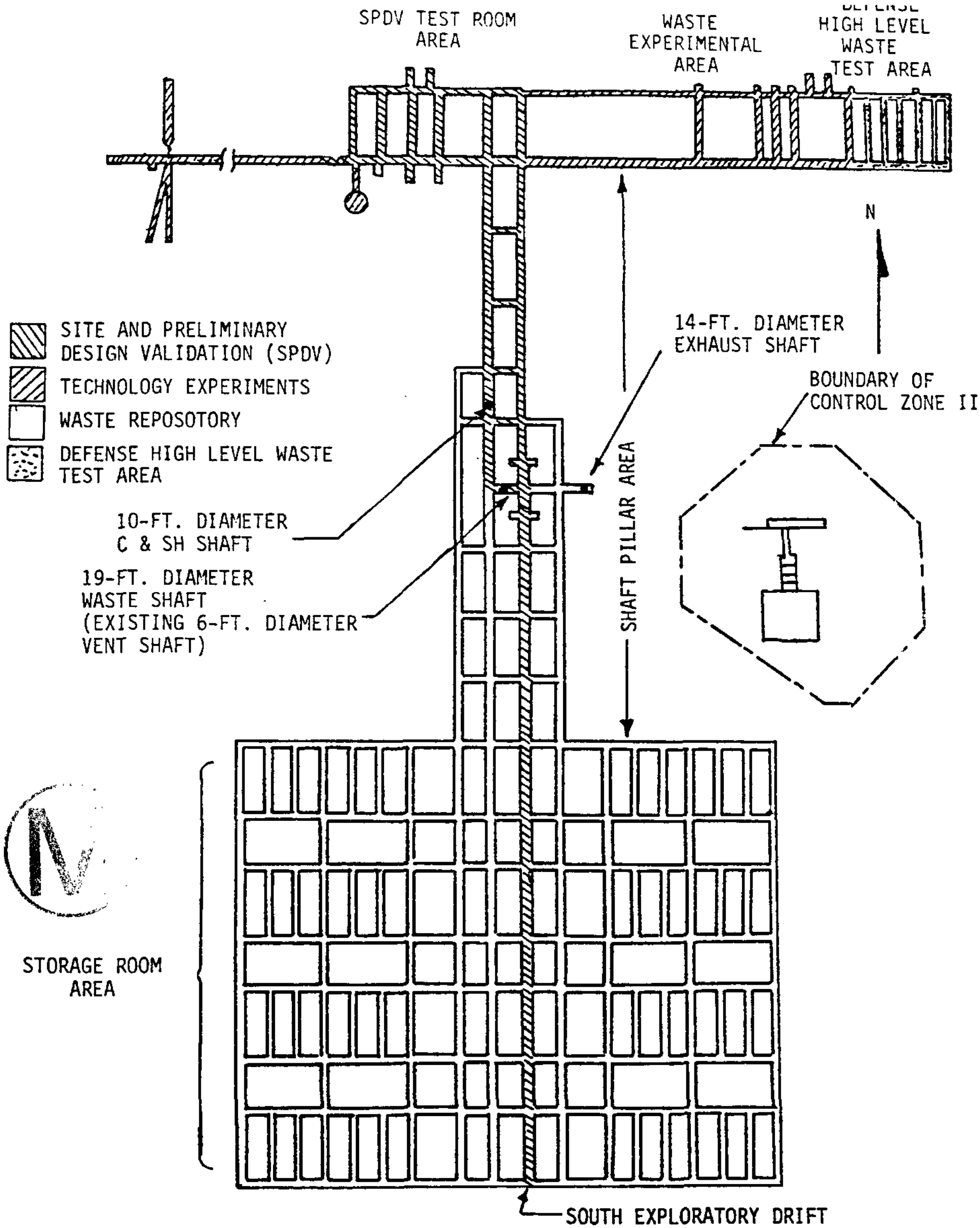


Figure 30. Layout of WIPP underground facility.

mapping of the shafts and of the drifts. Figures 31 and 32 summarize the geologic profile of the WIPP site.

The mean fluid content of the facility interval strata is 0.59% by weight. The principal mineral of the facility interval is halite with minor impurities consisting of polyhalite, quartz, magnesite, clay, anhydrite and gypsum. This statement is based on the analysis of 20 grab samples and 6 core samples. The locations from where the samples were obtained are shown in Figure 33.

The interbeds of the host rock interval are anhydrite and thin clay seams. Their physical properties do not pose an unmanageable problem on stability of the excavation. Based on laboratory testing, permeabilities of the interbeds measured under approximate lithostatic pressure were less than seven microdarcies. Test included Atterberg limits, direct shear, indirect tension, x-ray diffraction, and permeability. The sampling locations of interbedded materials is shown in Figure 34.

The observed inflow from the Rustler was approximately 1.5 gpm in the exploratory shaft and approximately 1 gpm in the ventilation shaft. The actual inflow may be larger, since all the water could not be collected during the inflow tests (ref. 14, p. 5-3).

No water inflows were encountered during excavations of the facility interval.

Permeability of facility interval samples tested under confining pressures approximating in situ conditions was less than 0.01 microdarcy. This statement is based on laboratory tests of 6 samples.

5.0 Results of Preliminary Design Validation Program

5.1 Preliminary Analysis

Sandia National Laboratory has performed calculations to predict the mechanical response of the shafts, the passageways, and the TRU demonstration rooms.

Figure 35 shows nominal calculated closures in the unlined shaft at three depths(ref. 15). These calculations are subject to considerable uncertainty and will have to be refined as more data are accumulated.

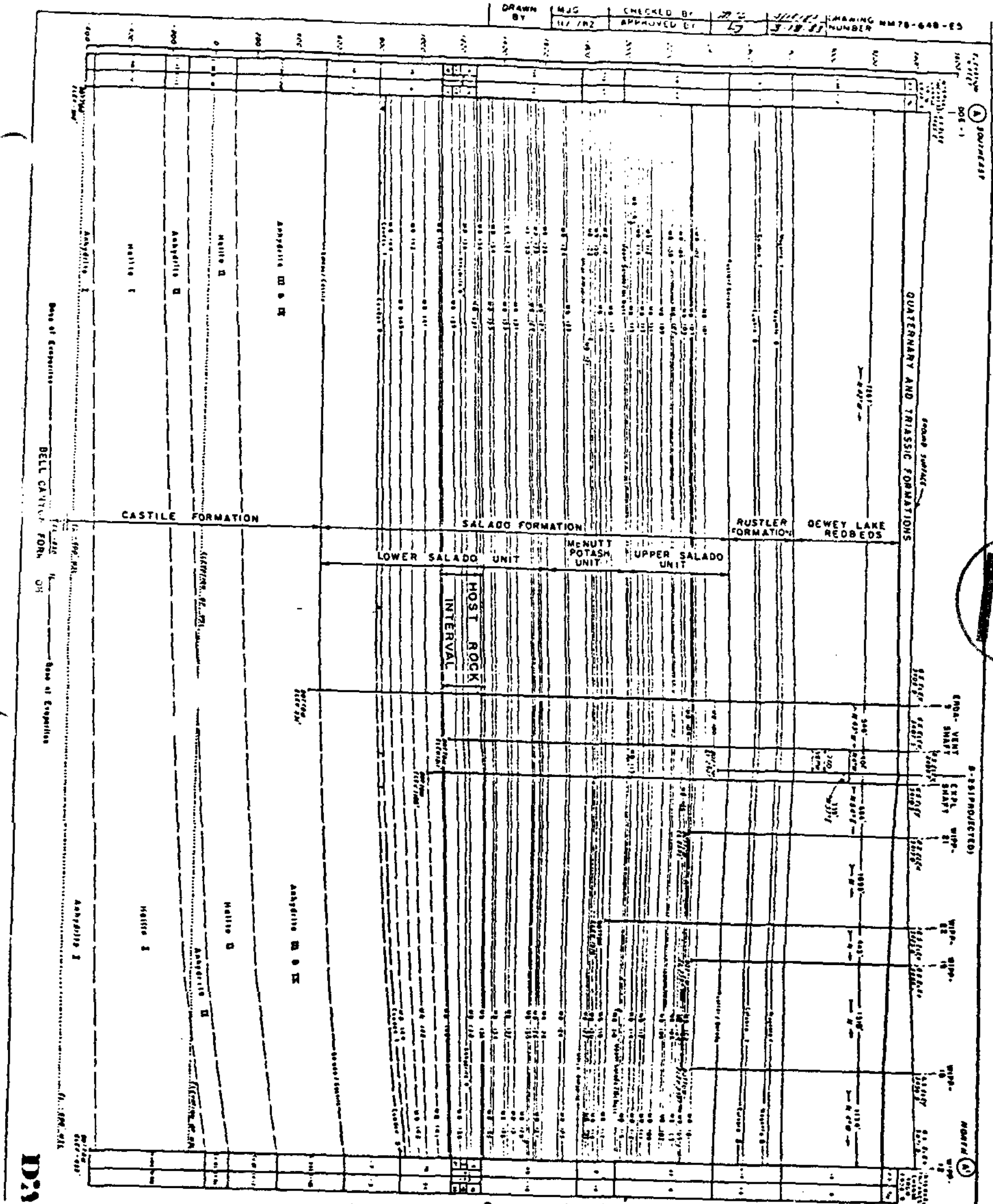
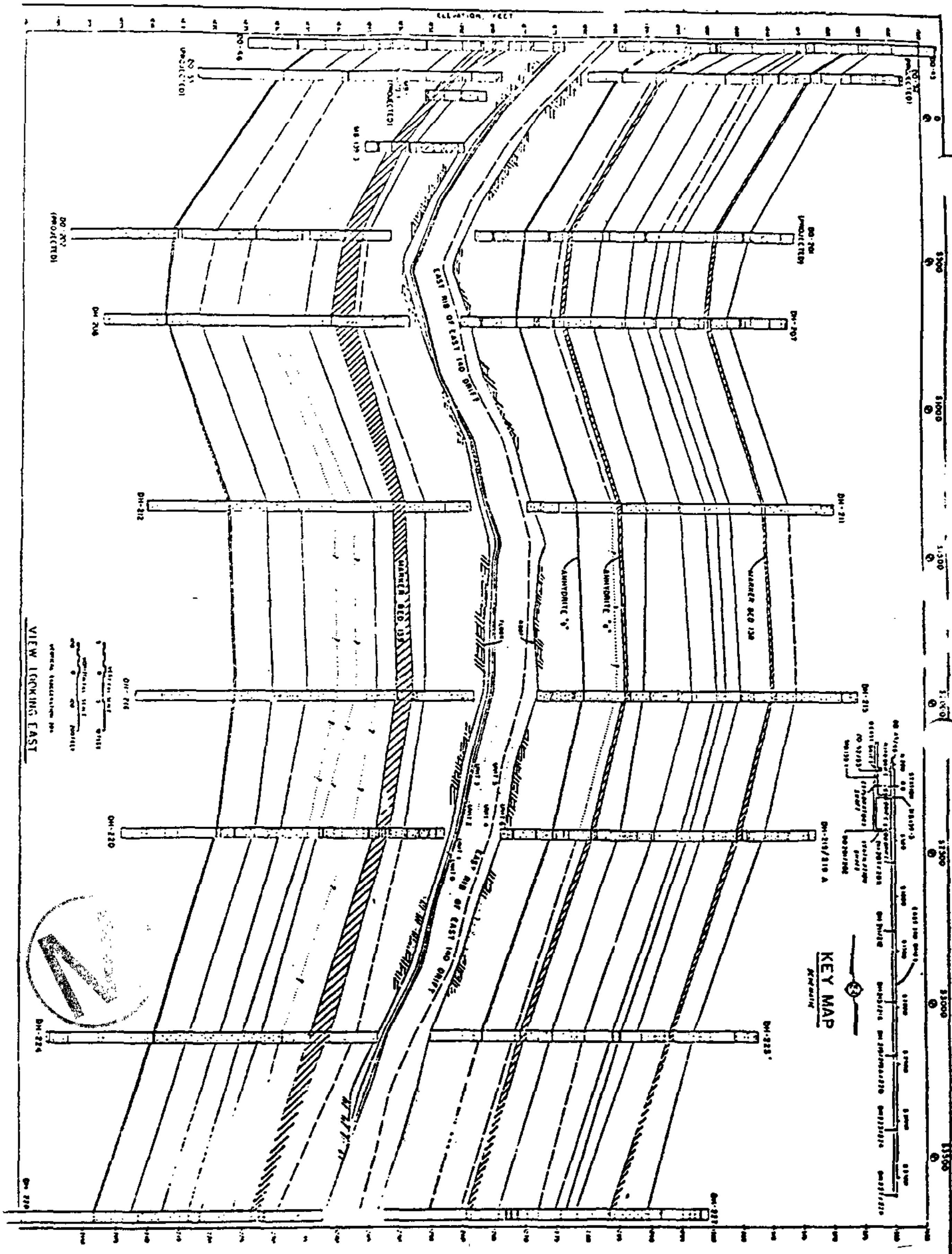


Figure 31
North to south geological cross section of the WIPP site.

TME 3179



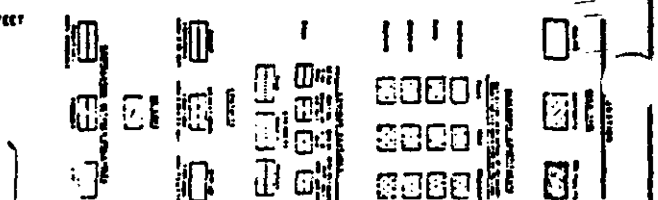


Figure 32. Correlation of vertical boreholes in the exploratory drift to the south

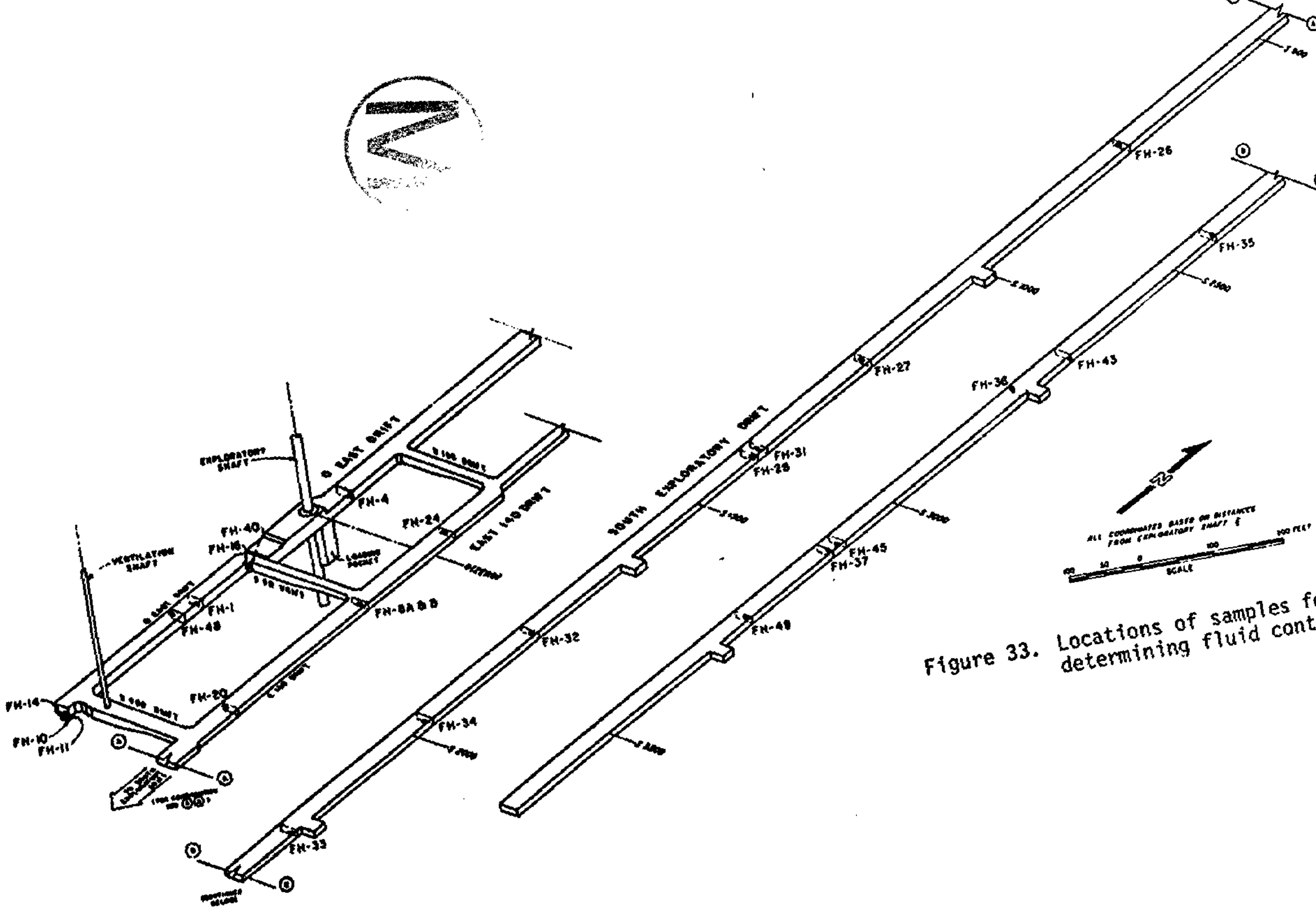
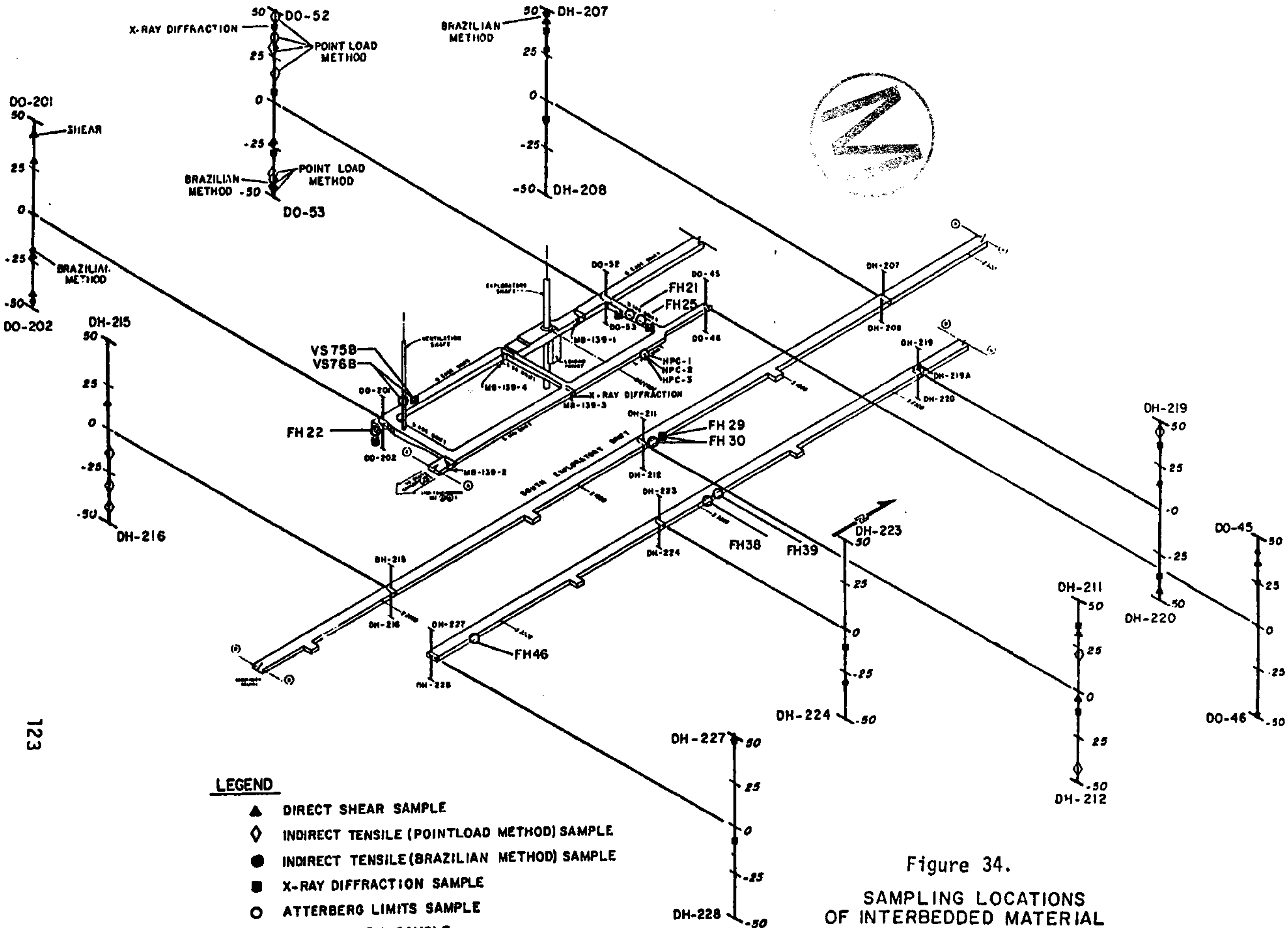


Figure 33. Locations of samples for determining fluid content.



NOTE: WHERE SAMPLE POINTS OVERLAY, TEST IDENTIFIED.

Figure 34.

SAMPLING LOCATIONS OF INTERBEDDED MATERIAL FOR LABORATORY TESTING PROGRAM

WASTE ISOLATION PILOT PLANT CARLSBAD, NEW MEXICO

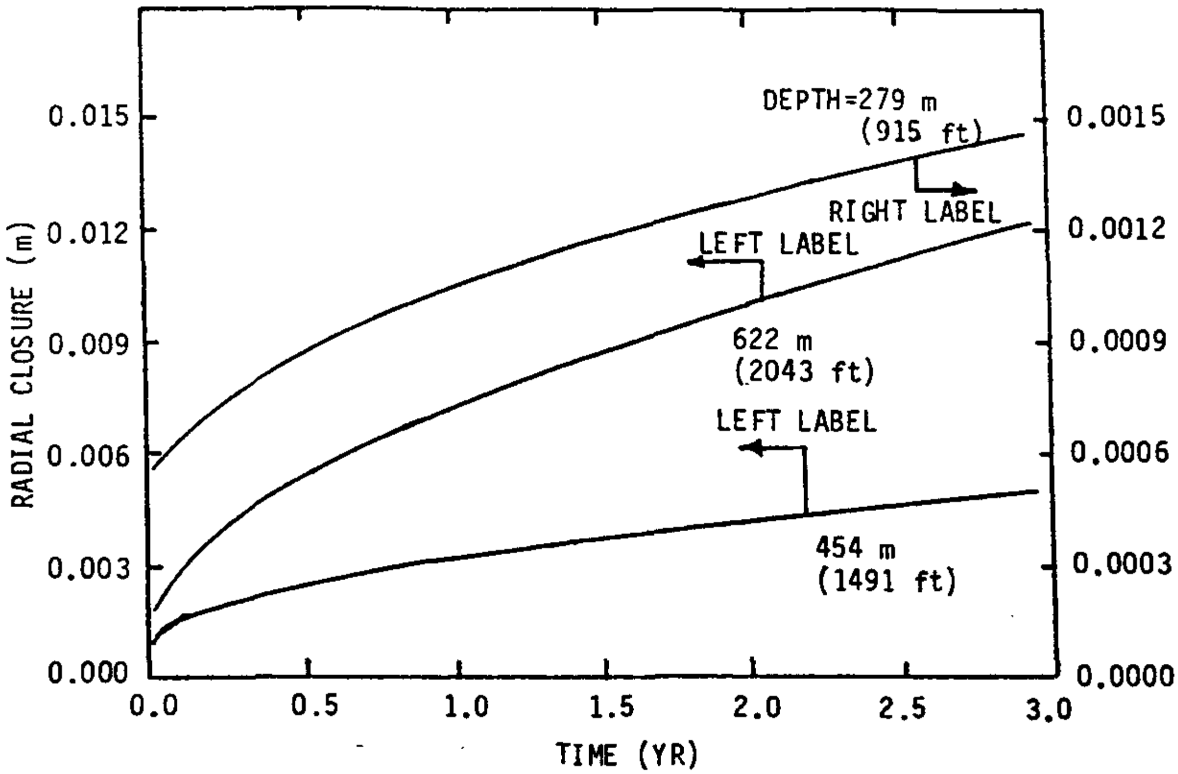


Figure 35. Calculated shaft radial closure at three extensometer locations for the SPDV (ref. 15).

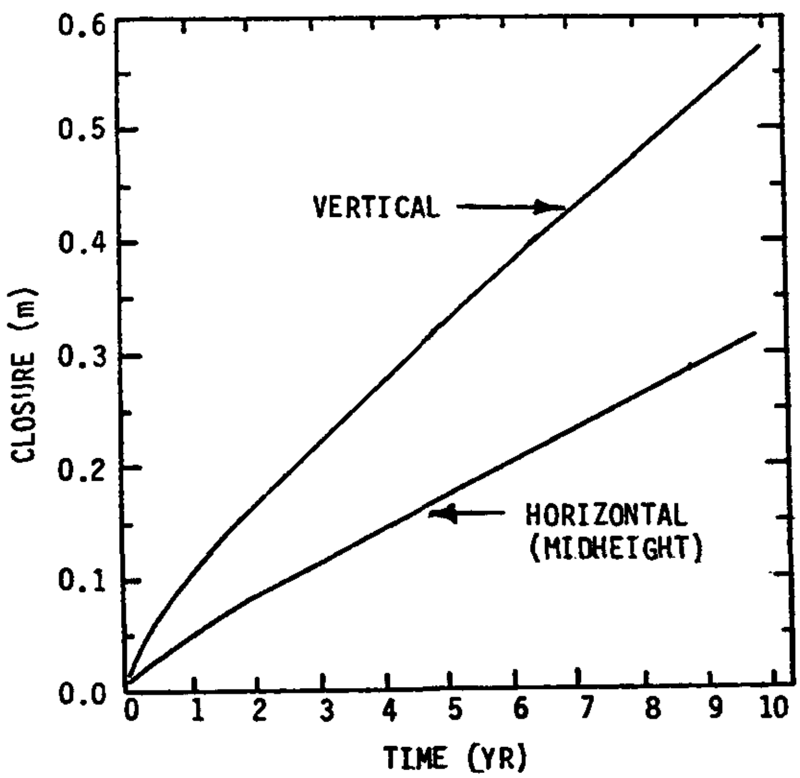


Figure 36. Preliminary calculations of storage room closure for design validation test panel of SPDV. (ref. 15).

Figure 36 shows typical calculation results for vertical and horizontal room closures. Figure 37 shows a two dimensional closure pattern. The calculations were made using sophisticated rock mechanics codes, the reference WIPP stratigraphy, and current steady-state constitutive models (ref. 16, 17). Again, the calculations will have to be refined as data are accumulated.

5.2 Early Design Validation Data

Most of the instrumentation, in particular that in the drift and in the test panel, has been only recently installed. A data gathering period of one year will probably be required before attempting any correlation between measurements and prediction. This is especially true of room and drift convergence. Hence only the sampling data is presented below and no attempt is made to correlate the observations with the calculated predictions.

Figure 38 shows the stabilized readings from the piezometers installed behind the steel lining in the exploratory shaft. Also shown is the design hydrostatic pressure. There is no correlation of pressure with depth; hence, more data will be necessary before drawing any conclusions on these pressure readings.

The piezometers installed in the salt formation behind the shaft key so far have shown a nominal reading of 6 psi. This indicates that there is no water pressure buildup behind the key.

Four earth pressure cells installed behind the shaft key do not indicate any pressure buildup between the salt formation and the concrete key. This confirms the prediction that the initial shrinkage rate of concrete is greater than the radial creep rate of the salt. An interactive pressure is not expected for two years. The strain gages in the concrete do not indicate significant strains.

Limited water leakage observed through telltales in the shaft key indicate that the chemical seal ring placed near the top of the shaft key is fairly effective in preventing the migration of water from the upper aquifers down to the shaft key and the salt formation.

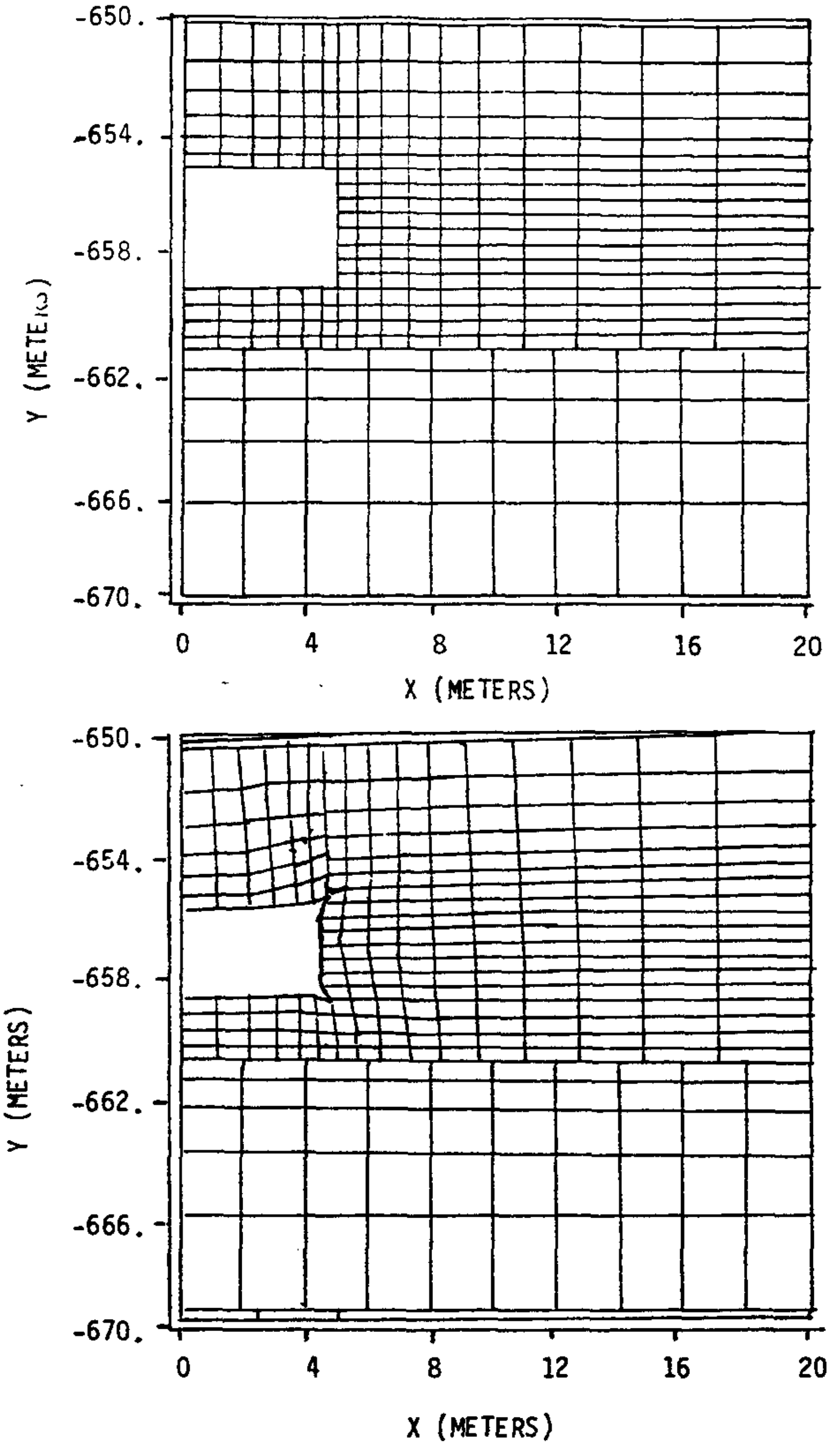


Figure 37. Two dimensional room closure calculations. Comparison of undeformed room and deformed room after 10 years (ref. 16).

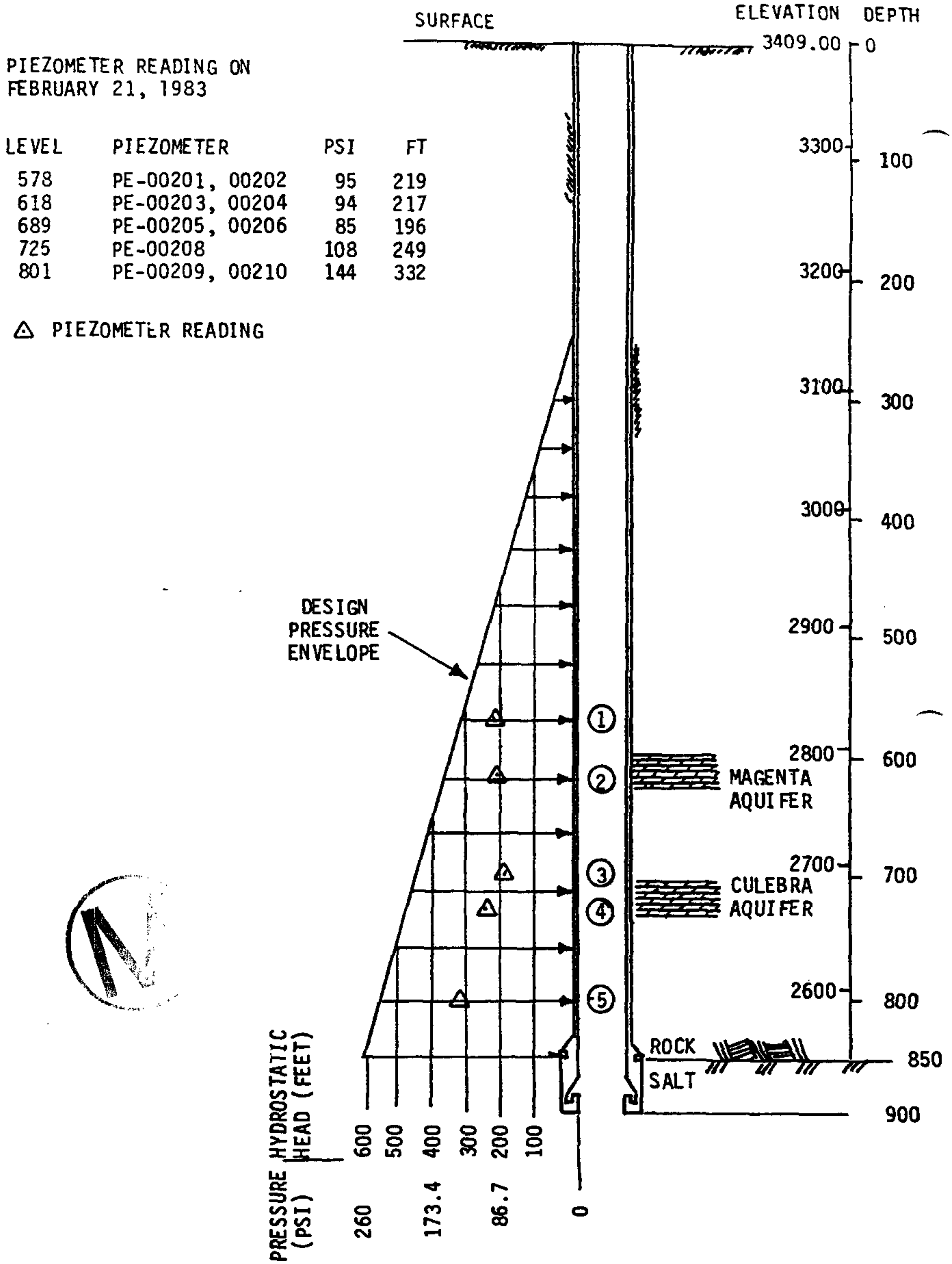


Figure 38. Stabilized piezometer readings and design pressure envelope of liner for exploratory shaft. (ref. 2).

Radial convergence of the unlined shaft has been monitored since July 1982. For the three extensometers at the level of 2057 ft., the seven month average radial convergence is 0.081 in. The calculated value is 0.087 in. For the three extensometers at the level of 1564 ft., the average radial convergence is 0.030 in. The calculated value is 0.027 in. For the three extensometers at the level of 1073 ft., the average reading is 0.002 in. The calculated value is 0.008 in.

The extensometer data thus indicate shaft closure rates ranging from 0.001 in./year at the top of the Salado formation to 0.10 in./year at the level of the repository horizon.

Six rock bolt load cells were installed in the exploratory shaft station in May 1982. Some showed a large increase in rock bolt load in the months following their installation. However, two cells indicate a significant decrease in rock bolt load since January 1983. Based on seven extensometers in the exploratory shaft station that were installed in July, September, and October, the total roof movement has been estimated at 1 1/2 to 2 1/2 in. up to the end of February. The roof movement appears to be decreasing. Figures 39 and 40 are samples of data obtained by extensometers in the exploratory shaft station. The figures suggest that the extensometers will provide data necessary to verify two dimensional room closure calculations.

Three extensometers installed since mid November in the ventilation shaft indicate that roof and wall movement is occurring at a decreasing rate.

Accumulated roof movement shown by the extensometers is less than 2 in.

Only minimal measurements are available for the 3256 ft. drift south, the instrumentation having been installed after January 1, 1983. However, all the room closure rate data show a gradual decrease.

6.0 Assessment of SPDV Program

General criteria for nuclear waste emplacement in geological repositories are in the process of being finalized. The Environmental Protection Agency (EPA) has published standards for comments under 40 CFR 191 (ref. 19) and the DOE has published general guidelines for comments under 10 CFR 960 (ref. 20). These criteria are similar to those published in NWTS-33 (ref. 9). For WIPP, criteria were first published in the GCR (ref. 8) and later in documents entitled Site Validation Program (refs. 7, 10, 2). In the site validation documents, the WIPP site criteria are cross-referenced with the NWTS-33 criteria. EEG also gave consideration to site criteria in its first report (ref. 21).

EEG concludes that the detailed geologic mapping at the repository horizons and a limited number of rock mechanics experiments conducted in the drifts and the shafts show no adverse conditions at the proposed repository level. However, the marker bed 139 (MB 139), which lies less than 10 feet below the repository horizon and consists of "mounds caused by growth of gypsum crystal clusters which were later slightly crushed by overburden pressure" (p. 6-4, ref. 22) may not satisfy DOE Criterion 13.2 (p. 12, ref. 22). EEG has recommended a detailed study of this layer to DOE.

No comprehensive set of criteria pertaining to the verification of design validation exists at present since an NRC licensed mined geological repository will not be built before 1990.

The excavations to date, the shaft and the underground facilities, clearly verify the first objective in Table 10. The piezometer readings in the Rustler formation (Fig. 38) show high hydrostatic pressures away from the Magenta and Culebra aquifers. Assuming that the Piezometers are functioning properly, this raises questions concerning the Rustler hydrology, which are raised in the Regional Hydrology section. Several years of data gathering will be necessary to verify the remaining objectives. EEG will evaluate this data as it becomes available and will make appropriate recommendations applicable to the design of the facility.

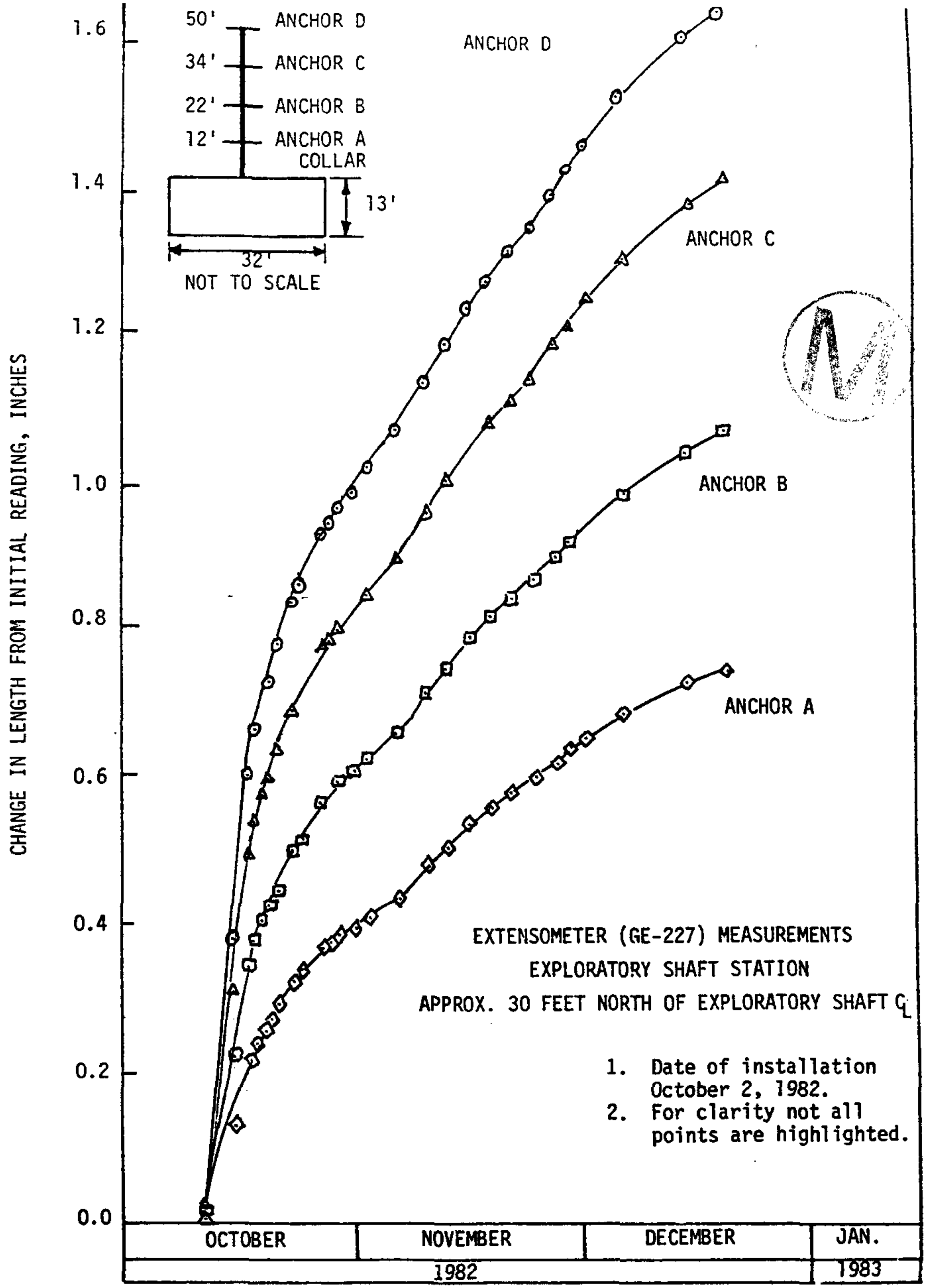


Figure 39. Closure data from an extensometer in the exploratory shaft station (ref. 18)

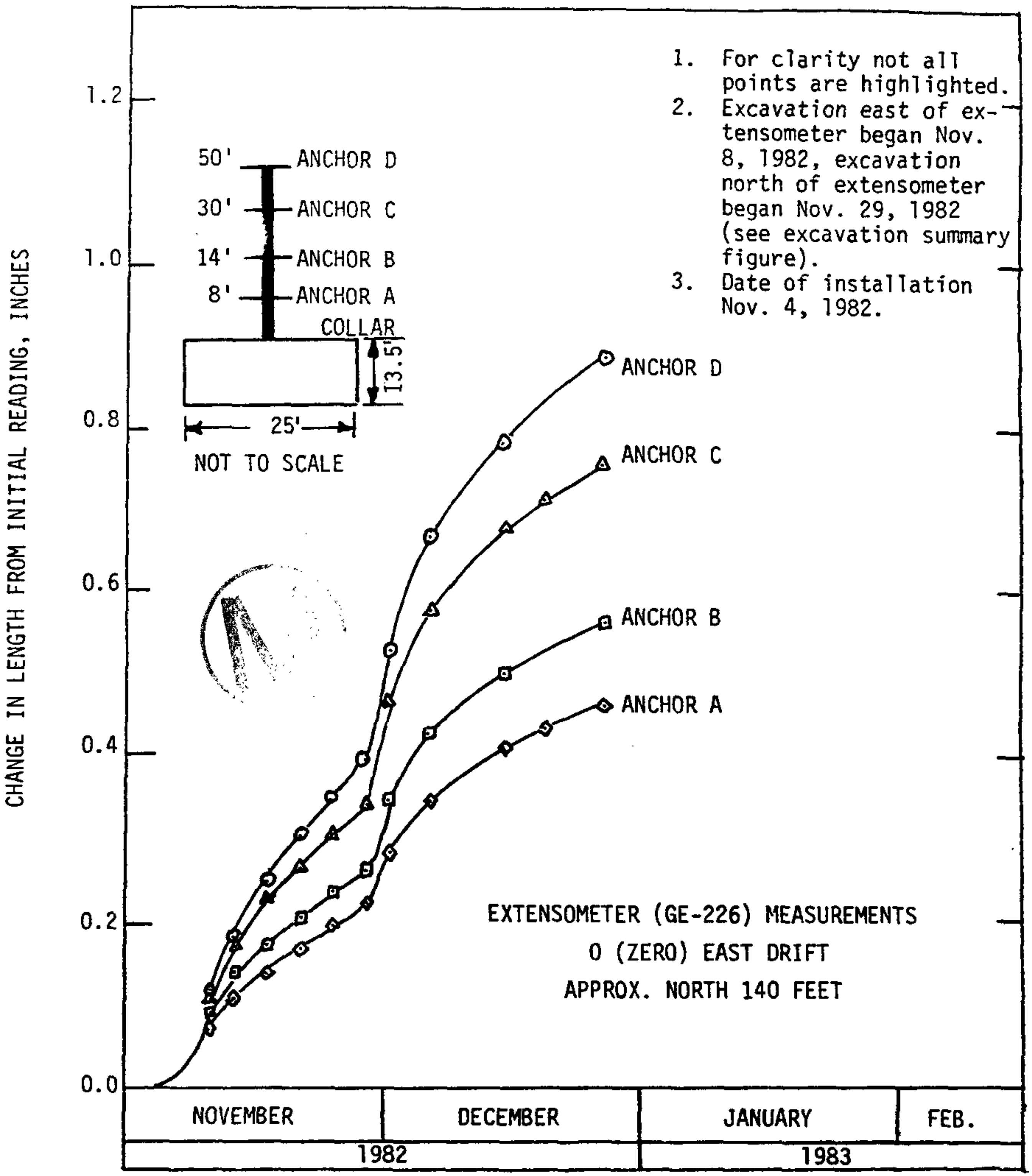


Figure 40. Closure data from an extensometer in the 0 drift 140 feet north of exploratory shaft.(ref. 18).

Additionally, EEG must also keep abreast of the WIPP R and D program because many of the experiments, notably the plugging and sealing of boreholes and shafts, and demonstration of waste emplacement, will provide important data applicable to design and operation of the facility.

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CONCLUSIONS AND RECOMMENDATIONS

The Environmental Evaluation Group (EEG) has concluded that the Los Medanos site for the WIPP project has been characterized in sufficient detail to warrant confidence in the safety of the site for the permanent emplacement of approximately 6 million cubic feet of defense transuranic waste. This conclusion is based on the assumption that the maximum surface dose rate for the unshielded remote-handled transuranic waste (RH-TRU) canisters will be 100 rem per hour with a maximum radionuclide concentration of 23 curies per liter as indicated in Table E-3 of the Final Environmental Impact Statement for WIPP. The Site and Preliminary Design Validation (SPDV) program, through the drilling of two shafts to the selected repository level at 2160 feet below the surface and excavation of about 9000 feet of tunnels, has confirmed the interpretations made about the subsurface geological conditions at the center of the site.

For an assessment of the potential radiation effects of the nuclear waste repository on the public health and safety, it is necessary to understand the regional geological and hydrological setting. A large amount of work has been done to understand these conditions and to address several specific issues which have arisen as a result of such studies. However, in an assessment effort of this magnitude, it is almost inevitable that some questions remain unanswered at a given time in the decision-making process. EEG has identified work which still needs to be done at the Los Medanos site in order to improve confidence in the worst case scenario models of possible breaches of the repository. Also, it is anticipated that some of the additional information will be necessary to assure compliance with the EPA standard when it is promulgated.

The following is a summary of EEG conclusions on each of the major issues of suitability of the WIPP site and a list of recommendations for additional work for further characterization of the site.

CONCLUSIONS

Dissolution

There is no doubt that a large amount of salt has been emoved from the Rustler and Salado formations in the Delaware Basin througn the process of shallow blanket dissolution. This process has removed the salt from these two formations in the western part of the basin and only the collapsed insoluble residue of the Rustler and Salado remain in that area. The two dolomite aquifers in the Rustler formation provide the unsaturat l water necessary for this shallow dissolution. The exit point for the brines produced by such dissolution near the WIPP site at the present time is the Pecos River at Malaga Bend and several points downstream. Piper (1973) calculated that the salts discharged into the Pecos River at Malaga Bend amount to 310,000 tons of NaCl and 170 tons of $CaSo_4$ each year. On the basis of an estimate of 955 tons per square mile per year of salt discharged by the springs and streams into the Pecos River, Bachman and Johnson (1973) calculated a present vertical-dissolution rate of about 500 feet of salt per million years. Using two different approaches for calculating the rate of advance of the "shallow" dissolution front towards the WIPP site, it has been shown that it would take at least 2 to 3 million years for such dissolution to a threat to the repository.

The question of deep-seated dissolution, which has been postulated to be responsible for removing up to 70% of the lower Salado salt (Anderson, 1981) is of more concern to EEG. This concern arises from the fact that the stratigraphic level from which the salt is postulated to have been removed is that of the proposed repository. EEG has examined the evidence for and against "deep dissolution" and concludes that there is sufficient evidence to accept the existence of deep-seated dissolution as a strong hypotheses to explain the missing salt from the lower Salado and Castile formations The mechanism for such a dissolution process, i.e., the source and the sink for the unsaturated water and the saturated brine respectively, still remains unexplained.

Anderson (1983) has argued that the lack of understanding of the mechanics of deep dissolution throws suspicion on the integrity of the Delaware Basin as a whole. However, a detailed examination of hundreds of logs in the Basin has resulted in the drawing of "dissolution edges" by Anderson (1981). These dissolution edges are at least 15 miles to the south and farther to the east of the WIPP site. Therefore, EEG views the WIPP site to be situated in an area which is safe from the effects of any deep-seated dissolution process, now or during the isolation time of the proposed repository. This conclusion is strengthened by the study of cores from deep boreholes at and around the WIPP site and the results of the excavation at the repository level under the SPDV program.

There is one area, two miles north of the center of the site, where the lower Salado marker beds show a depression. EEG recommends that the logs of boreholes in this area be reexamined and a modeling of the anomaly be conducted. After this work, a decision can be made whether to drill a new borehole to test the possibility of this anomaly having been caused by the process of point source deep dissolution.

Breccia Pipes

A chimney of brecciated rock represents collapse of the overlying rock into a cavity formed at some location at depth. Vine (1960) identified several domal structures in the Delaware Basin which have been explored during the investigations for WIPP, as possible breccia pipes. Anderson and Kirkland (1980) proposed the mechanism of brine density flow for the formation of breccia pipes. This mechanism requires an active participation of the DMG aquifer in supplying the unsaturated water and in removing the saturated brine. The characteristics of the DMG aquifer (Wood et al., 1982) do not appear to support this role.

Detailed investigations and analyses of the breccia pipes in the Delaware Basin have shown that the breccia pipes appear to form only over the buried Capitan Reef which borders the Delaware Basin. The domes in the basin show characteristics which identify them as having resulted from near surface phenomena. The "Castile" domes which are commonly found in the west-central part of the basin may have resulted from an interconnection between the DMG aquifer (which is at a shallow depth in the western part of the Basin) and the overlying evaporites. However, these are not "active" features. On the basis of a drill hole core, Anderson (personal communication) has identified a breccia pipe in the Basin, about 60 miles south of the WIPP site. Several miles of mining activity for potash in the upper Salado formation has not found a breccia pipe near the WIPP site. EEG, therefore, concludes that breccia pipes are not present at the WIPP site, and therefore do not pose a threat to the WIPP.

Spiegler, 1982 calculated the effect of a hypothetical breccia pipe developing under the repository and concluded that the radiological impact of such a feature returning radioactive materials to the biosphere would be insignificant.

Brine Reservoirs

Pressurized brine, at pressures between hydrostatic and lithostatic, have been encountered in the upper anhydrite layer of the Castile formation. Thirteen such encounters have been reported within eight miles of the proposed repository site. All except two of these were encounters in commercial oil and gas exploratory holes. ERDA-6 and WIPP-12 were WIPP project boreholes. WIPP-12 is situated at the northern edge of Zone II of WIPP. In addition to the pressurized encounters, brines at sub-artesian heads have also been found in the Castile formation, mainly along the Pecos River (Snyder, 1983, Personal Communication).

It should be realized that only the encounters at WIPP-12 and ERDA-6 were studied in detail. Varying degrees of detail are available on the other encounters.

Based on a study of all the data available, EEG has reached the following tentative conclusions.

- The Castile brine is not confined to a zone bordering the Capitan Reef. If one wishes to draw a zone, it would include the entire WIPP site.

- Each encounter of brine may not represent a distinct brine reservoir.

- Most of the brine encounters appear to be related to a structure in the Castile.

- Hydrologic testing and geochemical analyses of WIPP-12 and ERDA-6 brines indicate that the two are not connected.

- Geochemical data indicate that the brines may have been produced from water trapped in the rock at the time of deposition and later squeezed out at the time of structural deformation. However, the Capitan aquifer cannot be ruled out as a source.

- The brine, at least in WIPP-12 and ERDA-6, is not connected to any active aquifer at present.

- The presence of brine in the Castile formation underlying the WIPP site cannot be ruled out.

To provide an estimate of risk associated with a possible presence of brine under the repository, EEG modeled the case of a man-made future drilling intrusion 125 years hence. The results of EEG's two analyses (Channell, 1982; Bard, 1982) produce a maximum radiation dose to the bone of a nearby resident of 3.4 rem, less than the 5 rem permitted for a low probability accident. The man-made intrusion has been assumed to be a limiting case since a plausible scenario in which natural causes will allow brine to be brought to the biosphere more rapidly has not been identified. A recent EEG consultant's report (Logan, 1983) concludes that an unexpected communication between the brine reservoir in the Castile and the repository level, during excavation, will have serious consequences. DOE takes precautions for such a possibility although the chances of this occurrence are remote. To provide additional assurance and knowledge, EEG recommends further evaluation and field testing of geophysical methods such as CSAMT to identify possible occurrence of brine under the repository level.

Regional Hydrology

- The only perennial surface water in the vicinity of the WIPP is located at least 10 miles from the center of the site. The surface water bodies are discharge points for local groundwaters beneath the site. There is no direct threat to the repository from these surface water bodies.

- The groundwater in the Bell Canyon aquifer does not appear to pose a significant threat to the repository based on previous EEG scenario consequence calculations. Some recent data indicates that some parameters in the previous calculations were not conservative. Evaluation of the previous calculations is under way, but the results are not expected to yield significantly different consequences than the previous calculations.

- The Castile formation contains pressurized brines near the WIPP site. These brines are discussed in detail in the section on Brine Reservoirs.

- The Capitan Reef Aquifer is at its nearest point about 10 miles from the site. Since the basinward dissolution from the north has not progressed towards the site, the Capitan Reef Aquifer does not pose a threat to the repository.

- The characteristics of the Rustler aquifers are discussed in a separate section.

Disturbed Zone

The Disturbed Zone was initially defined (e.g. in Powers, et al., 1978) as the area where seismic reflection signals were uninterpretable. The cause for this was later determined to be the structural complexity within the Castile formation (Borns et al., 1983). Since the Castile formation shows extensive thinning and thickening of the salt layers, even within the WIPP site boundary, a conservative approach would be to assume that the so-called "Disturbed Zone" extends underneath the WIPP site.

The gravity foundering hypothesis provides a reasonable explanation for the deformation present in the Castile formation in the northern Delaware Basin. By using this hypothesis, DOE has calculated that if the deformation is progressing towards the WIPP repository area, it would take 4.6 m.y. for the deformation front to reach the area directly under the WIPP repository. EEG's calculations show that this may happen in 125,000 to 375,000 years. The progression of a structure such as that located at WIPP-12, however, requires conditions which facilitate the gravity foundering mechanism and these conditions (e.g., more trapped fluid in rock, low yield strength, etc.) may not exist under the southern part of Zone II of the WIPP site. The borehole DOE-1 drilled just outside the Zone II, to the southeast, certainly does not exhibit the Castile deformation structures except some minor lateral flow textures in the Castile halites. Further, with the reorientation of the WIPP repository to the south within Zone II, EEG concludes that the new location of the WIPP repository is in a relatively undeformed area.

Hydrologic Transport Characteristics of the Rustler Aquifers

There are three discreet zones in the Rustler formation through which the water moves. The quality and flow characteristics of these aquifers vary significantly but at the WIPP site, the waters are of poor quality and the flow rates are low. These aquifers are (a) the Rustler-Salado Interface Residuum (b) the Culebra dolomite, and (c) the Magenta dolomite. The water exists primarily in interconnected fractures in all three zones. In addition, there is some evidence that a very small quantity of water may exist in zones other than these three distinct aquifers. There is a possibility that features of karst hydrology may exist in the Rustler formation. However, all the information available at this time suggest that, if present, the karst solution channels would be very small in aperture.

The aquifers at the Rustler-Salado interface and the Magenta appear to carry a very limited volume of water at a very low velocity. The Culebra is the primary aquifer at the site and in case of a breach of the WIPP repository, it would be the most rapid pathway for radionuclides to reach the accessible environment. At the present time, the Culebra aquifer is not sufficiently characterized to model the hydrologic transport through it with confidence. Additional study of the Culebra aquifer is therefore recommended by EEG. These recommendations are outlined in the section of this title as well as at the end of this chapter.

Natural Resources

Extensive potash (sylvite, KCl and langbeinite $K_2Mg_2(SO_4)_3$) mining has occurred several miles to the north (in the McNutt Potash Zone) at a horizon 500 feet above the repository horizon. There are 38 million tons of sylvite and 122 million tons of langbeinite of varying economic grades in Zones I, II and III and DOE has banned any potash mining in these zones during the next 25 years - the operational lifetime of the repository. Seven percent of the known langbeinite resources in the U. S. are in these zones. To minimize possible future risk to the repository, we believe that mining of these potassium salts should be banned indefinitely.

If hydrocarbon resources exist at depths greater than 10,000' below the site, it is not clear their extraction is economically feasible via off-set slant drilling outside Zone III. The removal of natural gas does not present any radiological problems.

The presence of such resources appears to violate the provisions of the EPA proposed standard 40 CFR 191, Section 191.14(f).

SPDV Results

DOE has provided two reports entitled "Results of SPDV Site Validation Experiments" and "Results of SPDV Design Validation Experiments." Concerning site validation experiments, EEG concludes that the detailed mapping at the repository horizons and a limited number of rock mechanics experiments conducted to date in the drifts and the shafts, show no adverse conditions at the proposed repository level. However, in order to satisfy Section 13.2 of the DOE's Site Criteria and Qualification Factors, EEG recommends further stud on a bed (MB 139) underlying the repository level.

With respect to the design validation experiments, EEG concludes that several years of data gathering will be necessary to predict the closure and stability of the facility over its project lifetime of 25 years. EEG has not identified any additional experiments for design validation that should be conducted prio to the decision to construct.

RECOMMENDATIONS

The following is a list of certain investigations currently in progress or planned by DOE and additional work which EEG recommends that the State should demand if the construction is allowed to proceed.

Continuing or Planned DOE Studies

1. Evaluate and field test non-invasive geophysical methods to identify possible occurrence of brine under the repository.

2. Analyze the drawdown data in test holes H-1, H-2 and H-3 caused by the excavation of WIPP shafts.

3. Publish the results of solute transport modeling in the Rustler aquifers.

4. Analyze the Rustler aquifer waters for environmental isotopes (Carbon-14, Chlorine-36, Uranium-234, Uranium-238) to aid in understanding the groundwater flow direction and relative velocity.

5. Drill the planned additional wells for hydrologic testing, viz. H-11 and H-12. Obtain the cores while drilling these wells to determine the extent of fracturing and solution residues throughout the Rustler formation.

6. Conduct a water balance study for the WIPP site.

7. Study the mechanics of removal of salt from the Rustler formation at and near the site.

8. Drill a shallow auger-hole in the depression in the SW corner of Sec. 30, T225, R 31E in Zone III to address the suspicion of this depression being a doline.

9. Further study marker bed 139 (MB139) underlying the repository horizon to determine its origin and its effect on the repository and to confirm that it does not violate Section 13.2 of the DOE's site criteria and qualification factors.

Studies Recommended by EEG

1. Investigate the depression of the marker beds in the lower part of the Salado formation, centered two miles north of the WIPP shafts.

2. Perform computer modeling of groundwater flow in the Rustler aquifers.

3. Conduct the following hydrology tests:
   a) A long duration pumping test at the well H-3.
   b) Measure the anisotropy of the hydraulic conductivity at test pads H-1, H-2 and H-3.
   c) Perform convergence tracer tests at wells H-1, H-3 and H-4.
   d) Perform convergence tracer tests at well H-6 using sorbing tracers.

APPENDIX

SUMMARY OF EEG INVOLVEMENT WITH SITE SUITABILITY DETERMINATION FOR WIPP

SUMMARY OF EEG INVOLVEMENT WITH SITE SUITABILITY DETERMINATION FOR WIPP

APPENDIX

1.0 Review of GCR and DEIS (1979)

After an exhaustive review of available criteria for site characterization and selection (EEG-1), one of the first documents that the Environmental Evaluation Group reviewed upon its formation in 1978 was the Geological Characterization Report (GCR) by Powers, et al (1978). EEG's comments on this detailed compilation of up-to-date knowledge on the geologic and hydrologic characteristics were published in a report (EEG-2), which was included as Appendix III in EEG-3. The principal concerns expressed in that review were as follows:

What is the origin, evolution and occurrence of the high-pressure brine-reservoirs which were encountered in the upper part of the Castile formation in ERDA No. 6 and in at least 6 wells within 9 miles of the site?

What is the origin, evolution and occurrence of the "breccia pipes" which have been encountered in the area? They may be localized deep dissolution features which originate in the lower portion of the evaporites and migrate upward. Such localized dissolution features could now exist or develop later beneath the proposed site.

What are the processes and rates of deep dissolution of salt near the site? There may be a preferential removal of the salt horizon which is proposed for the repository.

What are the regional and site hydrologic conditions for the aquifers above and below the evaporites? The hydrologic information is necessary to assess any possible long-term release of radioactive material from the repository.

The Draft Environmental Impact Statement (DEIS) on WIPP was issued in April, 1979. This document contained very little additional information in the areas of geology and hydrology. In its review of the DEIS, EEG repeated the concerns expressed in EEG-2 and made additional recommendations as follows in EEG-3:

- The values of hydrologic parameters for WIPP site aquifers vary over a wide range. This data base should be improved and the subsurface hydrology should be better understood.

- The effect of impurities in salt at the proposed repository horizon should be taken into account in evaluating the physical, hydrological, thermal and strength characteristics of rock salt from the repository horizons.

- More information is needed on the regional hydrology of the WIPP site. Items such as surface runoff, existing and planned water resource development in the area, water use downstream of Malaga Bend and the present and potential well water use from aquifers in the area, need to be better understood.

- The long range modeling for potential breach of the site should take into account plausible future climatic changes in the hydrologic regime.

The correspondence between DOE and EEG following these comments reflects a consideration of most of these concerns and recommendations by DOE. In general, DOE conveyed to EEG that the continuing studies for site characterization would answer most of these concerns.

2.0 Geotechnical Meeting - January, 1980

EEG organized a two-day meeting of experts representing a wide spectrum of earth sciences, on January 17 and 18, 1980, to address the geotechnical questions concerning the WIPP site. The meeting, titled "Geotechnical Considerations for Radiological Hazard Assessment of WIPP", was attended by 66 persons, 35 of whom were geological scientists. The participants included members of State and Federal agencies, the National Academy of Sciences WIPP panel, the Governor's Advisory Committee on WIPP, several universities in the State, the mining industry and the state and national environmental groups.

The report of this meeting (EEG-6), published in April, 1980, contained the following recommendations in various geotechnical areas:

2.1 Geohydrology

- Better define the regional geohydrology through more field tests.
- Provide a clearer definition of recharge areas for the Rustler and DMG aquifers.
- Further refine Hiss' map of potentiometric surfaces in the Bell Canyon aquifer and its connection with the Ca; itan and/or San Andres aquifers.
- Evaluate the hydrologic transit times from the WIPP site to man from existing or potential water well development in all aquifers near the site.

2.2 Deep Dissolution

- Provide the arguments against active deep dissolution in a reviewable scientific paper format.
- Thoroughly investigate several anomalous features near the WIPP site, which have been pointed out by proponents of the deep dissolution idea. The results of such investigation should be presented to the scientific community in a reviewable paper.
- Assess potential consequences of deep dissolution and make the calculations available.

2.3 Brine Reservoirs

At the time of the meeting in early January, 1980, EEG was performing the hazard analyses described below and recommended that DOE do the same. EEG further recommended that DOE provide detailed documentation.

2.3.1 Salado Brine: The likelihood and potential extent of water movement into a waste-filled portion of the repository, both during and after the operating lifetime of the repository should be evaluated. If it is determined that a sealed repository might contain large amounts of brine, then hydrologic breach and drilling scenarios should be evaluated under the assumption that some waste is mixed or dissolved in brine at the time of the breach. In the hydrologic breach scenarios, the waste/salt dissolution rate is an important determinant of nuclide concentrations in the Rustler aquifer and in the Pecos River. The assumption that a portion of the waste is already in solution at the time of the breach might alter the scenario consequences significantly.

2.3.2 Castile Brine: Possible consequences of a connection between a brine reservoir, the repository, and the surface should be assessed and the plausibility of different sequences of events which might lead to such a connection should be evaluated. Consequences of a connection between a brine reservoir and the repository extending only as far as the Rustler aquifers are discussed in a draft of the final WIPP Environmental Impact Statement. At the time, EEG was reviewing this analysis.

2.4 Human Intrusion

- The DOE should publish detailed plans and restrictions on drilling for hydrocarbon resources at the site. The description should include:

  a) plans for regulating drilling and production outside of Zone IV;
  b) permissible drilling and production practices in and under Zone IV.
  c) whether secondary and tertiary recovery methods are being considered for Zone IV;
  d) possible use of slant drilling to recover natural gas or oil from beneath Zones I, II and III;
  e) the length of time over which drilling controls would be imposed.

The DOE should publish detailed plans and restrictions on mining of potash at the site. This description should include:

a) whether solution mining would ever be permitted;
b) whether any recovery inside of Zone IV would be permitted;
c) whether shafts will be sealed when potash mines are decommissioned;
d) the length of time over which mining controls would be imposed;
e) whether any controls are to be imposed on mining outside of Zone IV.

• Scenarios need to be evaluated for the following situations:

a) a repository breach involving an abandoned potash mine in Zone IV, either as a source of water into the repository or as a pathway for migration away from it;
b) drilling into a repository containing highly pressurized gas that has developed from decomposition of organic material in the wastes;
c) an exploratory well striking a brine pocket below the repository. The brine ascends to the surface (being under pressure) and brings contaminants with it.
d) appropriate breach scenarios for any additional exploration or mining activity that may be proposed (e.g., solution mining, secondary and tertiary air recovery methods, and exploitation of Zones I, II and III).

2.5 Additional Scenarios

The following scenarios had been proposed by EEG, its consultants, or other groups commenting on the WIPP DEIS. EEG suggested that DOE analyze the hydrologic or geologic events described in these scenarios, determine their plausibility, and whether other events should be considered in designing meaningful radiological hazard scenarios.

2.5.1 Event: Breaching of the excavation workings by pressurized brine after installation of substantial quantities of waste.

Causes: a) Penetration of a brine reservoir during excavation for WIPP.
b) Structural overburden adjustments.
c) Heat source effects.
d) Collapse of underlying beds from previous or renewed dissolution.

Result: A large flow of brine into the repository, rising to the surface and entering the local or Pecos River drainage and/or the Rustler aquifer.

2.5.2. Event: Hydraulic communication between the excavation for WIPP and the dissolution conduits connected to the Capitan Reef aquifer.

Causes: a) Existing conduits NE and E of site already in communication with the Capitan Reef aquifer.
b) Development of communication between the excavation and existing conduits from collapse of subjacent or underlying beds.
c) Development of communication from renewal of dissolution.

Result: Movement of brines into lower part of Capitan aquifer, transfer to San Andres limestone and escape from the basin (with possible effects on petroleum and gas exploration in Texas).

2.5.3. Event: Communication between excavation for WIPP and surface drainage, Rustler aquifer and Delaware Mountain Group aquifer.

Causes: a) Collapse of existing dissolution pocket beneath site.
b) Climatically induced renewal or development of a dissolution chamber beneath site.
c) Collapse due to retrieval of hydrocarbons beneath site.
d) Seismic activity, possibly induced by operation of repository or nearby mines.

Result: Movement of this fluid under artesian pressure to surface or down into Delaware Mountain Group aquifer with ultimate escape from the basin.

Note: This scenario is a variation on DEIS scenario 1, where water flows vertically from the Delaware Mountain Group to the Rustler horizon before moving laterally to Malaga Bend.

2.5.4 Event: Communication between the repository, a source of water, and reserves of potash, oil or natural gas.

Causes: a) Communications between aquifers and repository, as in items 2, 3.

b) Communication between brine reservoir and repository, as in item 1.

c) Solution mining for potash after site control is lost.

d) Injection of water for secondary oil recovery.

Result: Dissolution of a fraction of the waste and contamination of retrievable resources.

3.0 Geological Field Trip, June, 1980

A consensus which emerged from the geotechnical meeting of January, 1980 was that a geological field trip to the site and vicinity would further clarify the different views on the geological processes active at the site. A three-day field conference to the site was organized by EEG on June 16 to 18, 1980 for this purpose. Twenty-three participants in this field conference included seventeen geoscientists from State and Federal agencies, universities and the private sector. There were extensive discussions on many aspects of the geology of the site at each field stop. In addition, there was a 1-2 hour post-field trip meeting each day and a 1/2 day discussion session on the third day. Participants were also requested to send written comments on the geological issues debated during this field conference.

Based on the discussions and the written comments, EEG formulated and submitted to DOE the following recommendations for further work by DOE (EEG-7, pp. 105-106):

3.1 Review Papers. Prepare detailed review papers on the following topics:

a) Deep dissolution - Specifically addressing Roger Anderson's hypothesis about extensive deep dissolution in the lower part of the Ochoan evaporite deposits in the Delaware Basin.

b) Structural anomalies at and near the WIPP site - This should include the anomalies interpreted from geophysical data and from drill cores. The discussion should include the details of geological interpretation of the anomalies and the work being planned or conducted to resolve the seismic data discrepancies, as stated in the Safety Analysis Report, pp. 1.7-65 and 1.7-66.

c) Occurrence of brine reservoirs/pockets in the evaporite beds of Delaware Basin - This should include available information on location, quantity, pressures, quality, ideas on origin, methods of handling it in mines, etc.

d) Details of DOE plans to allow recovery of potash and hydrocarbon resources without disturbing the sealed repository.

e) Basic data and interpretations of boreholes WIPP-31 and WIPP-16 - drilled at hills A and C respectively to obtain more information on the origin of these breccia pipes.

3.2 Exploratory Program. DOE should perform and submit detailed reports on the following explorations:

a) Run a seismic reflection profile across the San Simon Swale to pass over WIPP-15 (sink) from the Antelope Ridge to San Simon Ridge. This should answer the question regarding the postulated fault between the sink and the ridge.

b) Drill 4 or 5 shallow holes across Bell Lake Sink or Slick Sink to reach the Red Soil horizon and drill one deep exploratory hole to the evaporites, if Red Soil is not missing. Even though it is far from the WIPP site, this testing program will answer an important question about the presence of deep dissolution in the Basin itself.

c) Drill one core-hole to the lower Castile in Section 9, northern part of the WIPP site.

d) Reopen one of the brine reservoir wells: AEC-7, Pogo or ERDA-6; allow it to flow for 10 days; measure the depletion of pressure and levels in all three and test the brine at regular intervals.

4.0 Scenario Modeling by EEG

In 1979, EEG published a "Simple Model for Estimating Maximum Radionuclide Concentrations in the Pecos River, and Associated Ingestion Doses, due to the Release of Radioactivity from the WIPP Repository" by Moses A. Greenfield in EEG-2. The results generally agreed within a factor of 2 with the calculated doses shown in the DEIS.

During the latter part of 1980 and the first part of 1981, EEG published two reports (EEG-8 & 9) on a sensitivity analysis and a well scenario and their impact on the hazard assessment for WIPP. This effort of radiological hazard assessments is continuing with the publication of 9 more reports (EEG-11, 12, 13, 15, 17, 18, 19, 20 and 21) to date.

5.0 Stipulated Agreement

As a result of a Stipulated Agreement between DOE and the State signed in July 1981 after the State filed a lawsuit against DOE, the DOE agreed to produce a number of reports addressing specific geologic issues and also agreed to perform additional experiments and field work at the site. The list of these reports and experiments is contained in Appendices B and C of the Stipulated Agreement. These appendices are reproduced below.

5.1 "Appendix B: Comprehensive Topical Reports to be Made Available to Environmental Evaluation Group Before the Decision to Construct the Permanent Repository

1. Deep Dissolution: Including all available pertinent up-to-date data and arguments for and against the hypothesis of deep dissolution in the Delaware Basin and its potential effect on WIPP.

2. Disturbed Zone: Including all available pertinent up-to-date data and analyses of the nature, extent and potential significance to the repository.

   Breccia Pipes: Including all available pertinent up-to-date data and analyses concerning the existence of breccia pipes in the basin and the reef, potential for future breccia pipe development, and their significance to WIPP.

4. DMG Hydrology: Including all available pertinent up-to-date data and analyses of the hydrologic characteristic, geochemistry, potential and rates for salt removal, and directions of flow and possible communication with other aquifers e.g., reef aquifer, San Andres Limestone aquifer and shallow aquifers.

5. Regional Hydrology: Including all available pertinent up-to-date data and analyses of the recharge and discharge area, flow times and interconnections of aquifers near the site.

6. Natural Resources: Including detailed plans to control recovery of potash and hydrocarbons without disturbing the repository, and the evaluation of potential consequences of these plans.

7. Results of SPDV Site Validation Experiments: Including all pertinent results and analyses of experiments as listed in WIPP-TME-2975, pp. 15-16.

8. Plans for SPDV Design Validation: Updated, detailed plans and rationale for the proposed design validation experiments as outlined in TME-3058 and TME-3063.

9. Results of SPDV Design Validation Experiments: Including all pertinent results and analyses of experiments as agreed by DOE and EEG. (Further results to be later provided per *note below.

10. Plans for Stimulated Wastes Experiments: Updated, detailed plans and rationale for the proposed experiments.

11. Results of Simulated Waste Experiments: Including all pertinent results and analyses of experiments as agreed by DOE and EEG.*

5.2 Appendix C: Additional Investigations, the Results of Which to be Made Available to Environmental Evaluation Group Before the Decision to construct the Permanent Repository.

1. Test Brine Reservoir in Deformation Zone: Reopen ERDA-6 and allow it to flow for at least 10 days to measure the depletion of pressure at regular intervals in this well, and if access can be obtained, in Pogo #1 federal well. Perform other necessasry tests to determine the size, age, origin, and possfible association with aquifers or other brine pockets.

2. Report on Brine Reservoirs: Provide a comprehensive topical report on available information concerning brine reservoirs in evaporite beds found in the Delawre Basin including the results of tests on ERDA-6. This should include available information on the location, sizes, quantity, pressures, quality, ideas on origin and methods of handling in mines.

3. Horizontal Exploration of the Disturbed Zone: At the earliest possible stage of facility construction and before emplacement of any waste at the WIPP repository, provide for an additional 3000 feet of drift north of presently planned station #2, which is approximately 2500 feet North of ERDA #9, and drill 3000 feet horizontal cores to the north from this new location.

4. Fracture Flow in Rustler Aquifers: Evaluate the extent of fracture flow in the Rustler aquifers and provide a report on the effect of fracture flow on the resultant release pathways considered in the FEIS.

*Note: To be completed prior to the 45 day review period and prior to the decision to proceed as set forth in Paragraph 5 of the Order.

5. Study of Aquifer Characteristics: Using in-situ methods, assess quantitatively and qualitiatively the lithology, porosity, permeability, bulk density and distribution coefficients of the Rustler aquifers."

6.0 Costs and Merits Evaluation for Stipulated Agreement Activities

As required in the Stipulated Agreement, the DOE provided a document titled, "Report Assessing the Merits and Costs of Experiments and Studies Set Forth in Appendix B and Appendix C of the Stipulated Agreement Between the State of New Mexico and the U. S. Department of Energy and Others," August 31, 1981. This report provided a detailed review of the items to be covered in the reports and experiments to be conducted by DOE. There was further correspondence between the State and the DOE to clarify some of these items.

After a careful study of all the reports received under the Stipulated Agreement, the EEG finds that the following items which are contained in the "Costs and Merits Evaluation" or in subsequent clarifying letters, are not contained in the reports and have not been transmitted separately.

6.1 Fracture Flow in the Rustler Formation

The proposed work for this report is contained on p. 37 of the "Costs and Merits" report. The following items have not been completed do date.

- Tracer tests in Well number H-5 has not been conducted. The H-4 test is in process, but no useful data has been generated to date.
- A model to represent the flow path and aquifer characteristics in the Rustler has not been released.

It is recommended that this work be completed.

6.2 Study of Aquifer Characteristics

The proposed work under this item is outlined on p. 39 of the "Costs and Merits" report. The following proposed work has not been completed.

- The water inflow tests in the shafts were not conducted for each aquifer. The total inflow down the shaft was measured but not very accurately. EEG concurs with the evaluation by D'Appolonia Consulting Engineers that it is extremely difficult to do this work.

6.3 Marker Bed 124 Depression at the Northern Edge of Zone III

In a letter (Goldstein toSchueler, 10/5/81) following the submission of the "Costs and Merits" proposal, the State suggested that the DOE should reexamine all available data on the MB 124 depression centered at well # F-92 and should determine if the evidence warrants a new borehole at that location. DOE agreed to evaluate this feature in the Disturbed Zone report. However, this report (SAND 82-1069) does not contain such an evaluation. It is recommended that this work be done.

7.0 Review of Stipulated Agreement Reports

During the period from November 1981 to April 1983, EEG received the Appendix B Stipulated Agreement reports as well as the certified data from the Appendix C experiments from DOE. Generally, the reports were first sent to EEG in draft forms, upon which EEG made detailed comments to DOE. Meetings of EEG and DOE technical personnel were then held to resolve any differences concerning the content and scope of the reports. The DOE subsequently issued each report with modifications that they deemed fit to make. EEG-22 contains the EEG comments and DOE replies for all the reports which had been received by EEG through March 1, 1983.

EEG-11 Channell, James K. Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, January 1982.

EEG-12 Little, Marshall S. Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP, May 1982.

EEG-13 Spiegler, Peter. Analysis of the Potential Formation of a Breccia Chimney Beneath the WIPP Repository, May 1982.

EEG-14 Zand, Siavosh M. Dissolution of Evaporites and Its Possible Impact on the Integrity of the Waste Isolation Pilot Plant (WIPP) Repository (Draft).

EEG-15 Bard, Stephen T. Estimated Radiation Doses Resulting if an Exploratory Borehole Penetrates a Pressurized Brine Reservoir Assumed to Exist Below the WIPP Repository Horizon - A Single Hole Scenario, February 1982.

EEG-16 Radionuclide Release, Transport and Consequence Modeling for WIPP. A Report of a Workshop Held on September 16-17, 1981, February 1982.

EEG-17 Spiegler, Peter. Hydrologic Analyses of Two Brine Encounters in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, December 1982.

EEG-18 Spiegler, Peter and Dave Updegraff. Origin of the Brines Near WIPP from the Drill Holes ERDA-6 and WIPP-12 Based on Stable Isotope Concentrations of Hydrogen and Oxygen, March 1983.

EEG-19 Channell, James K. Review Comments on Environmental Analysis Cost Reduction Proposals (WIPP/DOE-136) July 1982, November 1982.

EEG-20 Baca, Thomas E. An Evaluation of the Non-radiological Environmental Problems Relating to the WIPP, February 1983.

EEG-21 Faith, Stuart, Peter Spiegler, Kenneth R. Rehfeldt. The Geochemistry of Two Pressurized Brines From the Castile Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, April 1983.

EEG-22 EEG Review Comments on the Geotechnical Reports Provided by DOE to EEG Under the Stipulated Agreement Through March 1, 1983, April 1983.

ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-29

EEG-29

EVALUATION OF THE SAFETY ANALYSIS REPORT FOR THE WASTE ISOLATION PILOT PLANT PROJECT

Marshall S. Little

Environmental Evaluation Group
Environmental Improvement Division
Health and Environment Department
State of New Mexico

May, 1985

Environmental Evaluation Group
Reports

EEG-1 Goad, Donna. A Compilation of Site Selection Criteria Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, June 1979.

EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volumes I and II, December 1978.

EEG-3 Neill, Robert H., et al, eds. Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U. S. Deparatment of Energy, August 1979.

EEG-4 Little, Marshall S. Review Comments on the Report of the Steering Committee on Waste Acceptance Criteria for the Waste Isolation Pilot Plant, February 1980.

EEG-5 Channell, James K. Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, November 1980.

EEG-6 Geotechnical Considerations for Radiological Hazard Assessment of WIPP. A Report of a Meeting Held on January 17-18, 1980, April 1980.

EEG-7 Chaturvedi, Lokesh WIPP Site and Vicinity Geological Field Trip. A Report of a Field Trip to the Proposed Waste Isolation Pilot Plant Project in Southeastern New Mexico, June 16 to 18, 1980, November 1980.

EEG-8 Wofsy, Carla The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Doses from WIPP September 1980.

EEG-9 Spiegler, Peter An Approach to Calculating Upper Bounds on Maximum Individual Doses From the Use of Contaminated Well Water Following a WIPP Repository Breach, September 1981.

EEG-10 Radiological Health Review of the Final Environmental Impact Statement (DOE/EIS-0026) Waste Isolation Pilot Plant, U. S. Department of Energy, January 1981.

EEG-11 Channell, James K. Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, January 1982.

EEG-12 Little, Marshall S. Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP, May 1982.

(Continued on back cover)

EVALUATION OF THE SAFETY ANALYSIS REPORT

FOR THE WASTE ISOLATION PILOT PLANT PROJECT

Marshall S. Little

Environmental Evaluation Group

Environmental Improvement Division

Health and Environment Department

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May, 1985

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the potential radiation exposure to people from the proposed Federal radioactive Waste Isolation Pilot Plant (WIPP) near Carlsbad, in order to protect the public health and safety and ensure that there is minimal environmental degradation. The EEG is part of the Environmental Improvement Division, a component of the New Mexico Health and Environment Department -- the agency charged with the primary responsibility for protecting the health of the citizens of New Mexico.

The Group is neither a proponent nor an opponent of WIPP.

Analyses are conducted of available data concerning the proposed site-- the design of the repository, its planned operation, and its long-te stability. These analyses include assessments of reports issued by the U. S. Department of Energy (DOE) and its contractors, other Federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP.

The project is funded entirely by the U. S. Department of Energy through Contract DE-AC04-79AL10752 with the New Mexico Health and Environment Department.

Robert H. Neill
Director

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SUMMARY

The Safety Analysis Report [1] (SAR) for the Waste Isolation Pilot Plant (WIPP) Project was first published by the U. S. Department of Energy (DOE), WIPP Project Office (WPO) in 1980. Since that time a total of eight amendments to this Report have been published. As part of its independent evaluation of the WIPP Project for the State of New Mexico, the Environmental Evaluation Group (EEG) maintains a continuing technical assessment of the information in this Report and its amendments.

Beginning with the initial publication, and following the amendments, the EEG prepares detailed written comments and recommendations which are submitted to the WPO for consideration in future amendments.

The WPO has made many substantial changes to the SAR in response to the EEG's comments. On frequent occasions, meetings between the two groups have been held in an effort to reach an accord on some of the more controversial issues. These meetings generally have been very constructive, but several important areas of conflict remain. In many instances, these areas represent changes which are to be considered by the WPO at some future date, rather than irreconcilable issues.

The most important issues remaining to be resolved are included in the discussions of this report, and could be summarized as follows:

1. An amendment of the topical content to be more in accord with the DOE Order 5481.1A and AL 5481.1A.
2. Substantial revisions of the classification of components, structures and systems, and related quality assurance.
3. Revisions to the site geological and hydrologic data based on studies agreed to between DOE and the State.

TABLE OF CONTENTS

1. INTRODUCTION

The U. S. Department of Energy (DOE) published the Safety Analysis Report (SAR) for the Waste Isolation Pilot Plant Project (WIPP) in 1980.[1] Although the WIPP is not subject to licensure by the U. S. Nuclear Regulatory Commission (NRC), DOE order 5481.1A suggests that the SAR be patterned after the Safety Analysis Report required for licensure under the regulations of the NRC for nuclear reactors (10 CFR 50). It is a five volume report which, according to the NRC regulations, should include (1) the description and safety assessment of the site; (2) a description and discussion of the facility with special attention to design and operating characteristics; (3) the current design of the facility; (4) an analysis and evaluation of the design and performance of structures, systems and components to reflect their risk to health and safety; (5) the technical safety specifications for the facility and the bases for these specifications; (6) the plan for training and operation of the facility; the quality assurance program to be applied to the design, construction, and testing of components, structures and systems to confirm their adequacy; and (7) those plans and procedures which would apply in the event of emergencies.

In September, 1982 the Albuquerque Operations Office of DOE issued the current Order, AL 5481.1A for nuclear operations of the Albuquerque Operations Office of DOE. Chapter 1, section 3.b. lists the Table of Contents for SARs[a] as follows:

"b. <u>Table of Contents for SARs.</u>

Chapter	Title
1......................	Introduction
2......................	Summary
3......................	Description and Safety Assessment of Site[b]
4......................	Description of Facility
5......................	Description of Operations
6......................	Accident Analysis
7......................	ES&H Systems Critical to the Safety of the Facility
8......................	Air and Water Pollution Control System
9......................	Environmental Monitoring Program
10......................	Waste Management
11......................	Quality Assurance and Acceptance Programs
12......................	Facility Expansion Decontamination and Decommissioning
13......................	ES&H Safety Management Program
14......................	Summary of Emergency Response Plan
15......................	Summary Plan for Employee Training
16......................	Summary Plan for Operating Procedures
17......................	Operations Safety Requirements
18......................	Conclusions
19......................	Glossary"

(a) Chapters 1 through 12 and 18 constitute the Preliminary Safety Analysis Report (PSAR). Additional sections shall be included in the Final Safety Analysis Report (FSAR).

(b) When a formal site study has already been prepared, the study can be referenced in Chapter 3. Pertinent data specific to the facility can then be extracted and placed in Chapter 3.

As stated in Appendix B of the Consultation and Cooperation Agreement between the State of New Mexico and DOE.[2]

> "The Safety Analysis Report (SAR), as amended from time to time, constitutes the most comprehensive document concerning WIPP both in general and specifically as related to public health and safety as well as other matters. The SAR is a dynamic document describing all aspects of the WIPP design and shall be amended by way of revision and additions throughout the entire WIPP project."

The SAR has been rather extensively amended by DOE a total of eight times. These amendments were made in response to comments of the State Environmental Evaluation Group (EEG), as a result of changes in design of structures, systems and components, or because of new information considered by DOE to be more reliable. The EEG has reviewed each of these amendments and has forwarded detailed written comments and recommendations to DOE. This report represents a summary of the more significant EEG comments and associated DOE responses. In most instances, following the submission by EEG of written comments, appropriate DOE staff, and contractor representatives meet with EEG to discuss the DOE's interpretations and planned response to the EEG comments. Any controversial issues may be further debated in an effort to reach a resolution. This report includes a listing at the end of the discussion of each Chapter of those issues which remain unresolved.

The comments and DOE responses as presented below do not include all topics addressed in the original documents nor are they intended to be verbatim quotations from those originals. Instead, an effort has been made to provide only a summary of the more substantive issues raised. Copies of the original submittals, and the written response from DOE are available from EEG upon request. The comments are presented according to the organization of the SAR rather than in relation to their importance to health and safety. However, the more significant health issues are highlighted as appropriate following the discussion of each chapter.

II. EEG COMMENTS AND RECOMMENDATIONS

A. Chapter 1. Introduction and General Description

This Chapter of the SAR provides an introduction and very general description of the facilities, the types of wastes, and the DOE Contractors involved in either design, construction, or operation of WIPP. EEG has suggested additional information to be added to this Chapter, and recommended deleting conclusions not fully substantiated by the data. For example, in the original versions, the statement was made that there are "no major technical problems with the site as it is now understood." In the early stages of the site evaluation, discussed further with respect to Chapter 2 below, EEG urged that more information be provided on the Site and Preliminary Design Validation Program (SPDV) and that several geological issues relative to the suitability of the site be resolved through additional studies. EEG also recommended that the SAR provide details on procedures for verification and enforcement of the Waste Acceptance Criteria.

In general, the DOE responded favorably to these recommendations for additional geotechnical information by including the information in several chapters of the SAR, rather than Chapter 1. The DOE also agreed to perform additional geotechnical studies to resolve the questions concerning site suitability. This agreement, however, was made as a result of a lawsuit filed by the State against DOE. The DOE has continued to maintain in the SAR that there are no significant geotechnical problems with the site. The State/DOE litigation resulted in a Stipulated Agreement [2] signed July 1, 1981, requiring the execution of a Consultation and Cooperation Agreement between the parties. Appendices B and C of this Agreement provided for the completion of several topical reports and five additional studies designed to improve the understanding of the geology at or near the site and the hydrology of the water-bearing zones at the site. The following final or interim reports were to be completed before the decision to construct the repository:

"1. Deep Dissolution: Including all available pertinent up-to-date data and arguments for and against the hypothesis of deep dissolution in the Delaware Basin and its potential effect on WIPP.

2. Disturbed Zone: Including all available pertinent up-to-date data and analyses of the nature, extent and potential significance to the repository.

3. Breccia Pipes: Including all available pertinent up-to-date data and analyses concerning the existence of breccia pipes in the basin and the reef, potential for future breccia pipe development, and their significance to WIPP.

4. DMG Hydrology: Including all available pertinent up-to-date data and analyses of the hydrologic characteristic, geochemistry, potential and rates for salt removal, and directions of flow and

possible communication with other aquifers e.g., reef aquifer, San Andres Limestone aquifer and shallow aquifers.

5. Regional Hydrology: Including all available pertinent up-to date data and analyses of the recharge and discharge area, flow times and interconnections of aquifers near the site.

6. Natural Resources: Including detailed plans to control recovery of potash and hydrocarbons without disturbing the repository, and the evaluation of potential consequences of these plans.

7. Results of SPDV Site Validation Experiments: Including all pertinent results and analyses of experiments as listed in WIPP-TME-2975, pp. 15-16.

8. Plans for SPDV Design Validation: Updated, detailed plans and rationale for the proposed design validation experiments as outlined in TME-0358 and TME-3063."

The additional studies of the geology and hydrology at the site included the following:

"1. Test a (known) brine reservoir in the deformation zone (ERDA-6).

2. Present an up-to-date report of all data on other known brine reservoirs in the area.

3. Carry out horizontal exploration of the disturbed zone from the depth of the repository. (By mutual agreement between the State and DOE, this plan was deleted and instead the drill hole WIPP-12, located just north of Zone II and in the disturbed area, was deepened to the Delaware Mountain Group. In the process of deepening, another pressurized brine reservoir was encountered.)

4. Evaluate the extent of fracture flow in the Rustler aquifers.

5. Study the characteristics of other aquifers in the area."

In commenting on planned or ongoing studies referred to in Chapter 1 and other Chapters of the SAR, EEG has urged that target dates for completion of these studies also be included in the summary tables of Chapter 1. In some cases, DOE has preferred to delete reference to such studies. As an illustration, section 2.6.63 was deleted in that it referred to "Ongoing Studies" to determine the timing and magnitude of past climatic changes in the site region, and their impact on geologic events over the past ten thousand years. These studies were to include examination of cores, and radiometric dating of organic and ash fall materials. It was to be completed in Mid-1981. DOE stated in 1982 that "These studies have been temporarily suspended due to the magnitude of effort being expended to satisfy the requirements of the DOE State Stipulated Agreement. A schedule for completion of these studies will be established in a future amendment." This new schedule has not been included in any revision through Amendment 8. EEG recommended that provisions be added to this Chapter to reflect the fact that some wastes which do not meet all of the Waste Acceptance Criteria may be accepted at WIPP with prior approval of the WIPP Project Office. DOE had previously agreed that the State will be notified in advance of such shipments and be permitted to review these proposals before the decision is made to ship the waste. DOE responded to this comment by proposing that such provisions related to DOE/State agreements be added to the Consultation and Cooperation Agreement (C. & C.) and the WIPP Operational Procedures instead of the SAR. DOE stated on December 29, 1983, that draft provisions of such an amendment would be submitted to EEG. To date, no such amendment of the C. & C. agreement nor the WIPP Operational Procedures has been submitted.

Unresolved Comments

1. Although the First Modification to the C & C Agreement will provide for a description and anticipated schedule of reports on geotechnical studies, revisions should be added to the SAR to reflect all studies underway or planned by DOE and its contractors. Such revisions should include the anticipated completion date for each study.

2. The C & C agreement and the WIPP Operational Procedures should be amended to indicate that the EEG will be notified in advance and be given an opportunity to review any proposal to ship waste to WIPP which does not meet the WIPP Waste Acceptance Criteria.

B. Chapter 2. Site Characteristics

This Chapter provides details on the geography and demography of the site, nearby facilities, meteorology, seismicity, hydrology, and regional and site geology. Although DOE concluded in Chapter 1 that there were "no major problems" with the site, the data in Chapter 2 of the original SAR seemed to EEG to be inconsistent with this conclusion. For example, although the seismic reflection profile data were conflicting and inconclusive, they did suggest that faults may exist in the northern part of Zone III and IV from the DMG to the Salado formation, extending through the Castile. This zone of instability appeared to begin only about 3/4 mile north of Zone II, which originally represented the northern-most boundary of the repository. In early comments, EEG also called attention to the depression in Marker Bed 124 about two miles north of ERDA-9 (center of the repository). This collapse feature was considered possible evidence of deep dissolution such as a breccia pipe. Also an anticline in the Castile exists at WIPP-12 borehole, at the northern edge of Zone II, and the northern boundary of the proposed repository. Figure 2.7-25 illustrates three known depressions in MB 124, and since the depression two miles north of ERDA 9 is not reflected in the Salado and higher formations, the possibility was considered that it is a collapse feature due to deep dissolution.

EEG stated that the SAR had inadequately evaluated the extent of deep dissolution within or near the site. It was noted that several studies were being planned or in progress by DOE and its contractors which would help to resolve the questions on deep dissolution, and these were completed prior to the decision on the suitability of the site.

EEG called attention to the inaccuracies of the SAR's data and discussion with respect to numerous brine reservoirs in the Castile formation and their location and possible interconnection.

Certain of the reservoirs may be interconnected and cover a broad area including the WIPP site, however the data on the reservoirs at ERDA-6 and WIPP-12 suggest that these reservoirs are not connected. There remains the possibility that the WIPP-12 brine extends beneath the WIPP repository.

EEG also expressed concern over the natural resources present at the site and believed that this provided further evidence that the SAR should not conclude that no major problems exist at the site.

DOE responded by deleting Figures 2.7-23, 2.7-24, and 2.7-25, on the basis of Westinghouse "reinterpreting" the seismic profile data. The "disturbed zone" was considered a misnomer, and instead the zone was referred to as an "anomalous zone." The fact that the disturbed area did not extend into the Salado was considered by DOE to be evidence that it was not active "instability" and therefore would present no threat to WIPP. The MB-124 depression and the WIPP-12 anticline also were not considered problems for WIPP but rather reflect slow geologic processes of general interest. As a result of the State/DOE

Stipulated Agreement[2]. DOE carried out several additional studies to try and improve the understanding of possible deep dissolution, brine reservoirs and the nature of the anomalous zone and its potential impact on the proposed repository. The agreement provided that a final or interim report on these studies would be completed prior to a decision to construct the repository. For example, DOE agreed to drill an additional hole in the area 2 miles north of ERDA-9 to determine the cause of the depression of MB-124. This is being planned for the Summer of 1985. Horizontal drill holes at the level of the repository were to be drilled 3000 feet north of the northernmost drift in the repository, to obtain further data on the "Zone of Anomalous Reflection." This decision was subsequently rescinded by mutual agreement between the State and DOE and instead the Drill Hole WIPP-12 was deepened into the Castile to determine the cause of the anticline at this location. This well encountered a large pressurized brine reservoir at 3016 feet below the surface within fractures in the Castile formation, about 900 feet below the repository horizon.

More detail on the issues addressed above by EEG may be obtained from the EEG reports 2, 3, 6-18, 21, 22, 23, 25 and 27.

The original WIPP design put the underground 100 acre repository in the northern part of Zone II, which would have located a part of it directly above the deformed beds of the Castile Formation. From the seismic and borehole data, this area was thought to contain the potential problems of deformed salt at the repository horizon as well as the long-term uncertainties associated with regional deformation.

EEG proposed to DOE in the Spring, 1982 to reorient the WIPP repository to the southern part of Zone II in order to take advantage of an area with apparently more predictable structure and much less deformation. This decision received a strong impetus when pressurized brine was encountered in the borehole WIPP-12, one mile north of the center of the site, in late November, 1981. The DOE announced the decision to reorient the site to the south in Summer, 1982. To confirm the predictions of the geologic structure in the southern part, the DOE drilled a well, DOE-1, just outside Zone II. The data from this well showed a lack of deformation in the geologic units in this area.

There continues to be disagreement between DOE and EEG in the interpretation of the WIPP site characteristics in Chapter 2 of the SAR. EEG interprets the descriptions to be inaccurate or incomplete in many respects and omits references to potential problems which are not yet resolved. EEG maintains that the SAR should accurately reflect the current status of understanding of these issues and should describe the efforts being made to resolve them. The DOE agreed to address these concerns in SAR Amendment 9. Although additional information is needed to improve understanding of the geologic processes, EEG concluded in EEG-23 that the site has been characterized sufficiently to warrant site validation for the present WIPP project.

In commenting on section 2.1.1.2 concerning the boundaries for establishing effluent release limits, EEG argued against use of the

Zone IV boundary for purposes of accident releases. In the published interagency agreement between DOE and the Bureau of Land Management of the Department of Interior (BLM), it was clearly stated that BLM would have control of Zones II, III and IV and that only Zone I was under DOE control. In meeting with DOE[19], their representatives stated to EEG that they would seek an amendment to the Interagency Agreement to reflect DOE control of access to all four zones. This amendment has not been issued to date. In a recent communication from the WIPP Project Office, it was pointed out that the present Department of the Interior Administrative Land Withdrawl for the development of WIPP specifically prohibits bringing radioactive waste on site. Therefore no change is needed for radiological accidents under the current withdrawal authority. Legislation for permanent withdrawal of the WIPP area is being drafted and will provide for appropriate DOE control.

Unresolved Comments

1. Revisions are needed to the discussions of site characterization to reflect data as it becomes available from studies in progress or planned. Particular effort should be made to see that statements accurately reflect the current status.

2. Either the Department of Interior Withdrawal Legislation or the Interagency Agreement between DOE and the Bureau of Land Management should be revised to provide for DOE control of Zones I, II, III and IV for purposes of accidental release of radionuclides. This change is needed prior to shipment of the wastes to WIPP.

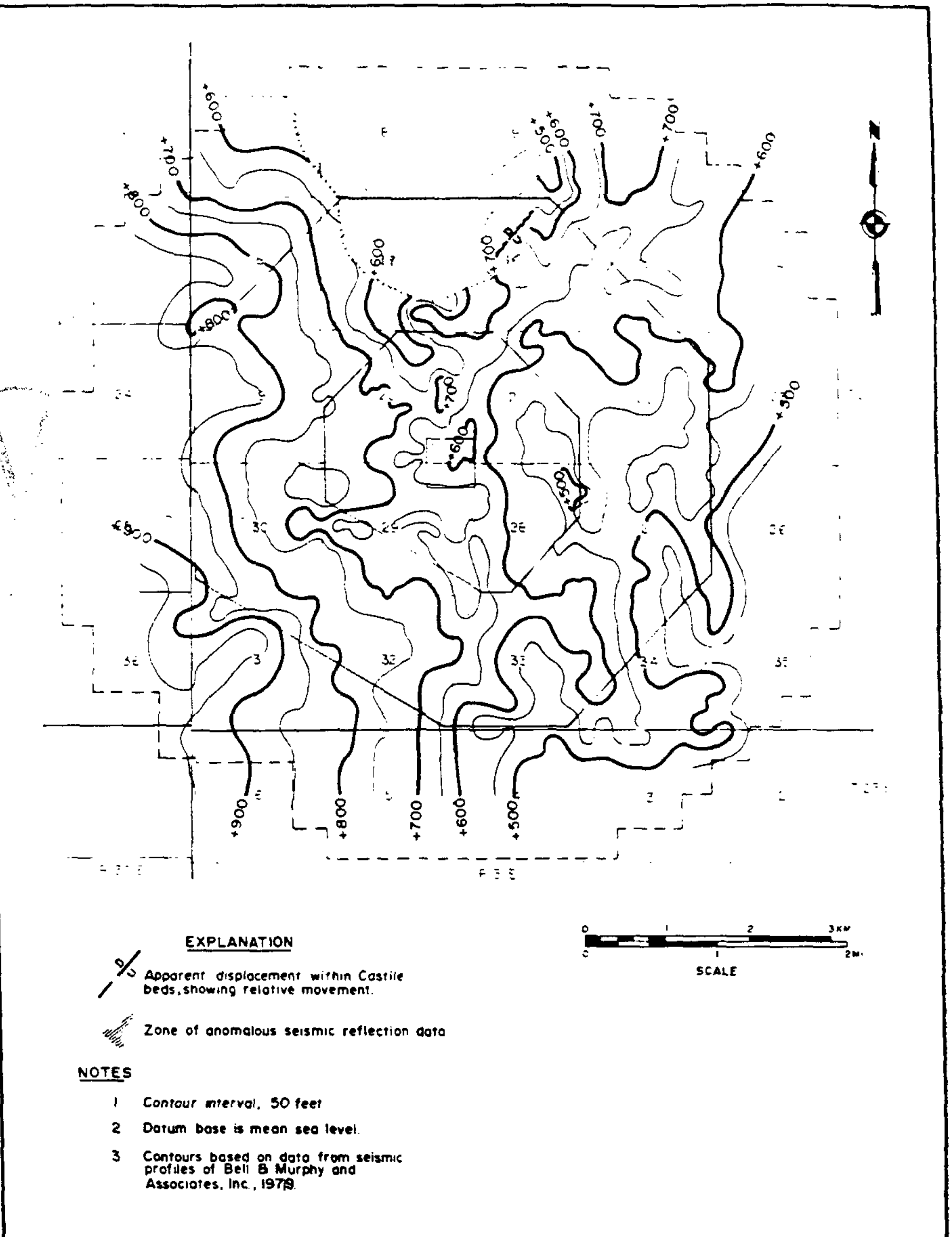
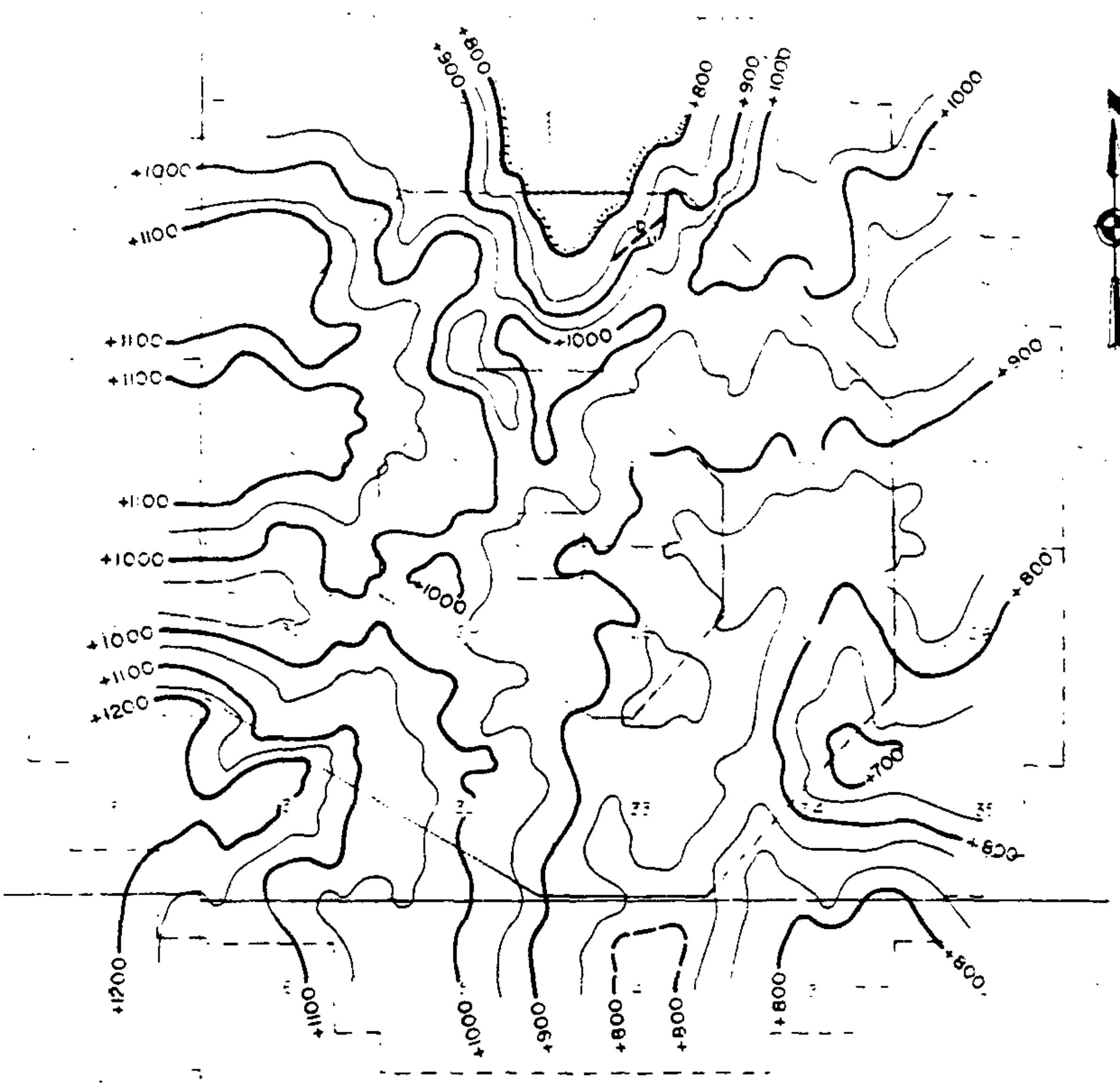


Figure 2.7-23 Structure Contours on Top of Castile Formation



EXPLANATION

Apparent displacement within Cowden Anhydrite, showing relative movement

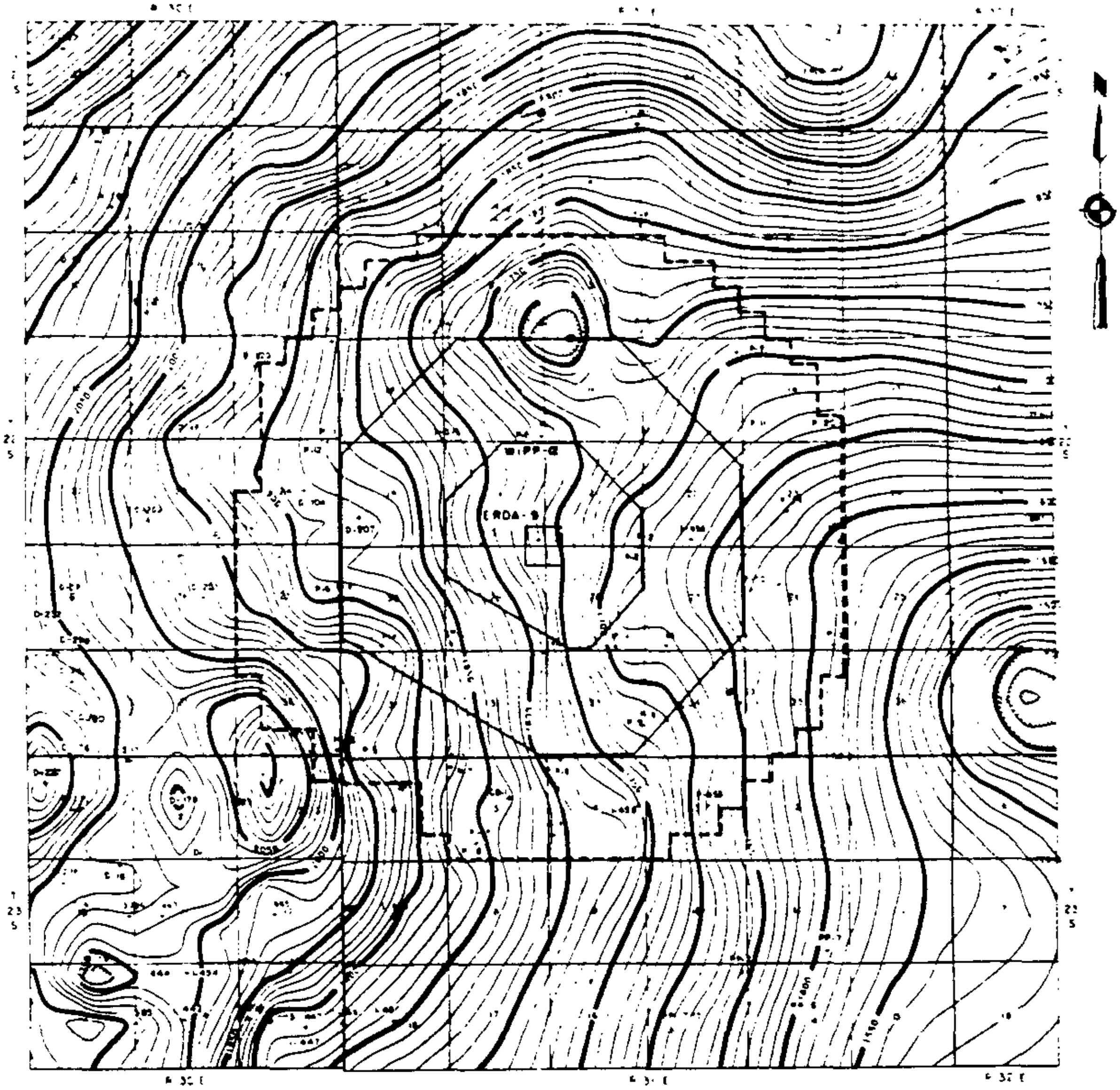
Zone of anomalous seismic reflection data

SCALE 0 1 2 3 KM; 0 1 2 M

NOTES

1. Contour interval, 50 feet.
2. Datum base is mean sea level.
3. Contours based on data from seismic profiles of Bell & Murphy and Associates, Inc., 1979.

Figure 2.7-24 Structure Contours near the Cowden Anhydrite



NOTES

1 Contour interval: 10 feet
2 Datum base is mean sea level
3 Contours based on data from geophysical logs of WIPP and industry potash exploration holes

REFERENCE

Griswold, 1977, Figure 13

Figure 2.7-25 Structure Contours on Base of MB124

C. Chapter 3, Principal Design Criteria

This Chapter describes the principal design criteria for the WIPP project. This includes the characteristics of the waste, waste handling and storage capacities, structural and mechanical design criteria, safety protection criteria, classification of structures, systems and components for purposes of quality assurance, and a few statements on decommissioning.

The EEG has pointed out some discrepancies between the wastes inventory in the SAR and the inventory as reported in the FEIS and other DOE publications. Also the characteristics of the wastes as described in the narrative (e.g. subsection 3.1.1.1) are not consistent with the tabulated characteristics in the SAR (e.g. Table 3.1-1A). DOE agreed that these inconsistencies exist and stated in November 1983 that a study was underway to obtain more accurate data, and on completion of this study, the SAR will be revised. Although subsequent amendments have been issued (Amendments 7 and 8), this data has not been revised. For example, subsection 3.1.1.1 states that the average density of the CH-Waste is 2 gm/cc, or approximately 930 lbs/55 gal drum. However, Table 3.1-1A indicates an average weight of 330 lbs/drum. The SAR indicated in Table 3.1-2 a maximum alpha TRU/55 gal drum of CH-Wastes of about 15 Ci, whereas on pages 3.1-4, a maximum of 85 Ci was indicated. This was changed in amendment 8 to indicate that a maximum ^{239}Pu equivalent limit would be provided at a later date.

Concerning the experimental Defense High-Level Waste (DHLW), the FEIS stated that the equivalent of 40 canisters would be emplaced, whereas the SAR indicated 60. The SAR since has been amended to be consistent with the FEIS on the number of equivalent canisters (40), but also stating that about 60 experiments may be carried out. Additionally, subsection 3.1.1.3.2 and Table 3.1-3 stated a volume of 23 ft^3/ canister DHLW, an increase over the previous volume of 520%. When EEG commented on this increase,DOE responded that the Ci/l for many nuclides will be sharply reduced in a future amendment, resulting in the same total curies/canister. Amendment 8 reported the nuclides of DHLW as 54.2 Ci/Lb. Based on a density of 2.8 gm/cc for the glassified waste, the total curies/canister of DHLW has been reduced from 444,000 to about half that number. However, a recent draft of the "Interim Bounding Criteria for Defense High-Level Waste for Receipt at the WIPP"[33] establishes a maximum of 430,000 curies/canisters. The SAR needs to be revised to reflect the authorized maximum.

EEG commented in 1983 that although the SAR discussed the possible retrieval of wastes, no information was given on the criteria to be used to determine the necessity for retrieval. EEG urged that this criteria be included in the SAR at an early date, so that it is clear that the decision process is based upon public health considerations, and there will be an opportunity for public input into the development of the criteria. In a letter of October 1, 1984,the DOE Albuquerque Operations Office stated that the retrieval criteria would be provided to the State by the end of 1985. In the reply from the State, this date was accepted.

In 1980 EEG objected to certain provisions of the classification system for structures, components and systems to be used in the construction and operation of WIPP. This classification system originally was based on Title 10, Parts 20, 21, 71, 100 of the Code of Federal Regulations. A design Class I item was regarded in the SAR as a basic component as defined in Title 10, Part 21, and applied to items essential to the prevention or mitigation of the consequences of an accident that could result in an annual radiation dose beyond the exclusion area boundary to the whole body, bone marrow, and gonads of 0.5 rem, or 1.5 rem to all other organs. "Exclusion Area" is defined in Title 10, Part 100. 3(a), and was interpreted by DOE as the area within Zones I, II, III and IV. The SAR concluded that no design Class I items have been identified at WIPP. EEG's original objections were based on the DOE conclusion that no items fell into Class I. For example, EEG urged that the shipping containers for the three types of waste be considered Class I, EEG contended that it was meaningless to define a Class such that no items were included. The purpose of the classification system is to designate the extent of quality assurance and design requirements for each item in relation to their potential hazard. The response from DOE was that the quality of the shipping container will be assured through the Waste Acceptance Criteria.

In January 1981, the definition of Design Class I was amended to apply to items essential to the prevention or mitigation of the consequences of an accident that could result in a <u>50 year dose commitment</u> to the whole body, bone marrow and gonads of <u>25 rem, or</u>

75 rem to all other organs beyond the protective area boundary. "Protective Area" was defined on p.4.1-2 as "controlled Zone I." But subsequent statements indicated that DOE interpreted the "Protective Area" as the four zones of WIPP. The conclusion that no items fell into Design Class 1 remained unchanged. In October, 1982 EEG pointed out that the classification system was inconsistent with the proposed final rule of the Nuclear Regulatory Commission (NRC) for "Disposal of High-Level Radioactive Waste in Geologic Repositories", 10 CFR 60. For example, 10 CFR 60 defined the phrase "important to safety" with reference to structures, systems, and components, or "Those structures, systems and components essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ of 0.5 rem or greater at or beyond the nearest boundary of the unrestricted area at any time until the completion of permanent closure." The preamble to this final NRC rule indicated that this value of 0.5 rem is equal to the annual dose to the whole body in an unrestricted area that would be permitted under 10 CFR 20 for normal operations. However under the SAR interpretation, a Class I component would be one which upon failure would allow a 50 year dose commitment of 25 rem, which could be delivered in a single incident. This would imply a higher radionuclide release limit for WIPP than for a high level waste repository. Although WIPP is not subject to NRC regulations, it certainly should not be a greater public health risk than a high level waste repository.

In further comments on the classification system in November, 1983, EEG noted that the Class assigned to various components, structures and systems did not seem consistent with the definition of the Class as stated in Chapter 3, and in some cases the assigned class was downgraded for no apparent basis. Also, the definition of Class II was changed. For example, items used to process waste, the Central Monitoring System (CMS), certain contamination alarms, and the auxiliary generator, were all downgraded from Class II to Class III. The word "permanent" was added to the Class II definition leaving the impression that items for occasional or emergency use only would not be assigned Class II, but would fall into Class III. Also the relationship between the quality assurance and the various classes was not clearly defined in the SAR.

The SAR indicated that the quality assurance requirements are applied on "a selective basis" to Design Class II and III items, and the methods used in the selection process are described in manuals and procedures developed by DOE and the major project participants. In reviewing these manuals and procedures, EEG has been unable to find reference to the classification system except in references 28, 29, 30. These describe a classification somewhat different from that used in the SAR. As further illustration of the inconsistency in the classification system EEG compared the WIPP classification as shown in Table 3.4-2 of the SAR with the office of Nuclear Waste Isolation (ONWI) classification of similar structures and components for an exploratory shaft for a HLW repository in the Permian Basin.[14] In the

ONWI classification several components of the Exploratory Shaft are identified as Class I and II, and there is a direct correlation between the design and QA requirements and the assigned Class. For the WIPP project, all shaft components are Class III. It is also interesting to note that the DOE Albuquerque Operations Office Order AL5481.1A on "Safety Analysis and Review System For AL Operations"[15] provided the following directive for new DOE facilities containing large quantities of radioactive material:

> "The postulated exposures to the general public (from credible accidents) shall be compared to 10 CFR 100 limits as maximal allowable dose commitments. More desirable upper limit accidental dose commitments are 5 rem whole body and 15 rem to an internal organ including the thyroid and 30 rem to the bone (limits in Draft of 10 CFR 101). These are 50 year dose commitments to be applied for each individual accident situation analyzed."

In reference to the DOE (ALO) Order, it was further noted that this Order presented a suggested Table of Contents for a SAR. This also was found to be significantly different from the WIPP SAR. For example, unlike the SAR the Table of Contents in the DOE (ALO) Order included Chapters covering "Summary of Emergency Response Plan", "Waste Management," "Summary Plan for Employee Training," and a "Glossary". EEG has repeatedly recommended that the SAR be revised to be more in accord with this Order, but the WIPP Project Office has replied that this Order is only a guide and the information on these topics is available in other published reports.

It is obvious that some inconsistency exists between the quality assurance criteria for WIPP, the more restrictive criteria of a HLW repository, and the directives of DOE (ALO) for new nuclear facilities.

In August, 1984, the EEG retained the Tenera Corporation to further examine the adequacy of the WIPP classification system, design requirements and quality assurance. A report of their findings has been prepared and will be distributed as an EEG report [31]. In general, this report concludes that the health or hazard implications of the classification system, as defined by Bechtel, is not substantially different from that used for a civilian nuclear reactor. However, they also noted inconsistencies between the classification as described in the SAR and that of Bechtel. Tenera's report recommended that the 0.5 rem dose in 10 CFR 60 be established as a WIPP criterion for determining whether components must comply with the quality assurance program. The report recommended that the EEG review the implementation of the quality assurance program during the construction of the WIPP facilities and the underground repository. At the present time, the EEG has a full-time radiological physicist and a part-time engineer on site. Their responsibilities include evaluation of the WIPP quality assurance program.

Unresolved Comments

1. Revisions should be added to the information in the SAR on the characteristics of the wastes and waste containers so that this information accurately reflects the waste packages coming to WIPP. It is understood that this information will be included in Amendment 9.

2. Extensive revisions are needed in the SAR to the definitions, data and discussions of the classification system for structures, systems and components. These revisions should show more clearly the relationship between the class, the design requirements, and the required quality assurance. The classification system should provide for the protection of the public at least to the same extent as that required for a high level waste repository licensed by NRC, and should conform more rigorously to applicable orders of DOE and the Albuquerque Operations Office. According to the WIPP Project Office of DOE, some of these revisions will be included in Amendment 9.

3. The SAR should be amended to include the criteria to be used to determine the necessity for retrieval of the wastes. DOE has indicated that these criteria will not be available until December, 1985.

D. <u>Chapter 4, Plant Design</u>

The principal features of the Plant are described in this Chapter, including surface and subsurface facilities. There is also provided a description of the service and utility systems, the waste handling, emplacement and retrieval equipment, and the underground excavation equipment.

The comments of EEG on this Chapter have previously focused on the need for more detailed information covering the various subjects. For example, EEG has noted the need for more details on the emplacement procedures and equipment for the RH waste. Additional information was also needed on the fire protection systems, components and procedures. In responding to the EEG comments on RH emplacement, the DOE indicated that this information would not be available until Title II plans were completed. Concerning the EEG comments on fire suppression, DOE responded by the addition of considerably more information in the SAR on fire protection facilities and consequence assessment.

In section 7B.2.17, the SAR recognizes that a fire could occur in the sample preparation room, because of the chemicals to be used there. After analysis of this event, the DOE concluded that such a fire is bounded by the fire considered in the underground facilities, but this conclusion was based on the assumption that the fumes and radioactive effluents would be removed by the fume scrubber and HEPA filters, and the fire would be extinguished by the automatic sprinkler system. As indicated in DOE Order 6430,[17] these assumptions may not be valid unless the fire protection systems are considered "critical", or Class I or II components.

Unresolved Comments

1. More detail is needed in either Chapter 4 or 5 on the waste emplacement procedures.

Chapter 5. Process Description

A description of the waste handling system for each type of waste is included in this Chapter. The Chapter also discusses process interruption modes, underground excavation operations, and procedures for the retrieval of each type of waste, when retrieval is decided upon.

The early comments of EEG requested additional information on how the WIPP facility intends to verify compliance of the waste shipments with the waste acceptance criteria and what action would be taken if a shipment fails to meet the criteria. Subsequent additions to this Chapter and Chapter 9 (section 9.5) have revealed that aside from routine visual inspection the only waste acceptance criteria to be verified at WIPP are the containment configuration, labeling, surface contamination, external dose limits, and documentation. In discussion with the Westinghouse staff, the EEG also was informed that the other waste acceptance criteria would be verified at the waste generator sites by means of DOE audits. Limited information has been provided to EEG on the frequency and the nature of these audits. Also, the WPO has agreed to have an EEG representative on each of these audits, so that EEG may verify their adequacy in protecting the public health of New Mexico.

The EEG also recommended that additional information be added on procedures for solidification of radioactive liquid waste generated at the site. The DOE response stated that solidification would be carried out on site by a local contractor, but no procedures were added to the SAR to provide sufficient information to make a radiation safety evaluation. The EEG also objected to the logging procedure for waste shipments illustrated in Table 5.5.1. This Table listed the type of information which would be recorded on each shipment of waste. It was satisfactorily revised in Amendment 4 as shown below to add logging information on all of the Waste Acceptance Criteria.

The SAR (Chapter 4) has indicated that RH-TRU is to be emplaced in rooms or entries where CH waste also is to be emplaced. However EEG requested additional information in Chapter 5 on the procedures for retrieval of CH waste when RH waste is emplaced in the walls. Additionally, more information is needed to evaluate shielding in the underground storage area. The DOE responded by clarifying in both Chapters 4 and 5 that CH and RH Waste would not be combined in a storage room until after the retrieval decision. Therefore it now appears that both wastes will be emplaced prior to the retrieval decision, but such emplacement will be in separate rooms or entries until after the retrieval decision. Concerning underground shielding, DOE indicated that results of their evaluation would not be available until after completion of Title II design.

Unresolved Comments

Additional information is needed in the SAR to provide evaluation of shielding in the underground facilities.

F. Chapter 6. Radiation Protection

This chapter reviews the measures designed to ensure that radiation doses to workers at WIPP and the general public are "as low as reasonably achievable" (ALARA). It discusses the types of radiation sources, the design features of the facility intended to prevent undue exposure, or radiation risks, the radiation protection instrumentation and the estimated on-site and off-site dose assessments to workers and the general population as a result of normal releases. The WPO has established the *operational* dose limit to workers at 1 rem/year, approximately 20% of the allowable occupational limit.

EEG's initial comments urged that more information be added to allow evaluation of the radiation shielding in the underground areas. Also the dose assessments did not address potential internal doses to workers using respiratory equipment. DOE subsequently expanded the dose assessment information to include doses to workers with respirators, but indicated that the underground shielding could not be completely evaluated until the Title II designs are complete. The SAR also contained inadequate information on the environmental sampling planned. Additional information was added, but this did not include location or frequency of sampling. In early 1985, the WPO provided for review by EEG a draft report on "Preoperational Environmental Monitoring Program for the Waste Isolation Pilot Plant".

This chapter refers to the DOE Order 6430 (Draft)[16] as a basis for the design criteria for WIPP. As reflected in our comments on Chapter 3, the EEG has repeatedly called attention to the fact that the design criteria should be upgraded to the DOE (ALO) Order 5481.1A or 10 CFR 60. We note that the draft document [16] referred to in Chapter 6 has been superceded by a revised DOE Order.[17] In Chapter XXI of this more recent Order, it defines "critical items" as "those structures, systems, and components whose continued integrity and/or operability are essential to assure confinement or measure the release of radioactive materials in the event of the DBA (Design Basis Accident)..." DOE has maintained that there are no critical items at WIPP. We also noted that the definition of the "Design Basis Fire" is consistent with EEG's recommendation for consideration of fires in the surface facilities at WIPP. EEG has pointed out to DOE that their failure to consider the fire suppression and manual fire protection equipment as "critical items" (either Class I or II) means that they must assume failure of this equipment in evaluating the design basis fire.

The recent DOE Order (6430.1)[17] defines the DBF as "That fire which is the most severe DBA of this type. In postulating such a fire, failure of the automatic and manual fire suppression provisions shall be assumed except for those systems considered critical items." (Emphasis added.) This point is discussed further under Chapter 7. The response from the WIPP Project Office on this point was that Chapter XXI of the DOE Order refers only to Plutonium Processing Facilities and WIPP is not such a facility. This does not appear consistent with the language of Chapter XXI. As stated in the first paragraph:

> "This Chapter supplements these other sources and provides, specific direction and guidance on particular requirements <u>which must be met</u> in the design and construction of facilities for processing <u>and handling</u> of substantial quantities of plutonium. These particular requirements are necessary because of specific toxicological problems associated with plutonium."

Certainly WIPP is a facility for handling large quantities of plutonium contaminated wastes, therefore it would appear to be subject to Chapter XXI. Furthermore in the third paragraph of this chapter, it states that:

> "Questions on the application of these design criteria in the planning and design of new DOE facilities should be addressed to the Director, Office of Project and Facilities Management and to the Deputy Assistant Secretary for Environment, Safety, and Health, EP-30, at DOE Headquarters, for resolution."

Therefore EEG believes that the question of the application of Chapter XXI should be referred to the offices indicated above for resolution.

EEG has also opposed the definition of Class I items on the basis that the radiation limits referred to are not consistent with current national criteria. This EEG argument, also, is supported by the more recent DOE Order[17], Chapter XXI, and DOE Order 5480.1A,[18] Chapter XI. The radiation limits for members of the public are prescribed as 0.5 rem/year and in DOE Order 6430.1, XXI-6, it states that "in no case shall the applicable exposure regulation be exceeded, either with respect to the operating personnel, or to the public at the boundary or <u>nearest point of public access</u>".

More recently, EEG has questioned the assumptions used for certain of the dose assessment calculations. For example, it is not clear why the RH-TRU gamma spectrum was used for CH-TRU. This would tend to ignore the neutron and ^{241}Am radiation. Also, further information is needed to support the assumptions used to calculate resuspended radionuclides (Section 6.2.2.1). DOE responded by pointing out that this assumption (RH-TRU spectrum) provided conservatism with respect to shielding calculations, and the Am-241 was ignored because it would cause no significant change in the shielding design. Also, the neutron dose will be monitored during operations, and appropriate action taken if neutrons are detected. This response was acceptable to EEG.

Unresolved Comments

1. Additional information is needed in the SAR on the environmental monitoring program for WIPP.

2. As recommended under comments on Chapter 5, more information is needed to permit evaluation of the adequacy of underground shielding.

3. As recommended for Chapter 3, revisions are needed to the definitions, and data on classification and quality assurance for structures, systems and components.

Chapter 7. Accident Analysis

This Chapter provides analyses of the radiological consequences of accidents which might occur during handling of the radioactive wastes at WIPP. These accident scenarios were based on studies of the effect of the misuse or breakdown of handling equipment on waste containers. It has not been revised since the 4th amendment to the SAR which was issued by DOE in September 1982. Therefore, it has not addressed certain changes in the design of components, facilities and source terms. For example, the cost reduction changes of 1983 led to several substantive changes in design, which might effect the Design Basis Accident (DBA). Also there have been changes in the characteristics of the wastes to be shipped to WIPP.

In commenting on Chapter 7, EEG noted that no consideration was given to the buildup of radioactive contamination during the operational life of WIPP. Because of the long-lives of some of the transuranics, and perhaps contribution of Sr^{90}, the total buildup could exceed the EPA limits of $0.2\ uCi/m^2$ in the top centimeter of soil. DOE responded adequately by extensive revision of Chapter 6 to include the total releases.

EEG recommended to DOE that additional surface accident scenarios be considered. For example, EEG considers a major surface fire credible if one assumes that fire suppression equipment fails. (See comments on Chapter 5.) Also transportation accidents in Zones II, III or IV should be considered. The DOE rejected these comments in that DOE does not agree that a major surface fire is credible, and transportation accidents will be addressed in the Safety Analysis Report on Packaging (SARP). (The draft SARP was transmitted to the EEG in December, 1984, and is currently under review.) EEG also urged that the SAR consider radiation doses to individuals within Zones II, and III because the general public will have temporary access to these areas. DOE agreed and included consideration of a person located between Zones I and IV at the point of maximum deposition from an airborne release. Concerning surface fires of serious proportions at WIPP in section 7B.2.17, the SAR recognizes that a fire could occur in the sample preparation room, because of the chemicals to be used there. After analysis of this event, the DOE concluded that such a fire is bounded by the fire considered below ground. This analysis was not included in the SAR, but it was based on the assumption that the fumes and radioactive effluents would be recovered by the fume scrubber and HEPA filters, and the fire would be extinguished by the automatic sprinkler system. As previously indicated, these assumptions may not be valid unless the fire protection systems are considered "critical", or Class I or II components, as required by DOE 6430.1[17]. Furthermore, it would seem reasonable to include the analysis of this event in the SAR, even if the consequences are bounded.

Unresolved Comments

1. This chapter needs extensive revisions to reflect changes in design and waste characteristics.

2. The analyses should be consistent with DOE Order 6430.1.

3. The analyses of potential surface fires should be included.

H. Chapter 8. Long Term Waste Isolation Assessment

This chapter assesses the long-term consequences to the public health and safety of hypothetical sequences of events leading to breach of the salt formation and repository by aqueous solution and movement of the radioactive material to the biosphere. It includes a description of the communication modes, the criteria for the selection of the modes, and the assumptions and methods of analyses used.

EEG offered some suggestions in 1980 and 1981 for clarifying some of the assumptions made in the communication modes considered, and also urged consideration of other plausible modes. The DOE responded by adding additional clarification, and also added a detailed analysis of some of the additional modes recommended. For example, DOE has indicated that the high salt content of the Rustler water ruled out the likelihood of a well into the Rustler between the WIPP repository and Malaga Bend, which could shorten the time needed for transport of the breached waste to the biosphere. However in response to EEG's comments, the DOE added a well scenario to Section 8.3.1.4. The results were acceptable and comparable to a similar study by EEG.[20] Also, DOE revised one of the earlier Communication Events (#1) on page 8.3-7 to consider the effect of buildup of radionuclides in the environment of Malaga Bend following a breach and leach scenario. The results demonstrated that accumulation of radionuclides over thousands of years at the maximum release rate would not lead to significant annual doses to the affected population. EEG also suggested that the scenario analyses include, or discuss, potential doses to infants and children. DOE agreed and included the results in a revision to the SAR. This analysis was acceptable to EEG.

Another area addressed in 1981 by EEG was the need for evaluating the effect of uncertainties in the distribution coefficients used by DOE to estimate the travel time from the repository to Malaga Bend. DOE agreed that there was considerable uncertainty in the Kd coefficients but did not revise the SAR. EEG subsequently published a report which included a sensitivity analysis for changes in several parameters including the absorption coefficient. This report[21] concluded that assuming wide variations in absorption coefficient (down to 0 ml/gm) did greatly affect the rate of transport of the radionuclides released from a breached repository, but did not substantially increase the resultant doses associated with use of the water at Malaga Bend.

In 1981, EEG suggested that additional detail is needed in section 8.3 to describe the communication events and methods of analysis, particularly the specific equations used. DOE agreed with this comment and stated that the detail would be provided "in a future amendment." It was added to an appendix to Chapter 8. EEG published several reports containing EEG's analyses of potential breach of the repository including transport, release and consequences. On September 16, 1981, these analyses [22-26] also were discussed by EEG at an open meeting with experts in several disciplines to further resolve whether all reasonable analytical approaches and potential breach and transport mechanisms had been adequately examined.[27] Although it was agreed that considerable uncertainty remains concerning the hydrology parameters used in the scenarios presented in the Final Environmental Impact Statement (FEIS) on WIPP[28], there were no new scenarios recommended at this public forum. Also there were no major objections to the EEG proposals or the approaches taken in the EEG analyses.

Additionally, in 1981, EEG urged DOE to consider scenarios in which human intrusion leads to the transport of the waste directly from the repository to the surface, such as possible communication with a brine reservoir below the repository. DOE believed that such a release would be bounded by scenarios already considered in the FEIS, and therefore did not agree to add such a scenario to the SAR. This type of release was considered by EEG in 1982 [23,26], and DOE in 1983 (amendment 6 to the SAR). The results showed that if the communication events occurred at least 400 years after decommissioning, the resultant doses would be less that what might be associated with normal background. The highest 50 year dose commitment to an individual was found to occur at 100 years post-closure and was 590 mrem from the inhalation of contaminated dust resuspended into the atmosphere.

In 1983, in commenting on amendments 4, 5, and 6 of the SAR, EEG noted that the assumed maximum CH-TRU/drum of 85 Ci is no longer consistent with the 140 Ci/drum of Pu-239 equivalent which is being considered by DOE as an amendment to the Waste Acceptance Criteria (WAC). DOE agreed to evaluate the effect of this change in a future amendment, but to date the change to the WAC has not been finalized, so no such evaluation has been made.

EEG called attention to the need to revise Chapter 8 scenarios as new hydrology data for the Rustler becomes available. DOE agreed to make such changes, if needed.

Unresolved Comments

1. An early decision is needed by DOE on the maximum TRU to be authorized for waste packages to be shipped to WIPP. This level must be sufficiently low so that long-term consequences will not exceed those published in the Final Environmental Impact Statement for the WIPP project[34] Chapter 8 will need to be revised to reflect this new limit.

2. An amendment may be needed to reflect the final results of hydrology studies currently in progress .

I. Chapter 9. Conduct of Operations

This chapter provides general information on the organization and administration of the WIPP project. It includes an overview of simulation preoperational tests, training programs, security and emergency plans.

In EEG's early comments on this chapter, in 1980, it was brought out that the organization of the WIPP project, as reported in Chapter 9, was not consistent with information reported in Chapter 6. Also the references to regulations applicable to WIPP should have included the environmental health regulations of the State Health and Environment Department. A subsequent revision corrected these deficiencies.

In EEG's comments on amendments 4, 5, and 6, in December 1983, it was noted that section 9.2 stated that all equipment and systems designed for the WIPP are tested prior to operation. No detail was provided on the nature of these tests or who is responsible. The section also indicated that administrative procedures are established to ensure that test procedures are prepared, reviewed and approved. Such a testing program is commendable, and is of considerable interest to EEG to ensure that it is carried out. However, when it was recommended to DOE that these administrative procedures be added to the SAR, DOE stated that "these procedures are beyond the scope of the document" (the SAR). In commenting on amendments 7 and 8, in April 1984, EEG requested a copy of these procedures because of their potential importance to health and safety. DOE responded in September, 1984.

that they were being transmitted under separate cover. To date, no such procedures have been received. EEG also noted that WIPP does not have an Emergency Plan to cover the construction phase. The SAR makes several references to an emergency plan, but no such plan has been prepared since the Site Preliminary Design Validation phase. DOE replied that a plan has been drafted, and a copy was transmitted to EEG in November, 1984. Shortly thereafter, EEG transmitted to WPO detailed comments on the plan.

Unresolved Comments

1. *This chapter should be revised to provide more detail on the* nature of the tests carried out on equipment and systems designed for WIPP, and what group or groups are responsible.

2. The WPO provided in November, 1984 to EEG for review a draft Emergency Plan for WIPP. EEG submitted comments on this plan in December, 1984. The plan should be completed without further delay, and referenced in this Chapter of the SAR.

J. <u>Chapter 10, Operations Safety Requirements</u>

This chapter was intended to provide operational limits to maintain compliance with the basic design assumptions used in Chapters 7 and 8, and to meet the operational objectives of WIPP. This information was intended to parallel the technical specifications for a commercial nuclear power reactor, as specified in 10 CFR 50.36. It subsequently was amended to delete reference to regulations of the Nuclear Regulatory Commission, and instead, references as a basis the DOE Order 5481.1A, pages I-3, and II-2. This does not appear to be a substantive change, since these provisions of the DOE Order closely parallel the NRC requirements pertaining to a Safety Analysis Report.

EEG concluded in its initial review of this chapter that the information was not useful, because so much of the detailed data were not available (to be included in a later amendment). Also many of the terms and administrative positions referenced in the chapter were not consistent with other chapters. For example, the description of RH-Waste in Section 10.1.9 was not correct, and the design limits in Section 10.2 referred to only some, but not all of the Waste Acceptance Criteria (WAC). Also no criteria were provided as a basis for rejecting a waste shipment. Some of the WAC were incorrectly described.

In Amendments 1 and 2, this chapter was extensively revised in response to the EEG comments. The consistency of the terms and position titles was expanded to be more in accord with the established criteria. Also additional information was added to more clearly reflect action if a waste shipment is received which is not in accord with the criteria. It was noted, however, that the certification papers of the waste shipments would be checked for compliance with the WAC, but other than containment configuration, contamination, surface dose rate, labeling and documentation, no other verification would be made. Also there was no provision for notifying the State if a shipment is received which is not in compliance with the WAC. In discussions with the WPO on this point, at a meeting on December 9, 1983, it was agreed that the Consultation and Cooperation Agreement would be amended to indicate that the State EEG would be notified in advance of an approved shipment which is not in accord with the WAC. Also, the WIPP operational procedures would reflect this point. The WPO did not believe that such an agreement should be stated in the SAR. To date, this amendment to the C & C Agreement has not been made; also, the WIPP Operational Procedures should be revised to verify that the procedures require notification of EEG if a nonconforming shipment is received at the site. Such a notification is needed so that the State can evaluate the possible health implications to the public of New Mexico during transportation of the shipment.

It has been pointed out to the WPO through several letters from EEG during 1984 that the SAR is not in complete accord with DOE Order 5481.1A or the supplement to this Order issued by the Albuquerque Operations Office, AL 5481.1A. Specifically in reference to Chapter 10, the SAR is not in accord with certain of the provisions on page I-

3, I-4, and I-5 of AL 5481.1A. For example, this order indicates that desirable upper limits for accidental 50 year dose commitments would be 5 rem whole body and 15 Rem to any internal organ. The WIPP SAR has a 25 rem 50 year dose commitment upper limit. Additionally, it has been repeatedly called to the attention of the WPO by EEG, that the content of the SAR does not include all of the topics referred to on page I-5 of AL 5481.1A, such as a Summary, Environmental Safety and Health Systems Critical to the Safety of the Facility, Environmental Monitoring Program, Conclusions and a Glossary. The WPO indicated that these sections may be added at a later date, however, more recent correspondence states that they have no plans to add the information referred to above, and in AL 5481.1A.

Unresolved Comments

1. It was also stated in a previous chapter that DOE needs to revise the DOE/State agreement and the WIPP Operational Procedures to document DOE's commitment to notify EEG in advance of a proposed shipment which is not in compliance with the WAC.

2. The SAR should be revised to be more fully in accord with the Orders of DOE and Albuquerque Operations Office.

K. Chapter 11, Quality Assurance

This chapter describes the Quality Assurance (QA) Program to be implemented by the WIPP Project Office and the major project participants -- the architect-engineer, the construction manager, the scientific advisor, and the technical support contractor. It is applicable to the site evaluation, design and construction phases of the WIPP Project.

Sections 11A and 11B are blank. Section 11C of Chapter 11 contained a summary of the comments of the EEG on the SAR and the DOE (WIPP Project Office) responses covering all eleven chapters. Section 11C was deleted in Amendment 4.

As stated on page 11.1-1, it is the intent of DOE that each of the QA Programs of the Project Participants be based upon the American National Standard ANSI/ASME NQA-1-1979 and selected supplements. However, that document has been updated and is now ANSI/ASME NQA-1 1983.[33]

In the early comments on this chapter (1981)' EEG called attention to lack of clarity and consistency with other chapters in the description of the organizations as they relate to QA. Amendment 4 extensively revised this chapter to more clearly describe the organization and to define responsibilities for QA. However, the descriptive information of the QA program for each of the Project Participants was provided by reference to their individual operational manuals. Therefore the QA procedures for the WIPP project could only be reviewed by reviewing the procedural manuals of each of the Project Participants, which is neither practical nor consistent with the established format for a SAR. The only documents which provided detailed procedures for QA were references 28, 29 and 30, however, these procedures were not entirely consistent with various chapters in the SAR.

EEG has requested that the WPO extensively revise the SAR with respect to Quality Assurance to include more details on the relationship between the classification of structures, systems and components and the quality assurance assigned to each class. In section 11.1.2.3 it is stated that such a design classification document is in preparation. However, Chapter 11 has not been revised since Amendment 4, so perhaps the information from this document will be added to the SAR in a future amendment.

Unresolved Comments

As discussed extensively under Chapter 3, the SAR does not adequately provide information on the relationship of the classifiction system to quality assurance. This information should also be provided in Chapter 11. Information referred to in section 11.1.2.3 should be provided without delay, because it is applicable to the construction activities now in progress.

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EEG-17 Spiegler, Peter Hydrologic Analyses of Two Brine Encounters in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site . December 1982.

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ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-40

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EEG-40

REVIEW OF THE FINAL SAFETY ANALYSIS REPORT (DRAFT), DOE WASTE ISOLATION PILOT PLANT, DECEMBER 1988

Environmental Evaluation Group
New Mexico

May 1989

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EEG-8 Wofsy, Carla, The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Doses from WIPP, September 1980.

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EEG-11 Channell, James K., Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, January 1982.

(Continued on Back Cover)

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DOE/AL/10752-40

REVIEW OF THE FINAL SAFETY ANALYSIS REPORT (DRAFT), DOE WASTE ISOLATION PILOT PLANT, DECEMBER 1988

Environmental Evaluation Group
7007 Wyoming Boulevard NE, Suite F-2
Albuquerque, New Mexico 87109

May 1989

CONTENTS

FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure protection of the public health and safety and the environment. The WIPP Project, located in southeastern New Mexico, is being constructed as a respoitory for permanent disposal of transuranic (TRU) radioactive wastes generated by the national defense programs. The EEG was established in 1978 with funds provided by the U. S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and provided for continued funding from DOE through Contract DE-AC04-79AL10752.

EEG performs independent technical analyses of the suitability of the proposed site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria and the generator sites' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP. EEG also performs environmental monitoring for background radioactivity in air, water, and soil, both on-site and in surrounding communities.

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SUMMARY

These are the Environmental Evaluation Group's comments on the December 1988 Draft of the DOE Final Safety Analysis Report (FSAR) on WIPP which was received by EEG on February 13, 1989. Previously we commented (October 14, 1988 letter from the Director of EEG to the DOE WIPP Project Manager) on the earlier Draft FSAR, the initial 1980 Safety Analysis Report (SAR), and all nine subsequent amendments to the SAR. EEG's comments on the SAR and its amendments are summarized in EEG-29, Marshall S. Little, "Evaluation of the Safety Analysis Report for the Waste Isolation Pilot Plant Project," May 1985.

EEG's October 1988 comments were extensive and indicated there was much we believed needed to be corrected, amplified, and included in the FSAR. The current comments are equally extensive and we believe a significant amount of work still needs to be done by DOE to produce an acceptable FSAR. Many comments are repeated from our October 1988 review because the December 1988 Draft either failed to respond to all of our comments, or responded inadequately. Additional comments on the current draft involve the hazardous wastes analyses in Chapter 6 and 7 which are in the Draft FSAR for the first time. A few of the comments address issues not covered in our October 1988 review but which may have been raised previously in EEG's comments on the various SAR amendments or in other WIPP Project Office (WPO) Reports.

Another point needs to be made. The FSAR does not contain all of the detailed information and procedures necessary to determine operational readiness of the WIPP facility. In fact, it is apparent from the detailed description in the Working Agreement to the July 1, 1989, Consultation and Cooperation Agreement (see Appendix B,

Working Agreement, Revision 1, March 23, 1983, Article IV, K. Operations) that the review of the FSAR is intended to be only one of the milestones under the Operations Key Event and not the sole criteria for determining operational readiness. EEG has concluded, from participation in the DOE Preoperational Readiness Appraisal in March 1989, that there are a significant number of outstanding items. We have made no attempt to address all of these concerns in our FSAR comments because they don't appear to be pertinent to the document and because we intend to make our operational readiness decision separate from the FSAR.

Our more important comments are summarized below in the order the items are addressed in the Draft FSAR. The significance we attach to each should be apparent from our discussion. More detail is provided on these issues under individual chapter comments.

1. Since the FSAR does not include the long-term risk assessment required by EPA in their disposal standards for TRU waste (40 CFR 191, Part B Performance Assessment), the Safety Analysis Report only applies to the five-year demonstration phase of the project. This should be clearly stated in Chapter 1 of the FSAR. There must then be a supplement to the FSAR prior to a disposal phase of the WIPP Project. Also, the supplement would need to contain the operational safety requirements for handling RH-TRU waste.

2. The Second Modification to the July 1, 1981, "Agreement for Consultation and Cooperation" on WIPP by the State of New Mexico and the U.S. Department of Energy requires the FSAR to "document DOE's ability to comply with the provisions of Subpart A of...(40 CFR 191)." This Draft FSAR does not explicitly address Subpart A compliance. Explicit documentation must be provided.

3. EEG strongly objects to the exclusion of calculations for the hoist drop scenario (C8) on the grounds that it is not a credible event. We have never believed that failure mode analysis can be relied on to prove that low probability accidents will not occur. The history of evaluations on the waste hoist system support this skepticism. The DOE WIPP Project Office published a report in 1985 showing the probability of a catastrophic accident was less than 1E-07 per year. Then in 1987, as part of the Operational Readiness Review, a DOE study indicated the probability to be 1E-03 per year. But we are assured (on page 1A.4-5) that this will be corrected and the event will still be incredible. Implicit in this assurance is the belief that every possible failure sequence has now been recognized and correctly evaluated. EEG does not share this conclusion and believes calculations for this scenario should be included in the FSAR.

4. We consider the assumed low failure rate (1E-04) of the exhaust filtration system claimed on page 1A.4-6 to be unproven. For one thing, the system did not work properly during a scheduled drill during the March 1989 Preoperational Appraisal Audit. Secondly, even if this portion of the system performed perfectly, the Continuous Air Monitors (CAMs) would also have to perform adequately with the required sensitivity in order to signal the switch to the filtration mode. As mentioned below, we also consider the CAM system to be unproven. We believe a great deal of effort needs to go into proving the capability and insuring the reliability of both systems.

5. The FSAR should specify in as much detail as possible the volumes, curies, and distribution within both CH-TRU and RH-TRU containers and the totals. Also, possible

ranges and uncertainties in these estimates should be discussed directly. All of these parameters have a bearing on evaluating different aspects of safety at WIPP and are required (by Article VI of the Consultation and Cooperation Agreement) to be included. (See comment in Chapter 3.)

6. Appendix 6A, which contains the methodology necessary for evaluating airborne radionuclide concentrations from routine operations, contains serious flaws. The corresponding radionuclide concentrations and doses in Chapter 6 are incorrect. Appendix 6A and related portions of Chapter 6 need to be completely redone.

7. The CAMs located in the Waste Handling Building, underground, and in the Exhaust Filtration Building are vital to the protection of workers and to the warning of environmental releases. The ability of these instruments to detect airborne radionuclide concentrations with the required degree of sensitivity has not yet been proven. The adequacy of the CAMs must be established by the WPO and verified by an outside peer review group, including EEG, before wastes can be brought to WIPP. (See Chapter 6 comments.)

8. Several of our comments on Chapter 6 refer to concerns about the WIPP Operational Health Physics Program. Since the FSAR does not address this Program in a comprehensive manner, these comments will not respond in detail. However, EEG's serious reservations about the present status of this Program were provided to DOE in our April 7, 1989, comments on the WIPP Phase II Preoperational Appraisal.

9. Analytical samples for both high- and low-level counting rooms should not be prepared in the same preparation room. Also, routine (as well as incident) bioassays must be carried out on radiation workers. (See Chapter 6 comments.)

10. The use of a 1000 PE-Ci upper limit for individual waste containers at WIPP is unacceptable to EEG. Even with a somewhat lower limit it may still be necessary to impose operational restrictions on high-curie drums. (See our comments under Chapter 7.)

11. The potential doses calculated in Chapter 7 to radiation workers from accidents involving CH-TRU waste handling are unreasonably low because the assumptions include only an average PE-Ci quantity in a drum and because (in the C2 and C3 scenarios) the forklift operator is not considered to be exposed. It should be recognized that very high occupational doses are possible and that operational restrictions need to be employed to minimize them.

12. It is appropriate to include the safety aspects of the non-radiological hazardous waste component coming to WIPP. There are some numerical inconsistencies or ambiguities in this draft (see our comments on Chapters 6 and 7) which should be corrected in the next draft. Our principal observations on the methodology and assumptions are:

(a) the exclusion of all chemicals that represent less than 1% of the hazardous waste constituents (by weight) may not be conservative, because toxicities can vary over several orders of magnitude, and should be reconsidered;

(b) the assumption that average concentrations of Rocky Flats Plant waste are conservative averages for the entire system has not been adequately explained;

(c) the atmospheric dispersion models used give drastically different results than the ones used for radionuclides; and

(d) assumptions about zero mobility of lead and any other hazardous chemical (except VOC's in head space gas) following accidents is non-conservative and inconsistent with assumptions and observations about loss of transuranics (which should be as immobile as virtually all chemicals) from damaged containers.

Because of the extensive re-writing needed on the hazardous waste sections in Chapters 6 and 7 we will not try to reach a conclusion at this time about the potential hazard.

13. The FSAR takes credit in Chapter 8 for a Peer Review Panel providing assurance on suitability of WIPP as a repository. Since the Department has never involved EEG with any of the Peer Review Panels, nor provided us with the agenda, minutes, or recommendations, we believe that the committees do not provide credibility as stated in the FSAR, but in actuality detract from it. In order to take credit, EEG must be involved.

14. It is noted that all references to backfilling the waste storage rooms have been deleted from the FSAR. The FSAR should clearly state whether backfilling will be done during the experimental phase, when the decision on backfill will be made, and the probable final backfill design during operation. (See Chapter 1 comments.)

15. The Operational Safety Review (Chapter 10) lacks sufficient detail to permit us to evaluate the operational safety of WIPP. EEG's specific comments describe the areas in which extensive expansion and revision are needed.

16. A Design Basis Accident (DBA) assessment addressing the requirements of DOE Order 6430.1 and the guidelines to "A Guide to Radiological Accident Consideration for Siting and Design of DOE Non-Reactor Nuclear Facilities," LA-10294-AC,

should be performed and summarized in Chapter 7.

17. This draft of the FSAR evaluates only the proposed disposal mode waste emplacement procedure. Yet, the FSAR is fully applicable to only the (approximately) Five-Year Performance Assessment and Operational Demonstration Test Phase which is not evaluated in any manner. The FSAR should contain analyses of the operations required during the Test Phase. The analysis should include the period at the end of the Test Phase when the wastes at WIPP must be either permanently emplaced or retrieved and shipped elsewhere. (See our comments in Chapters 6 and 12.)

CHAPTER 1

Introduction and General Description

A. General Comments

1. This chapter, including Appendix 1A, has several significant improvements, including a more comprehensive list of pertinent references and an updating of general scientific, technical and physical descriptions. The WPO has made significant responses to EEG's previous comments and recommendations. The chapter provides a good introduction to the FSAR, and there are only a few areas where further changes are recommended. These are discussed in the detailed comments below.

2. After reviewing the entire FSAR, it was noted that it does not contain the performance assessments required by 40 CFR 191 Part B. Therefore, the safety analyses appear to be limited to the five-year pilot plant phase of the WIPP operations. This fact should be clearly stated in Chapter 1.

3. Chapter 1 should include a brief discussion of the status of the potash leases which cover part of the WIPP site, and indicate how and when DOE plans to address this problem.

4. The decision to dispose of the wastes at WIPP or retrieve them will not be based on the results of the Five-Year Pilot Phase as described in the text, but should be based on the ability to meet the EPA Standards for disposal.

B. Detailed Comments

1. Section 1.1, Introduction, Page 1.1-2. The second paragraph on this page refers to the WIPP facility as a "low hazard facility," namely, one "which presents minor onsite and negligible offsite impacts to people of the environment." This conclusion is contrary to DOE/AL Order 5481.1B. According to this Order, a low hazard facility involves only "hazards of a type and magnitude routinely encountered and accepted by the public." As pointed out in the FSAR, the WIPP is a first-of-a-kind facility and, pursuant to DOE Order 5480.5, it is a nuclear facility. Therefore, the hazards of a nuclear facility should not be considered as a type "routinely encountered and accepted by the public." DOE/AL Order 5481.1B also states that all nuclear facilities shall be supported by a SAR. The second paragraph on page 1.1-2 also states that this classification of WIPP as a low hazard facility is in accord with Chapter II of DOE/AL Order 5481.1B. Chapter II discusses "Operational Safety Requirements" and provides no guidance whatsoever for classification of nuclear facilities.

On page 1.1-4, the third paragraph discusses experiments and operational demonstrations needed to reach a decision regarding the permanent isolation of wastes at WIPP. Such experiments and demonstrations are not described in the FSAR, therefore it does not seem appropriate to refer to them in Chapter 1 until such time as they become a part of the FSAR. Also, the latter part of this paragraph discusses the EPA Standard, 40 CFR 191, and leaves the impression that WIPP compliance with the standard is delayed because the standards were vacated and remanded by the courts back to EPA for reconsideration. It should be added that DOE and the State of New Mexico have formally agreed that DOE will proceed to demonstrate compliance with the vacated standard.

On page 1.1-7, there is a statement that technical data, unless it directly supports the Safety Analysis of recent facility modifications, is current through December 1986. Please clarify why technical data on site characterization collected in 1987 and 1988 is not included.

At the bottom of page 1.1-7 and top of page 1.1-8, there is a discussion of the plans to prepare a Supplemental Environmental Impact Statement. Among the reasons which should be added for the need for the SEIS is to summarize the considerable amount of information acquired between 1980 and 1989. This information may change the assessment of the site for the mission of WIPP. For example, concerning the Castile brine reservoirs, FEIS (p. 9-134) stated, "...brine pockets of the size assumed in this example are extremely unlikely near the repository..." In 1981, WIPP-12 borehole, located at the edge of the repository, was deepened and a brine reservoir was encountered which was estimated to contain 17 million barrels of brine, 2 million barrels more than the amount assumed in the FEIS example. After the location of the repository was moved 1.25 miles to the south geophysical surveys performed over the new location showed, "...brine appears to be present 250 meters below portions of the waste panel horizon..." (DOE letter to EEG, 12/29/87). Many such examples of new facts, revised concepts and updated data will need to be addressed in the SEIS.

2. Section 1.1.2, Mission, Page 1.1-11. The Mission Statement emphasizes the research and development aspect of WIPP and mentions the possibility that wastes will not be permanently disposed of at the site. Because of this possibility, the FSAR should indicate where retrieved waste would be sent for storage or disposal.

3. Section 1.1.2, Mission, Page 1.1-11. The Mission of WIPP includes permanent disposal of TRU waste and not simply "to demonstrate many technical and operational principles." The FSAR should clearly state this.

The statement in this section that "the studies and experiments using simulated wastes...are discussed in numerous publications by Sandia National Laboratories and other project participants" is wrong. We are not aware of any published report that lists, describes, or discusses experiments with simulated or real TRU wastes. Room J experiments to evaluate the corrosion effects of brine on the 55 gallon drums cannot be considered to be a "simulated wastes" experiment. The heater experiments were designed to simulate the high level waste and not the TRU waste.

As we have stated before (EEG comments on Draft FSAR, October 1988, Chapter 1, #3, P. 7), the decision to use WIPP for permanently disposing of the waste should be based on demonstration of compliance with the EPA Standards 40 CFR 191, Subpart B, and not "until sufficient operating and scientific data have been accumulated." The Standards do not require operating experience.

4. Section 1.1.3, Design Capabilities, Page 1.1-12. Please delete all references to experiments which are not described and made a part of the FSAR.

5. Section 1.1.4, Schedule, Page 1.1-13. This section should indicate when experimental data and other information will be provided which support the need for the pilot plant phase of WIPP, i.e., emplacing CH-TRU waste at WIPP.

6. Section 1.3, Page 1.3-1. "The shipments are surveyed for external contamination prior to their movement

into the WHB..." During the preoperational audit this was done at the gate. What is planned? EEG believes the check should not be done at the main entrance gate (see our comments on the Phase II Preoperational Appraisal).

7. Section 1.3.1. It is noted that references to backfilling the waste storage rooms that were in Amendment 9 of the SAR have been deleted from the FSAR. We know that the Department has decided to emplace the experimental CH-TRU waste without backfill to avoid crushing the drums during the retrieval period. The FSAR should clearly state this decision and the reason for it and should state that when the waste is emplaced for disposal, a properly selected, tailored backfill will be used to fill the space between the drums, above the drums, and between the walls of the drums. The FSAR should also state that only the amount of waste expressly needed for conducting experiments to help in performance assessment (to show compliance with the EPA Standards 40 CFR 191, Subpart B) will be emplaced in a temporary mode without backfill.

8. Section 1.5.2.1, Repository Plugging and Sealing Studies, Page 1.5-4. It would be helpful to include in this discussion an indication of when the final decision on plug and seal design will be made. Such a decision is important to the Final Safety Analysis.

9. Section 1.5.3, Site and Design Validation Activities, Page 1.5-9. The last paragraph should be revised to delete the indication that there is no recognized function for crushed-salt backfill. There is a well recognized value for such backfill as was discussed in the paper by Chaturvedi, Channell, and Chapman (1988) published in the Waste Management 1988 Conference Proceedings.

10. Section 1.5.3.1, Site Validation Program, Page 1.5-11. In the discussion of Hydrologic Tests, it should be pointed out that the piezometers in the C&SH shaft have not performed well. The groundwater pressures measured in the water-bearing zones of the Rustler were approximately the same as pressures measured at levels where no groundwater is supposed to exist. Also, please clarify the statement that "pressure changes could be diagnostic of changing conditions in the rock or deterioration of seal materials."

11. References for Section 1.5, Page 1.5-15. This reference list includes several unpublished documents which are not available for evaluation. Yet, the discussion in Section 1.5 failed to recognize many of the published works of EEG which are quite relevant to the topics discussed.

CHAPTER 1A

Summary Safety Analysis

A. General Comments

This Summary Safety Analysis Chapter reflects items and conclusions covered in somewhat greater detail elsewhere in the FSAR. Our reaction to the presentation and conclusions of the individual items is expressed elsewhere in comments on the other chapters and is usually not repeated below.

1. This draft responded reasonably well to our October 1988 comments on Chapter 1A. Responses were made to 7 of our 11 comments, with partial responses to two others. However, all responses were not completely satisfactory.

Our first comment asked for a summary of the criteria used to determine that the facility could be operated safely. This was partially answered by mentioning original site design criteria. However, there are other safety-related EPA regulations and DOE Orders the facility will be required to meet. What are they? Have you shown that you met them?

2. This draft of the FSAR appropriately includes an assessment of occupational and public exposures to the hazardous waste component of TRU waste; yet, this is not mentioned in Chapter 1A. It should be.

3. Section 1A.1.1.2, Wind, Page 1A.1-5. The exhaust filter building is mentioned elsewhere as a Design Class II Structure (not III). Also, since it is Design Class II, why is it not designed for a 110 mi/hr wind?

4. Table 1A.3-1, Page 1A.3-3. The title and column

heading in this table are confusing. What is being reported is the average dose for six CH-TRU workers (four waste handlers and two radiation control) and three RH-TRU workers (two waste handlers and one radiation control). See Table 6.1-9.

5. Section 1A.4.5, Waste Hoist Hydraulic Brake System, Page 1A.4-5. The discussion on hopefully reducing the estimated waste hoist brake system annual failure rate from 2.7E-02 is not convincing. All that is expressed is a feeling of faith that the total system failure rate will be shown to be less than 1E-06 per year. See our comments under Section 7.3.2.

6. Section 1A.4.5, HVAC Waste Handling and Exhaust Filter Building, Page 1A.4-6. The estimation that the unavailability of the Exhaust Filter Building would be only 1.4E-04 per release event is unproven. It is understood that this system did not perform properly during the March 1989 Preoperational Appraisal Audit. Furthermore, no allowance is made for the failure of the CAMs to deliver a proper signal in the event of a release. The ability of the CAMs to perform with the required sensitivity in the underground environment has yet to be proven. Also, EEG would appreciate receiving information on the relay test circuits "being considered." How can the problem be considered solved when the specific correction is still being considered?

CHAPTER 2
Site Characteristics

A. General Comments

1. This Chapter has been greatly improved, and we were gratified to note that many of the improvements were in response to comments and recommendations of EEG.

B. Detailed Comments

1. Section 2.1.2.1.2, Potash Leases, Page 2.1-7. This section does not provide adequate discussion of the potash leases. Because there is indication that these private leases may involve large sums of money, it is important that they be resolved before the first shipment of wastes to WIPP. Please add information on when a resolution is anticipated. Also, add a description by section numbers of the 1600 acres referred to.

2. Section 2.2.3.1, Fort Bliss/Biggs AAF, Texas, Page 2.2-2. We understand that there have been 14 flights per year of UH-1H aircraft from the Biggs Air Force Base which fly 500 ft. above the ground directly over the WIPP site. These flights pose a threat to the safety of the WIPP facility, and DOE should take steps to insure they will not occur in the future.

CHAPTER 3
Principal Design Criteria

A. General Comments

1. Although Chapter 3 was extensively revised since the earlier version of the FSAR, and there were many editorial corrections, there was little substantive response to EEG's previous comments and recommendations. We continue to be opposed to the Design Classification definition of Class I items, and believe that the definition should be consistent with that contained in 10 CFR 60.

2. EEG would appreciate the opportunity of reviewing the design classification evaluations for all Design Class II items prepared in accordance with WIPP PROCEDURE WP-300, CHAPTER 4. Please provide information on where this documentation may be obtained.

3. Additional sections should be added to describe the application of the Quality Codes 1, 2, and 3 that are assigned to on-site work requests, to design documents, and to purchase requisitions and for certain analytical or laboratory services for Design Class I, II, and IIIA facility SSC's. Also, the Quality Codes should be described as they apply to certain services associated with the design validation, environmental monitoring, radiological monitoring and geological programs. An additional section should also be added, either here or in Chapter 11 to describe the implementation of the Quality Assurance Surveillance Program.

4. The total expected inventory of CH-TRU and RH-TRU wastes is never stated directly in Chapter 3 or elsewhere in the FSAR. One can make estimates from various sources,

including: (1) Tables in Section 3.1; (2) Table 6.1-4; and (3) statements about design volumes, operating lifetime, and maximums permitted (for RH-TRU). But none of these calculations are as likely to lead to as good an estimate as that determined by those in the WPO who are most knowledgeable about waste characteristics, generation rates, and treatment and emplacement plans. Inventory data affect several aspects of safety analysis: (1) estimates of the number of transportation and operational accidents; (2) probabilities of given concentrations of radionuclides being involved in accidents; and (3) the amounts of radionuclides available for release in post closure scenarios. The FSAR should summarize as much detail as is available on quantities, curies, and distribution in containers for both CH-TRU and RH-TRU. Possible ranges and uncertainties should be discussed in all these values.

B. Detailed Comments

1. Section 3.1.1.1, Container Configuration. Pages 3.1-3,30,31. The text on page 3.1-3 and the Tables 3.1-1 and 3.1-2 on pages 3.1-30,31 do not give a complete picture of the CH-TRU containers since the TRUPACT Efficient Box (Standard Waste Container) is not mentioned on any of these pages. Also, several of the approved CH-TRU waste containers (Table 3.1-2) cannot be shipped in TRUPACT II and it is unclear how the waste in these containers will be transported to WIPP. These pages should be updated and adequately describe the present situation.

2. Section 3.1.1.2.4, Thermal Power, Page 3.1-6. It is unreasonable to assume an average thermal power of 60w for RH-TRU if the average concentration is really similar to that shown in Table 3.1-5. The watts from the Table 3.1-5 inventory would be about 0.6/canister. Furthermore, a

maximum canister subject to the constraints of 1000 PE-Ci, 23 Ci/l and 200 gm fissile material would produce only about 86 watts (assuming the same fission and activation product mixture as in Table 3.1-5). A 1000 PE-Ci CH-TRU drum would generate about 36 watts with no MAP or MFP radioactivity.

3. Table 3.1-5, Page 3.1-35. The average curies per canister of RH-TRU waste has been reduced from 1000 in the previous draft FSAR to 37 (47 if daughter radionuclides are included). This drastic change is not discussed in the FSAR. The current Table is closer to the values reported in the latest Integrated Data Base and in DOE/WIPP 88-005 but there are a lot of internal inconsistencies within these documents. It can only be concluded from the various reports that the volume of RH-TRU coming to WIPP may be as little as 2500 m^3 or it may be over 5000 m^3. The number of curies may be from less than 50,000 to over a million. There are other uncertainties; for example, some of the waste reported in DOE/WIPP 88-005 do not appear to be TRU (less than 100 nCi/gm).

The FSAR should explicitly discuss what is known as well as the uncertainties of the total RH-TRU inventory expected to come to WIPP. This discussion should include estimated ranges of volumes and curies expected to come to WIPP during its lifetime.

4. Table 3.3-2, CMS Vital Information Processing, Pages 3.3-31 through 3.3-34. This table should be revised to tabulate the CMS functions for each of the systems described in Section 3.3.2 Air Handling, i.e., Section 3.3.2.1 Surface Ventilation Systems for the Radioactive Materials Area, Section 3.3.2.2 Surface Support Facilities Ventilation System, Section 3.3.2.3 Subsurface Facilities Ventilation System, Section 3.3.2.4 Interactions Between Air Handling

Systems. The present table appears to incorporate all of the air handling functions in the one designation, HVAC, which could be interpreted to be only the surface air systems with air conditioning. The CMS functions for the Subsurface Facilities Ventilation System, Section 3.3.2.3 are detailed on pages 3.3-12 through 3.3-16 and should be tabulated in Table 3.3-2.

On page 3.3-32, Table 3.3-2 should be revised to tabulate the CMS functions for each of the four Shaft & Hoist Systems identified in Table 3.1-8, i.e., Waste Hoist, Construction & Salt Handling Hoist, Exhaust Shaft, and Air Intake Shaft. For the Waste Hoist, the CMS functions should indicate when TRU waste is being transported, when there is hoist or shaft maintenance, shaft inspection, and personnel transportation.

5. Section 3.4, Decommissioning and Decontamination Design Criteria, Pages 3.4-1 through 3.4-3. The Decommissioning and Decontamination Design Criteria section should discuss and reference the design criteria and programmatic requirements of DOE Order 5820A, "Radioactive Waste Management, Chapter V, Decommissioning of Radioactively Contaminated Facilities." The current reference to Chapter 12, which references DOE 5820.2A, is considered to be inadequate for the purposes of the FSAR since neither Section 3.4 nor Chapter 12 address each of the major design and programmatic requirements (5.1 through 5.e) of DOE 5820.2A.

The reference to the ALARA program should reference DOE Order 5480.11, "Radiation Protection for Occupational Workers," which references (paragraph 9.a) PNL-6577, "Health Physics Manual of Practices for Reducing Radiation Exposure to Levels that are As Low as Reasonably Achievable (ALARA)."

CHAPTER 4
Plant Design

A. General Comments

1. This chapter has been expanded to include significantly improved descriptions of ventilation, fire protection, electrical and water distribution. This information was quite helpful to EEG's review.

2. Inspections and testing of important equipment and mechanical systems is discussed throughout this chapter, but only occasionally is the frequency given for such inspections and tests. This additional information should be added for all of the important systems, or a reference cited where such information is specified.

B. Detailed Comments

1. Figure 4.1-2, WIPP Surface Structures, Page 4.1-8. Buildings 364 and 365 are not identified on the Explanation page.

2. Section 4.2.1.1, Inventory and Preparation Area, Page 4.2-4. The description of this area refers to a waste surge storage area, a battery recharge area, and office space for waste handling personnel. These areas should be identified in Figure 4.2-1 or reference made to other figures where the areas are identified.

3. Section 4.2.1.2, RH Waste Handling Area, Page 4.2-6 to 4.2-10. Figures 4.2-1 and 4.2-3 should be changed to label and identify the cask preparation area, the cask maintenance station, and the cask transfer cell.

4. Section 4.2.1.5, Fire Protection, Page 4.2-14. The last paragraph of this section discusses solidification of contaminated liquid wastes. As previously requested, the FSAR should provide further details of this processing - either here or elsewhere in the FSAR. It should address radiation protection and include the processing procedure, where such processing will take place, and how separation will be maintained of contaminated RH-waste water from CH-waste water.

5. Section 4.2.1.6, Effluent Monitoring System, Page 4.2-15. The air that exhausts the WHB is filtered by a prefilter and two HEPA filters, not "...3 multiple stages of HEPA filters..."

6. Section 4.2.2.2, Construction and Salt Handling Shaft Headframe and Hoist House, Page 4.2-17. Please provide further clarification of the "placement of the emergency escape hoist over the C&SH shaft." Is the emergency escape hoist not part of the existing/in-place mucking hoist, or will there be a requirement to change cages prior to evacuating the mine through the C&SH shaft?

7. Figure 4.2-7, Support Building, Page 4.2-34. Rooms 124 and 125 are mislabeled. The High- and Low-Level Counting Labs are not located here. The walls that remodeled rooms 107 and 139 into offices are not shown.

8. Figure 4.2-8, Support Building, Page 4.2-35. The floor plan for rooms 250 through 253 are incorrect.

9. Section 4.3.2.1.2, Electrical Utility Services, Page 4.3-9. The description of the Electrical Utility Services should be revised to state that one diesel generator can be remotely started and brought on line from the Central

Monitoring Room, as stated in Section 4.4.2.1.2. As shown on the legend to Table 4.4-6, DG No. 25P-E504 is able to be synchronized and brought on line automatically.

10. Section 4.3.2.1.3, Subsurface Structural Features, Page 4.3-10. The third paragraph on this page suggests that vapors from diesel fuel constitute the principal risk of an underground explosion. Of possible greater risk is an explosion from hydrogen formation around the battery recharge areas. Battery recharge in the WHB is shown in Figure 4.4-2 and discussed in Section 4.4.3.1.2, but no mention is made of subsurface battery charging. This should be addressed here and in other sections of the FSAR. This deficiency was mentioned in previous EEG comments. Also, it was previously brought out that the wastes may contain small amounts of pyrophoric materials, or materials which may produce explosive mixtures. Since backfill will not be used during the first five years, some consideration of this potential problem should be discussed.

11. Section 4.3.2.3, RH-TRU Waste Storage Area, Page 4.3-13. EEG requests that up-to-date reference design documentation be cited on pages 4.3-13 and 4.3-15, and that EEG be supplied with drawings of the current design of the shield plug and documentation that supports the 3 - 5 mrem/hour statement.

12. Section 4.4.1, Ventilation Systems, Page 4.4-1. The last paragraph on this page refers to WP 04-1, "Facility Operation Manual." This is an important document which EEG needs to complete review of the FSAR. As of this date, it has not been made available.

13. Section 4.4.1.2.1, CMR and Instrument Shop, Page 4.4-10. The last paragraph should be revised to reflect the

fact that the CAMs located at stations B and C do not monitor ambient air, but monitor only HEPA-filtered "clean" air and therefore do not necessarily represent ambient air.

14. Section 4.4.1.3.2, System Description, Page 4.4-18, 4.4-19, 4.4-20. On page 4.4-18, the statement, "Alarm of any two CAMs can activate HEPA filtration" is misleading. According to J.P. Harvill, at the 28th Quarterly Meeting between DOE and EEG, an alarm by any two underground alpha or any two underground beta/gamma CAMs will initiate HEPA filtration.

On page 4.4-19, please clarify how the reversal of air flow will impact the emergency traffic flow underground pursuant to the escape markings.

The last two paragraphs on page 4.4-20 refer to "periodic" leak and operational tests. Please indicate the frequency of testing, and appropriate action levels.

15. Section 4.4.2.1.5, Backup Loads, Page 4.4-25. This discussion of the backup loads should be revised on page 4.4-25 and in Table 4.4-8 on page 4.4-126. The electrical power needs of the Exhaust Fans, items 28 and 29 on the Legend to Table 4.4-5, page 4.4-105, should be identified rather than the backup electrical load for ventilation for the Air Intake Shaft Hoist on page 4.4-25 and the Air Intake Shaft Hoist Fans on Table 4.4-8. Also, the discussion of the minimum load for backup should be consistent with the above revision.

16. Section 4.4.3.1.2, Fire Characteristics, page 4.4-32. The discussion of <u>spontaneous ignition</u> includes mention of hydrogen formation and venting through a separate exhaust system. It is presumed that this "separate exhaust" venting of hydrogen applies only to the battery recharge area of the

WHB. Please also indicate what safety design features are available in the subsurface battery recharge areas.

17. Section 4.4.6, Radioactive Waste Systems, Pages 4.4-49 and 4.4-50. This section refers to section 5.4 for a description of decontamination procedures, process operation, and radwaste properties. Section 5.4 anticipates radioactive waste will be generated above and below ground at WIPP, however no mention is made of how water mixed with waste and salt in the underground will be collected, assayed or solidified, nor how the underground tunnels will be decontaminated.

The last paragraph of this section on page 4.4-50 refers to the "Waste Handling Operations Manual," WP 05-1. The EEG has not been provided a copy of this manual which is necessary to complete our review of the FSAR. The section also refers to the FMEA, Table 4.4-13. This table does not appear to address the waste water from the RH area, which is contaminated and may have to be treated separately from the CH-liquid waste. This problem should be addressed.

18. Section 4.4.6.2, Liquid Radioactive Wastes, Page 4.4-52. This section describes a trench system which holds fire water pending sampling and analysis for radioactive contamination. If contamination is confirmed, then the contaminated water is manually transferred to a collection tank. This section does not provide details of radiation protection for workers, and procedures needed to collect, mix and measure the activity of the supernatant or precipitate in the holding tank and sump.

19. Section 4.4.9.4, Air Filtering Equipment, Page 4.4-63. Please provide more information on the criteria for filter changeout - the radiation level or pressure drop.

This information should either be provided here or a reference to where such information is available should be provided. Also, it is noted that there is no airlock included in the present design of the Exhaust Filter Building HEPA filter plenum. Further details of the changeout procedure are needed.

20. Section 4.4.9.4, Air Filtering Equipment, Page 4.4-64. It seems likely that the negative pressure of the filter plenum in the Waste Handling Building would collapse the bag for the used filters.

21. Section 4.4.10.2.2, Exhaust Filter Building, Pages 4.4-69, 4.4-70. This section indicates that the compressed air requirements are met by two compressors. It was EEG's understanding that compressed air to the EFB is provided by a buried pipe to the Compressor building.

22. Table 4.4-1, FMEA for the WHB HVAC System, Page 4.4-79. Item 6 on this page describes a Failure Mode as "Permissive to supply air handling unit fails." Please clarify this failure mode.

CHAPTER 5
Process Description

A. Detailed Comments

1. Section 5.1.1.2, Inventory/Preparation Area, Page 5.1-4. Further details are needed here or elsewhere in the FSAR on the procedures for removal and assay of the HEPA filters to avoid potential contamination.

2. Table 5.1-3, CH-TRU Waste Handling Failure Mode and Effects Analysis. This table fails to consider the potential for fire or explosion resulting from hydrogen gas around the battery recharge area in the subsurface. According to Figure 4.3-5, there are five battery recharging stations in the subsurface.

3. Table 5.1-3, CH-TRU Waste Handling Failure Mode and Effects Analysis, Pages 5.1-16, 5.1-19. On page 5.1-16, accident 13 refers to use of breathing air masks for fire in a site-generated rad waste room. Only SCBA would be approved for use during a fire. Please clarify.

On page 5.1-19, Item A1 for Accident 19 is not a safety feature as stated.

4. Table 5.2-1, RH-TRU Waste Handling Failure Mode and Effects Analysis. This table also fails to consider fire or explosion in the underground battery recharge areas. See previous comment.

5. Section 5.4.2, Solid Radwaste System, Page 5.4-2. This section states that all solid radwaste is anticipated to be CH, however, if contamination is found or occurs in the

hot lab or RH-canisters, the resultant cleanup could produce RH-waste. This should be reevaluated and a procedure developed to handle RH-TRU generated wastes.

6. Table 5.5-1, Waste Package Information, Page 5.5-7. This table omits several items which are required pursuant to WIPP/DOE -157, Rev. 2. For example, the Shipment Certification Date, the name of the official who certified the TRUPACT payload, the organic materials volume present, the thermal power (if the amount exceeds the specified limit), the Pu-239 Gram Equivalent, the Waste Package Certification Date, and name of the certifying official are either required or conditionally required.

CHAPTER 6

Environmental, Safety and Health Protection

A. General Comments

1. Appendix 6A, which is necessary for the review of the radionuclide concentration and dose calculations in this chapter, was not received until April 26, 1989, after most comments for the chapter were completed. Our comments on the appendix are summarized at the end of the chapter. We consider the appendix to be seriously flawed.

2. There appears to have been a failure to address in this chapter the changes brought about by the introduction of the new ventilation shaft and the new fans. Also, there is a need for more careful consideration of the placement of monitoring equipment in the Waste Handling Building. There should be a systematic ventilation and contaminant migration study with smokes and tracer gases to arrive at more realistic decisions on placement.

3. The Draft FSAR makes only two brief references to the requirements of 40 CFR 191 Part A and does not explicitly say how compliance will be shown. Neither does the Draft FSAR compare expected doses estimated in this chapter with Part A. The Second Modification of the C&C Agreement requires that the FSAR document comply with Subpart A. Therefore, this documentation of compliance must be included in the FSAR.

4. The Draft FSAR does not fully cover the disposal phase of the project because compliance with 40 CFR 191, Part B, has not been shown, and final decisions have not been made on waste treatment, backfill, and emplacement details.

The need for a supplement to the FSAR has been recognized in the Draft FSAR and is included elsewhere in our comments. However, this Draft FSAR does not address any of the operational procedures that will take place in the proposed experimental phase of WIPP. There are important differences in the waste form that would be used for proposed bin experiments and in underground handling procedures for both experimental and proposed operational demonstration wastes. In addition, the movement and/or backfilling of wastes emplaced during the experimental phase into the final disposal mode must be evaluated. There are possibilities of increased radiation exposure and perhaps mine safety when working in rooms that will have been open for six to eight years. In addition, treatment of waste containers on-site is a possibility. Also, some emplacement rates which have been proposed during the experimental phase could lead to a three-panel operation during the first few years when experimental phase waste is being finally emplaced and new waste is being brought in for the disposal phase. The adequacy of the ventilation system to allow waste handling operations in three panels needs to be evaluated.

B. Detailed Comments

1. Section 6.1.1.2, Design Consideration, Page 6.1-2. In view of recent moves to super-compact waste and heavily load boxes, and the possibility that the existing inventory of boxes may be repacked into the smaller TRUPACT-II standard waste containers, it may be prudent to reevaluate the assumption that radiation fields from boxes will be smaller than from a 55 gallon drum.

2. Section 6.1.2.1, Direct Radiation Sources, Page 6.1-5. The third paragraph uses "mr/h" as allowed neutron dose rate. This should be "mrem/h." Also, please provide

the basis for ignoring the neutron contribution to total dose rate, particularly from high alpha content (heat source Pu-238 and enhanced Am-241) wastes.

3. Section 6.1.3.1, Plant Arrangement Designs for Keeping Exposures ALARA, Pages 6.1-8, 6.1-9. On page 6.1-8, there is a need for further information on the contamination check points. For example, describe the equipment to be used, the procedure for survey of personnel and control of potential contamination, and the procedures and facilities for handling contaminated personnel when or if found. On page 6.1-9, please include information which supports the assumption that pressure differential values created by the ventilation system correspond correctly and appropriately to the identified contamination "zones" in the WHB such that contamination spread between zones will be controlled.

4. Section 6.1.3.3, Radiological Control Zoning and Access Control, Page 6.1-12. More detail is needed here on how personnel are surveyed for contamination at the control points, equipment used, what action is taken when contaminated workers are found (where decontamination occurs), etc.

5. Section 6.1.3.4, Radiation Shielding, Page 6.1-17 to 6.1-18. It is very difficult to review input parameters for the operation of the QAD-P5A computer code from figures 6.1-6 through 6.1-8. A listing of the structural and configurational, as well as source term magnitude/location for this analysis, and those involving the execution of two other shielding codes (G3 and ANISN) is required to make an analysis of this activity with any degree of confidence.

6. Section 6.1.3.5, Ventilation, Page 6.1-20. Please clarify and revise the grammatical errors in the first

paragraph on this page.

7. Section 6.1.3.6, Radiation Monitoring Equipment, Pages 6.1-24,25. The discussion on page 6.1-24 concerning the placement of alpha CAMs and FASs is misleading and implies a lack of understanding of the purpose of these sampling systems in meeting the monitoring requirements of DOE Order 5480.11:

(a) CAMs are not designed to provide indications of concentrations of airborne radioactivity. Their role is to provide alarm in the event of accidental releases;

(b) The decision to utilize a CAM, according to DOE Orders, is not based on whether personnel occupancy is "low" or not; and

(c) FAS sampling is not an adjunct to CAM monitoring in cases of "low occupancy." FASs have their own proper function in monitoring and control of worker exposure. This should be clearly described here.

The second paragraph on page 6.1-25 states that each monitoring system is set to alarm within "acceptable levels of the limits in DOE 5480.1B, Chapter XI." Since DOE 5480.1B does not address alarm levels, please provide an indication of the criteria which will be used to establish these levels. For example, perhaps the level will be set at some designated fraction of the maximum permissible exposure range. It would be desirable to specify that fraction either in the FSAR or the Radiation Safety Manual, so that it could be verified and would not become an arbitrary value.

Also, the discussion of airborne radioactivity monitoring assumes that the monitors are "designed to operate in the expected environmental conditions." Based on recent reviews of the CAMs for both collecting and detecting transuranics in a radon daughter and salt loading environment, this assumption is unproven. Also the calibration of the CAMs, while traceable to NBS and which provide instrument checking, do not calibrate for the actual environmental conditions. Proper operation of the CAMs is vital to the protection of workers at WIPP and to the warning of environmental releases. EEG's concerns about the ability of these instruments to detect radionuclide concentrations with the required sensitivity (particularly in the repository where the greatest amount of interference from salt loading and radon daughters are encountered) have been well documented elsewhere. It is mandatory that further studies be carried out to insure that an adequate monitoring system will be in place before wastes arrive.

8. Section 6.1.4.2, Normal Operation, Page 6.1-27. In the description of the input for annual exposure during normal CH-TRU and RH-TRU waste handling operations, dose rates of 14 mrem/h, 5 mrem/h, and 2 mrem/h four inches from the surface are given for CH-drum, CH-box, and RH-cask, respectively. Please provide the basis for these values. Also, please clarify whether the surface level on a drum is from an individual drum or a 7-Pack.

9. Section 6.1.5.3, Radiation Protection Instrumentation, Page 6.1-34, 6.1-38.

On page 6.1-34, it is stated that samples for both the low level laboratory and the high-level laboratory are prepared in the sample preparation room. It is unacceptable to prepare a sample for high-level counting in the same room as samples for low-level counting since cross contamination of the low-level facilities will likely occur.

Please provide a reference where further details for the calibration procedures may be found.

The first paragraph on page 6.1-38 states that bioassay services are available on a contract basis. The implication is that bioassays would be performed only following evidence of a contamination incident. The WIPP "Radiation Safety Manual," WP 12-5, Revision 1, indicates that preassignment baseline assays and annual bioassays will be routinely carried out. This would suggest that on-site capability for certain types of bioassays (urine, fecal and chest counting) should be available, and the annual bioassays for radiation workers scheduled to minimize assay work loads. This section should be revised to clarify that routine and incident assays will be carried out pursuant to the "Radiation Safety Manual." The discussion on page 6.1-41 clarifies this ambiguity to some degree, but has a typographical error in the sixth paragraph where "routing" should be "routine."

10. Section 6.1.5.5, Radiological Control Facilities, Page 6.1-43, 6.1-44. Please provide more information on the facilities and methods for personnel decontamination, and for detecting such contamination. With respect to personnel decontamination, reference is made to the transport of patients to "a hospital, which has agreed to handle injuries involving radioactive materials." Has a hospital(s) been identified for this purpose? If so, please identify it in this document.

On page 6.1-45, under equipment for the dosimetry laboratory, a statement indicates that compressed nitrogen gas is used for heating. Please clarify this statement.

11. Section 6.1.6.1, Sources of Potential Release, Page 6.1-48. The first paragraph states that the assumptions used in assessing releases are shown in Table 6.1-5. This table provides the estimated results only, but does not indicate

the basic assumptions used to obtain these values. The basic assumptions are needed in order to properly evaluate these data. Neither Table 6.1-4 or Appendix 6A provide sufficient information to arrive at the data shown in Table 6.1-5. Also the first sentence in this paragraph should be revised to state that "the design of WIPP recognizes that very small amounts of radioactivity will be released." To state that it "may" be released implies that no radioactivity may be released, which is not possible.

12. Section 6.1.6.2, Dose Calculation Models, Page 6.1-51. The use of the mean reciprocal wind speed in the atmospheric dispersion equation instead of the mean wind speed biases the equation toward the lower wind speeds. The resulting deposition would be higher than if the numerical average of the wind speeds were used in the equation. Please clarify how the average of the reciprocal wind speeds can save computer time, or other reason why these values were used.

Also on the following page (page 6.1-52), in the determination of the effective stack height for air discharges, credit is taken for the effluent air velocity in the vertical direction. It is our understanding that these stacks are not arranged to release air in the vertical direction, nor will they emit air equally well in all directions. Therefore, the angle of discharge, and the effects of shrouding to effect releases in one direction from the stacks, should be taken into consideration when utilizing the Rupp equation to determine effective stack height. Lower effective stack heights and greater momentum of air in the horizontal direction (and possibly turbulence when the airstream must change direction) after exiting would be expected. Some consideration should be given toward determination of the exiting plume as a function of wind direction and velocity since the dry deposition rate is affected by wind speed in the horizontal direction as well as by radionuclide concentration.

On page 6.1-53, the use of a constant precipitation factor for the determination of radionuclide deposition is questionable for several reasons. The first reason is stated in the document: precipitation occurs in discrete events of varying magnitude throughout the year. At the WIPP, there are about three to nine events/month on the average (Climates of the United States, U.S. Dept. of Commerce, Washington, D.C. 1973) depending on the month of the year. However, most of the precipitation, and the greatest number of precipitation events, occur during the growing season. Hence, most of the deposition of this type occurs during livestock foraging periods and does not occur equally throughout the year. This period also marks the greatest surface contamination of forage plants which are consumed by livestock. During the spring when biomass densities are limited, livestock must forage over large areas to obtain their food requirements when compared to later in the growing season. During the growing season the deposition is affected by the leaf area index of the plant on the one hand, and lower grazing areas/animal unit as well as tissue dilution of the areal radionuclide concentration on the plants. Thus a complex set of processes involving both precipitation events and biomass densities affect livestock intake of radionuclides deposited on plant surfaces. A simplistic approach in using a constant scavenging coefficient is probably not conservative, and should be tested with a model that can take these factors into consideration in evaluating this dose pathway to man to give it validity.

This document does not mention, and presumably does not include, resuspension events which can contaminate plant surfaces via additions to the air concentration resulting from stack emissions. They are mentioned only with respect to inhalation hazards to man. Curiously, it does mention washoff of contamination from these surfaces in estimating pathways. The document is totally silent on soil saltation-creep (erosion) events which contaminate forage and crops up to about one meter above the ground, and also rainsplash momentum which does the same thing. In a region where radionuclides accumulate on the soil surface as a result of deposition from a plume, these processes become very important to consider as pathways of radionuclides to man. It is well known that insoluble plutonium compounds are not readily eluviated from the soil surface. Hence, this pathway is ever present, particularly in an arid environment, and should be taken into account in a risk model for this purpose.

Although dose calculation equations from reference (39) were used, it is not clear what specific equations were used, and what differences in parameter input assumptions were made. This should be clarified. Also the meaning of "exponential transfer from one segment to another" is not clear. Presumably this refers to the four-segment catenary model of the GI tract developed by Eve. This should be stated. Generally, the integrated form of transport processes can be expressed as exponential equations with constant or time variant coefficients, but the actual transport processes are not of this type.

13. Section 6.1.6.3, Dose Calculation Parameters and Discussion of Results, Page 6.1-55. The assumed value for the deposition velocity at the WIPP site of 0.18 cm/sec was not found in reference (38), however, a value of 0.68 cm/sec was found for typical meteorological conditions at Oak Ridge, Tennessee. This value for the WIPP site appears to be low by

a factor of about two. A justification and an exact reference for this parameter should be added. It is generally assumed that there is a one order of magnitude difference between wet and dry deposition amounts (wet = 10 x dry).

It is not clear whether the 0.28 kg/m^2 and 1.9 kg/m^2 values on page 6.1-56 are wet or dry weight units. The value of grassland biomass density appears to be greater than expected by a factor of two for arid sites if wet weight units are assumed. Please clarify whether the reference cited specifically addresses arid sites. The value used for forage consumption for cattle is 15.6 kg/day dry weight. The value recommended by NRC is 12.5 kg/day. Why was the latter value not used? Also, it is not clear why it was assumed that the entire beef herd was consumed on an annual basis, or why a specific fractional part of the herd was assumed to be consumed per day if one assumes constant biomass density and an adequate number of beef cows are available to feed the individual(s). Because beef cows are not slaughtered until they have reached a certain stage of maturity (discrete event), and a human's beef consumption is continuous, a lag period accounting for maturation (seasonal), and another between slaughter and consumption (NRC recommends 20 days, although it is not important for transuranics) should be implemented. Please indicate how the seasonal factor was addressed in these analyses. If mean annual concentrations in beef tissue are being utilized each day to account for the maturation period, the validity of this assumption should be documented. Please also indicate the extent to which water ingestion was considered in these analyses.

14. Section 6.1.6.4, Effluent and Environmental Monitoring and Exposure Pathways, Page 6.1-57. The first paragraph of this section states that the nonradiological

monitoring is discussed in Chapter 3. We could find no such discussion in Chapter 3. There was a reference to handling non-radioactive hazardous materials, namely the "Operations Program Plan," DOE/WIPP 85-001, Rev. 3, July 1988. This document has not been provided to EEG.

On page 6.1-62, it is not proven that either of the alpha CAMs can correctly measure the release of TRU from underground in the presence of salt loading of the filters. In the case of the beta CAM, the correction for radon progeny beta emitters is not discussed, and how the salt loading on the monitor will affect the gamma correction on the opposed "nonloaded" detector. What are the lower limits of detectability for the WIPP radionuclides in environmental media for these detector systems?

On page 6.1-64, first sentence. This sentence should read: "The filters obtained from this FAS will be collected and analyzed by the New Mexico Environmental Evaluation Group, for independent verification of releases from the facility."

On page 6.1-64, please provide more information on the minimum detectable concentrations (MDC) which determine quantitatively the meaning of the phrase "significant release." Also indicate what total release and/or release rate would correspond to these levels based on calculated X/Q and deposition velocities for the predominant plume direction. It should be noted that once the HEPA filters are activated in the EFB, Station B must remain in operation continuously from that time on, because it is the sole point at which this effluent can be monitored after it passes through the HEPA filtration system.

15. Section 6.1.7.1.1, Overall Approach, Page 6.1-70.

Under item (4) it is stated that a 50-year effective committed dose equivalent is used. This concept is commonly used for radionuclides, but it should be made clear how the methodology would be applied for hazardous wastes.

On page 6.1-72, the first paragraph includes a statement that risks for hazardous wastes are being overestimated by one to three orders of magnitude by the use of conservative assumptions. The basis for this statement should be added or the statement deleted.

16. Section 6.1.7.1.2, Assumptions and Considerations of Uncertainty, Pages 6.1-71, and 6.1-72. The first sentence of this section indicates that conservative estimates are provided in Table 6.1-16. Please provide a justification for this statement. EEG agrees with the first sentence of the second paragraph on page 6.1-72 in that this statement recognizes the uncertainties in the chemical data base. Also, the assumption of 24 hours-a-day, 365 days-a-year occupancy may lead to a conservative factor of two or three, but not a factor of 10 to 1000.

17. Section 6.1.7.2.1, Migration Pathways, Page 6.1-73. We agree that for normal operations the volatile organic gases would be the predominant releases, however, it is not obvious that 100% of the lead would be in a monolithic form. Since there is so much lead in the waste, the mobility of only a few percent of it could be significant. A contrary assumption should be justified.

Also there is no indication that surface contamination has been considered. Data is needed on surface contamination so that exposure can be evaluated.

This section concludes that the ingestion pathway was not evaluated. This conclusion is based on the assumption that the chemicals are relatively insoluble and tend to break down in the atmosphere and through biodegradation. Please provide data or references which support such assumptions.

18. Section 6.1.7.2.2, Characteristics of Potential Hazardous Contaminants, Page 6.1-74. It may not be valid to consider only those hazardous wastes present to the extent of 1% or more. It is possible that a highly toxic component present in amounts less than 1% by weight may be of greater significance in toxicity evaluations. For example, cadmium has a cancer potency factor about 425 times as great as methylene chloride and is listed in Table 6.1-17 as having an average concentration about .006 of that of methylene chloride. Therefore, perhaps cadmium should have been considered. Was the data base examined to determine the presence in low concentrations of other highly toxic waste?

The statement in the second paragraph on this page that the method of calculation leads to a "worst case" scenario is correct for some of the waste forms but not for those waste forms in which the concentration of a hazardous constituent may be greater than the "calculated" average. Also, the concentrations of hazardous waste from other generators may substantially exceed that from RFP/INEL. Therefore, more convincing evidence is needed to support the claim that this is a conservative estimate.

At the bottom of page 6.1-74, it appears to be assumed that lead is not one of the mobile constituents. With the very high quantities of lead in some of the drums, this may not be valid. Evidence should be provided to support such an assumption. Furthermore, lead can be assumed to be controlling for the other heavy metals only if the mobile fraction and/or toxicity of these other metals is substantially less than for lead.

On page 6.1-75, a statement that volatilization of liquid organics need not be considered because the WAC does not allow liquids is inaccurate. Actually, the WAC does allow small amounts of liquid residues.

As previously indicated, the statement at the top of page 6.1-77 that using an average concentration represents a worst case assumption is not valid for all waste containers.

19. Section 6.1.7.2.3, Exposure Modeling, Page 6.1-78. Using the "nearest residence," the Mills Ranch, as the location of the maximum exposed individual from routine releases is probably not conservative. The X/Q concentrations at Crawford Ranch (5 miles NNW-NW in the prevailing downwind direction) are about 50% greater than at Mills Ranch (Table H-49, page H-93 of FEIS). For accidents, Mills Ranch has one hour X/Q values about 10% higher than Crawford Ranch.

In the second paragraph on page 6.1-78, there appears to be a typographical error in the first sentence. The volatile releases should be "from" the waste handling building and underground area rather than "to." Also please address the potential for adsorption of the VOC's to particulates. In which case, why should not the particulate form of hazardous materials be considered? Please also clarify whether the mixing heights utilized for VOC's are the same as those used for the dispersion of radioactive material. Do VOC's have a higher effective mixing layer because of diffusion?

20. Section 6.1.7.3, Routine Releases and Exposures for Hazardous Chemicals, Page 6.1-80. This section states that "before opening the TRUPACT-II, samples will be taken from the sample port to detect any accumulation of hazardous

chemicals." This monitoring procedure is not described in Chapter 5. It should be indicated whether such analyses of hazardous chemicals will be a routine procedure, and, if so, what methods of analysis will be used. If these materials will be routinely analyzed in the gases of all TRUPACT-II's, the procedure should be addressed in Chapter 5. The average flow rates in Table 6.1-19 for 14 drums sealed in TRUPACT-II for 100 hours would lead to air concentrations in the TRUPACT-II cavity that exceed threshold limit values for carbon tetrachloride and are about 15% of the TLV for 1,1,1 trichloroethane. Therefore, concentrations inside the TRUPACT-II may be significant and routine sampling should be required.

21. Section 6.1.7.3.1, Routine Releases, Page 6.1-80. The statement is made here that "backfilling is expected to effectively reduce exposure to VOCs to negligible levels." This would be true only after a storage chamber has been sealed, but not necessarily during the filling of a chamber with waste.

Also on this page, there appears to be an error in the assumed air velocity in a storage room. Since the empty room has a cross-sectional area of about 40 m^2, the velocity of 3 m/s yields a ventilation in the storage room of 120 m^3/s or 254,000 ft^3/min, which is 60% of the entire repository ventilation air. Also using the data in Table 6.1-22, one can calculate the air flow to be in the vicinity of 116 to 123 m^3/s. The WPO ventilation drawings indicate that the entire flow in a waste panel will be 122,000 ft^3/min. Thus the air flow assumption here appears to be high by at least 108% and the calculated air concentrations in Table 6.1-22 should be more than doubled. (Methylene chloride concentration appears high by a factor of 10.)

22. Section 6.1.7.4, Health Risks and Ecological Consequences of Chemical Releases, Page 6.1-83. Please clarify this paragraph and indicate whether the acceptable excess cancer risks (1 in 10,000 occupational, etc.) are per year or per lifetime.

The assumption of 65 to 70 individuals exposed does not appear consistent with information in Tables 6.1-8, and 6.1-10. Please clarify. Also the significance of the last sentence on this page is not clear.

Concerning the discussion at the top of page 6.1-84, the use of human risk standards when considering exposure risks to animals may be conservative for certain species, and/or hazardous materials, but not valid for others. For example, herbivores do not wash forage prior to consumption and are more likely to inhale resuspended contamination for longer periods of time in a contaminated area. Therefore, it may be desirable to carry out additional environmental studies of the ecological system to further support these assumptions.

On page 6.1-85, it was possible for EEG to derive the risk factor for carbon tetrachloride as stated in the second paragraph by using a cancer potency factor of 0.13 $(mg/kg/d)^{-1}$, and by assuming the values in Table 6.1-22 are in mg/kg/d. However it was not possible for us to arrive at the risk factor for methylene chloride. Please clarify these derivations. Also, the statement that 2.7E-06 is "at least two orders of magnitude less than 1E-04," is not correct.

23. Tables 6.1-16 and 6.1-17, Pages 6.1-108 and 6.1-109. By using the values in Table 3.1-6, it was possible to derive the values shown in Tables 6.1-16 and 6.1-17. It is recommended that these two tables reference Table 3.1-6.

24. Table 6.1-20, Page 6.1-112. Except for the values of Freon 113, it is not possible to correlate the values in this table with the respective emanation rates shown in Table 6.1-19. Please provide the methodology for deriving these values or information to indicate why the respective routine releases should not be the product of the number of drums times the emanation rate per drum.

25. Table 6.1-21, Page 6.1-113. The inhalation values given in this Table cannot be obtained from data in other tables when using normal inhalation rates of 12 m^3/d for occupational exposure and 22 m^3/d for the public. Possibly these tables should have been labeled as mg/kg body weight per day.

26. Table 6.1-22, Page 6.1-114. In evaluating this Table, and as indicated in comment 21 on this Chapter, the air flows appear to be high by a factor of at least two. Also if the mg/day values in Table 6.1-21 should be mg/kg/d and are multiplied by 70 for a 70 kg individual, and using an AIC value of 6.30 mg/Kg/day the risk would be 5.1E-04 for 1,1,1 trichloroethane. The risk value for carbon tetrachloride was verified but we did not agree with the methylene chloride value when using a cancer potency factor of .0143 $(mg/kg/d)^{-1}$. Also, isn't the cancer risk the excess lifetime risk from a 25-year exposure at WIPP, rather an excess annual risk as stated in the footnote?

27. Table 6.1-23, Page 6.1-115. No information is given on the EPA ISG Dispersion Model used to calculate off-site air concentrations. The values reported in Table 6.1-23 could be obtained by using an effective X/Q factor of about 5E-08 s/m^3. The X/Q factor used in the FEIS (Table H-49) is about 6E-07. Even the equivalent X/Q factor used to calculate individual radiation doses in this chapter (in

Table 6.1-13 from releases in Table 6.1-12) is over six times greater (about 3.3E-07 s/m^3). It was not possible to check the values for carcinogens. Also, as mentioned in comment 19 on this chapter, it appears that Crawford Ranch would have higher concentrations than at Mills Ranch.

The risk values were verified for all hazardous chemicals except methylene chloride by assuming the mg/d values from Table 6.1-21 should have been mg/kg/d.

28. Figure 6.1-16, Page 6.1-135. The shaded areas referred to in this figure are not shown.

29. Section 6.2, Environmental Protection, Page 6.2-2. In the discussion of the applicability of subpart B of 40 CFR 191 to the FSAR, it is not clear how WIPP can become a disposal facility without demonstration of compliance beforehand. The FSAR will be incomplete until such demonstration has been achieved, and this should be clearly stated.

30. Section 6.2.1.3, Non-Radiological Environmental Surveillance Program, Page 6.2-7. This section should be expanded to indicate the extent to which environmental studies, if any, will be made of the ecological system to support the assumptions and conclusions in the FSAR concerning RCRA requirements.

31. Section 6.3.2, Occupational Medical Program, Page 6.3-4. Please provide additional information on this program, such as how employees are informed about the program, particularly the termination medical examinations.

32. Section 6.4, Industrial Hygiene, Pages 6.4-1 through 6.4-5. While this section has been expanded from two

to five pages, there is nothing WIPP-specific in the section, neither are there any references. This section is inadequate in describing the potential industrial hygiene problems at WIPP or the program being developed to control them. More WIPP specific detail is needed to demonstrate that industrial hygiene problems have been evaluated and control is assured. Please include in this discussion an indication of how RCRA requirements will be interfaced into the industrial hygiene program. Also references to documents which support the discussion should be added.

C. Appendix 6A

EEG believes this draft of Appendix 6A is seriously flawed. There are two major errors of logic in the calculations. The values that are calculated are not reflected in appropriate tables in Chapter 6. Also, there are non-conservative changes in assumptions from the previous draft FSAR that are not justified.

One principal problem is that the procedure used to calculate the radionuclides present in the surface contamination is incorrect if one starts from the assumption (which you did, and EEG agrees with) that "the internal content of the drum would also tend to reflect the radionuclide distribution on the external surfaces of the respective container." The average drum contains 65% alpha radioactivity and 35% beta plus gamma radioactivity. Yet, the calculation method assumes that the beta plus gamma contamination limit (which is nine times the alpha limit) is reached first and depresses the maximum alpha contamination. The final result is that, from an alpha/beta plus gamma ratio of 1.86 in the drum, the calculation ends up with a ratio of 0.024 on the surface! Because of a different radionuclide distribution in boxes, the Appendix 6A methodology is only in error by about 3%. However, because alpha radiation delivers most of the internal dose, the overall dose would be about 90% higher than calculated with the Table 6A-2 and 6A-3 values.

Furthermore, it does not appear that the values calculated with the Appendix 6A methodology are used in Chapter 6. For example, the 6A calculation indicates a normal Pu-239 concentration of 6.6E-16 $\mu Ci/cm^3$ near the drum from resuspension, while the value in Table 6.1-5 is 6.1E-14 $\mu Ci/cm^3$. Appendix 6A does not explicitly state how one goes from resuspended activity from a drum or box to the average concentration for the year. Apparently, it is assumed that the resuspended concentration endures for one hour for each contaminated drum or box. The number of workers exposed during each incident is not stated. Likewise, there is no indication of how long the resuspended concentration from damaged containers is assumed to persist. If it is assumed that all 24 workers are exposed to the "6A concentration" for 1,900 hours per year and six persons were exposed to damaged containers for 20.4 hours/year (which seems low), then the dose would still be 0.30 + 1.00 = 1.3 person-rem/year committed effective dose equivalent (CEDE). But Table 6.1-10 presents a value of 0.66 person-rem. To further confuse the issue, the concentrations in Table 6.1-5 would result in a CEDE of 0.54 rem per worker-year of exposure. It is noted that DOE/WIPP 88-012 estimates about 10.3 person-hours of handling for each trailer and this would be about 3.4 person-years/year near enough to containers to receive external radiation doses. This would result in a dose of 1.8 person-rem/year (CEDE) from Table 6.1-5. We conclude that the estimated doses in Table 6.1-10 cannot be reproduced from assumptions given in either Chapter 6 or Appendix 6A and are probably low.

Another fundamental error in methodology is the use of the resuspension factor to calculate the amount of radioactivity being discharged to the atmosphere from surface contamination. Using the assumptions in Appendix 6A, one can calculate that the total amount of radioactive contamination on containers brought on-site during a year would be about 2.8E-05 PE-Ci. Yet, Table 6.1-12 indicates that 1.2E-03 PE-Ci are released to the atmosphere in storage exhaust and about 0.3E-03 PE-Ci/y is released into the Waste Handling Building. The total in Table 6.1-12 is then almost 55 times the amount brought in! Similarly, the amount of Pu-239 reported as being released in Appendix 6A (1.9E-5 Ci/y) is about 4.7 times that calculated in Tables 6A-2 and 6A-3. The resuspension factor cannot be used to determine amounts lost from a contaminated surface over a period of time because it includes a fraction that is being continuously deposited (as well as suspended material being transported from the location).

The "Assumptions Used" table (Table 6.1-4) corresponds to Table 6.1-5 in the earlier FSAR draft. However, two key assumptions are less conservative compared to the previous draft:

1) the assumed number of contaminated containers received during a year is only 5%; and

2) the assumed number of damaged containers received per year is only 19%.

What is the basis for these reductions? Are there data from waste generation and storage facilities to justify them?

CHAPTER 7

Accident Analysis

A. General Comments

1. This chapter failed to adequately respond to several of EEG's previous comments. For example:

(a) There is still no indication that a formal Design Basis Accident (DBA) has been performed. There are requirements for such a DBA assessment in DOE Order 6430.1, Chapter 1. This assessment should be performed and summarized in Chapter 7.

(b) Contamination of the underground by releases from several accident scenarios in the CH-TRU portion of the WHB from ventilation air flow down the Waste Handling Shaft should be assumed. Of even greater probability would be the transport of contamination off-site by workers, visitors or equipment. Such incidents have occurred in nuclear facilities on several occasions over the years. Because of the difficulty of detecting alpha particles this could be of particular importance at facilities like WIPP.

(c) We had also recommended that some of the events of moderate frequency be considered for a drum loaded with the maximum PE-Ci level. This comment was ignored with no explanation or justification for retaining the "average" loading. Also see comment 2 below.

(d) Concerning Accident C2, Drum Drop from a Forklift in the Inventory and Preparation Area, we had recommended that 100% credit not be taken for safety features of the facility and equipment, and for worker training. Instead, no change was made in the assumptions, and the exposure "allowed" is to a worker located in a remote location. What if the forklift operator is injured or stunned by the falling drums, or trapped and fails to immediately leave the scene? Therefore, we still consider this scenario to be insufficiently conservative.

2. Although the WPO has assured EEG the 1000 PE-Ci upper limit value would not be adopted until we had resolved our differences, the WIPP Waste Acceptance Criteria has incorporated it and it appears to be becoming a de-facto limit. The EEG has objected to this limit since 1985, and remains opposed to such a high value. For example, significant comments have been made by EEG on September 27, 1985 (see comments on Chapter 7 of the SAR), November 1, 1985, and June 22, 1988. Most of these comments are still applicable. The basis for our objections include the following:

(a) Such a limit permits a drastic increase in the consequences of the scenarios presented in the FEIS. The need to limit accident consequences from the newer inventories to those estimated in the FEIS was the principal reason why the WPO developed the PE-Ci concept in early 1983.

(b) The occurrence of the C2, C3, C4, and C6 operational accident scenarios with a 1000 PE-Ci container would result in a committed effective dose equivalent of 400 to 700 rem to a worker. The effective dose equivalent delivered in the first year would be about 42 rem. Those are unacceptable doses. The FSAR avoids presentation of this problem by assuming that these scenarios (each assumed to occur once a year for 25 years for a total of about 100 accidents during the lifetime of WIPP) will always occur with a container with the average concentration.

(c) The results of Accident C10 indicate a committed effective dose equivalent to the maximum off-site individual of 1.7 rem. Dose commitments of 3.9 rem to the lung, 29.8 rem to endosteal surfaces, and 6.5 rem to the liver would also occur. These doses greatly exceed a maximum dose of 0.5 rem to any organ of an off-site individual. NRC regulations (10 CFR 60) for a high-level waste repository require "important to safety" structures, systems, and components to prevent or mitigate accidents that could result in a one-time off-site dose greater than 0.5 rem. The FSAR has concluded that there are no items important to safety at the WIPP facility, consequently accident doses off-site from the WIPP facility are allowed to exceed those from a high-level waste repository. The effect of a serious accident could be greatly reduced by significantly lowering the PE-Ci limit.

(d) If a drum containing very high PE-Ci concentrations were intercepted by a human intrusion borehole, there could be more curies of TRU reaching the surface than would be permitted by the EPA standard. It would be possible to produce about 7,000 drums of newly-generated waste at SRP and LANL during the lifetime of WIPP with an average of 470 Ci/drum. The probability of hitting one of these drums would be about 0.1.

(e) Hydrogen gas generation is likely to limit the concentration of radionuclides in most waste forms that can be transported in the TRUPACT to much below 1000 PE-Ci per container.

(f) We don't believe DOE should encourage the production of newly-generated waste that may approach concentrations of 1000 PE-Ci per container and are unaware of any need to do so. If the intent is not to encourage the creation of such containers, why does DOE insist on such a high limit?

In summary, we believe that the 1000 PE-Ci limit has to be significantly lowered. Even with a somewhat lower limit it may still be necessary to address related problems in some other way, such as limiting the number of high PE-Ci drums, imposing more restrictive operational procedures for these drums, etc. We would be pleased to meet with representatives of the WPO to discuss such options.

B. Detailed Comments

1. Section 7.2.1, Source Term, Page 7.2-1. The assumption is made that for accidents expected to happen once a year the

average waste package radioactivity will be used. This is not sufficiently conservative. There should be a consideration of the dose workers could receive from high curie packages, which are likely to be involved in some of the approximately 100 accidents (once each year for C2, C3, C4, and C6 over 25 years) estimated to occur. This assumption also renders the maximum permitted PE-Ci content irrelevant for operational accidents. The FSAR should calculate doses to workers from the C2, C3, C4, and C6 accidents with high-curie containers, including the maximum PE-Ci limit that is finally established.

2. Section 7.2.2.1.2, Dose Assessment, Page 7.2-4. Please clarify whether the described use of the Rupp equation adjusts for the acute angle release of the effluent (45 deg.), and the forced exit direction. If not, the adjustment should be made.

On page 7.2-5, it is difficult to see the logic in excluding scavenging from consideration. In Chapter 6, a constant scavenging coefficient was used for estimating non-accident exposures, and although there was some question as to the validity of using this approximation, it was not specifically excluded. The discussion here should address the possibility of an accident during a precipitation event assuming that an average of about 4 such events occur per month throughout the year at WIPP (U.S. Climate Atlas), with the greatest number of events occurring during the summer. Also it should be made clear whether resuspension of deposited radionuclides and/or saltation-creep-rainsplash contamination were considered. The latter phenomenon is particularly important in affecting plant surface contamination in arid environments. As noted in an earlier comment under Chapter 6 (Comment 13), the deposition velocity assumed for the WIPP site appears to be low by a factor of two. The basis for the selected value should be more clearly documented.

3. Section 7.2.2.2, Doses to Individuals Inside the

Facilities, Page 7.2-6. Consideration should be given to doses to non-radiation workers inside the facilities. It is possible that a significant exposure could occur within the fence from a release from the exhaust stack.

4. Section 7.3.1, Incidents of Moderate Frequency Involving CH-TRU Waste, Page 7.3-1. We concur with the conclusions in the CO scenario that accidents involving the unopened TRUPACT-II in the radiological control area would be less than the hypothetical accident tests and no release would be anticipated.

On pages 7.3-2 and 7.3-3, two changes were made in the C2 Accident scenario. One clarified that only one drum was assumed to be breached. The other updated the average PE-Ci value for a drum. However, EEG's two main concerns (use of an average drum instead of maximum, and assumption of maximum exposed worker) were not addressed. It is not sufficiently conservative to assume the forklift operator has left his position in about 6 seconds and thereby receives no dose. Ten seconds of inhalation from an average drum would result in a committed effective dose equivalent of about 38 rem, whereas a 1000 PE-Ci drum would result in a dose of 2900 rem. This illustrates that very significant doses are possible from handling TRU waste, and this fact needs to be recognized when establishing a maximum PE-Ci limit and operating procedures for drums. The location of the maximum exposed worker and the assumption of the average drum also applies to the C3 scenario.

EEG comments on Amendment 9 of the SAR objected to the low assumed fractions of the damaged drum's waste contents that were assumed to be aerosolized and respirable (1.25E-05 in this case). We still believe they are non-conservative by a factor of 2 to 5. We don't want to resurrect this issue except to note that the release fraction used should not be claimed to be a conservative assumption to offset the non-conservative assumptions of an average drum and the maximum exposed individual being 20 feet away.

5. Section 7.3.1, Accident C4, Page 7.3-5. In the second paragraph on this page, it is assumed that the depletion of the released activity is 20%. Please provide the basis for assuming that this is a conservative value.

6. Section 7.3.2, Limiting Incidents Involving CH Waste, Page 7.3-7. The C8 (hoist cage drop) scenario is still listed as "not credible" and is not evaluated. There has been a long standing difference of opinion between EEG and the WPO about the credibility of this event. In 1985, the WPO produced calculations indicating the probability was about 1.7E-08 per year ("Probability of a Catastrophic Hoist Accident at the Waste Isolation Pilot Plant," TME-063).

However, a December 1987 draft report ("Quantitative Fault Tree Analysis of the Waste Isolation Pilot Plant Waste Hoist Hydraulic Brake System"), prepared as part of the Operational Readiness Review, evaluated this same system and concluded that "the total probability of a catastrophic accident of the Waste Hoist is 1.0E-03 per year (or one failure expected in 1000 years of hoist operation)." This draft report goes on to assure the reader that the suggested modification (providing a solenoid-operated emergency dump value) reduced this probability to 5.2E-08, so failure is still a "not credible" event.

We are not sanguine about the assurance the probability is now 5.2E-08. The 1987 analysis concluded that the 1985 analysis was in error by a factor of 60,000. How can we be expected to now accept the 5.2E-08 value as reliable? EEG still insists that the C8 hoist drop accident be considered credible and the dose consequences of it be evaluated in the FSAR.

It is noted that when using the assumptions for the C8 accident in the FEIS and assuming a load of seven 7-Packs, each with the maximum thermal load permitted in TRUPACT II (40 watts for two 7-Packs), one calculates a release to the environment of 1.15 PE-Ci. By extrapolation from the C10 Accident in Table 7.3-1, this would result in a maximum off-site dose of 3.9 rem (committed effective dose equivalent).

Concerning the C9 Accident on page 7.3-8, EEG had urged in its October 1988 comments on the draft FSAR that the procedures necessary to protect against a diesel fire be incorporated into the "WIPP Standard Operating Procedure Manual," and that the FSAR reference these procedures. This comment was not responded to in the discussion of the C9 Accident. It is essential that these procedures be formally adopted and rigorously followed during the life of the facility.

7. Table 7.3-1, Page 7.3-13. The internal inconsistences in this table that were commented on by EEG in October 1988 have been corrected (except that the second footnote is no longer applicable). The doses in the table can be obtained by using X/Q factors of 2.0E-05 s/m^3 for the maximum individual, 1.7E-05 s/m^3 at the site boundary, and 1.3E-05 s/m^3 at Mills Ranch. The X/Q value at the location of the maximum individual dose is only 1/3 of the 50% frequency 1-hour value from the FEIS. The X/Q values for the other locations are 20% to 40% of the 5% frequency 1-hour values in the FEIS. Without a detailed reevaluation of both of these computations, it is not possible to judge which values are the more appropriate. However, the value for the C10 accident is high enough to be considered "important to safety" as defined in the FSAR and the NRC regulations without using the higher X/Q values.

8. Table 7.3-2, Page 7.3-15. The doses presented in this

table are correct for the assumptions described in Chapter 7, however they are misleading because they apply only to an average drum and assume the forklift operator is not exposed. Assuming a 1000 PE-Ci drum, the C2 scenario dose would be 400 rem (committed effective dose equivalent). For our assumptions discussed in comment 4 above, the forklift operator would receive 2900 rem.

9. Section 7.4, Accidental Releases and Exposure to Hazardous Wastes, Page 7.4-1, 7.4-2. These accidental releases are related to the same scenarios used for radionuclide releases, which is a reasonable approach. The assumption that all VOC head space gases would be released in an accident seems quite likely because of the properties of VOC's. However, it also seems likely that a fraction of the hazardous components of the drums which are not in gaseous (or volatile) form would be released. Therefore, it is recommended that these releases be revised to assume a fractional release of the hazardous components in a manner similar to the fractional release of the radionuclides. The SAR has always assumed that radionuclides would be released from the waste matrix following an accident and there is experimental evidence to indicate that such releases are likely. The release fraction being used in the draft of the FSAR is 1.25E-05 of the container's waste contents in an aerosolized and respirable form except for the C10 fire scenario which uses 2.5E-03 to the drift and 5.0E-04 to the environment. Therefore it seems appropriate to assume that all hazardous constituents in the containers will be released from the waste matrix in the same proportion as the radionuclides. Also, the assumed concentration of the constituents in the drums should be that in the highest waste form category rather than the average. These assumptions will increase the VOC release by 20% to 70% except for the fire scenario, where it would be increased by factors of 5 to 28. The lead release would be increased about 2.5 times for those scenarios other than the fire scenario, and 100 times for the

fire scenario.

On page 7.4-2, third paragraph, either the ground receptor concentration or the 30 minute intake value for lead is in error. A person would inhale about 0.6 m^3 of air in 30 minutes and if the air concentration was 5.46E-12 g/m^3 the intake would be about 3.3E-09 mg.

10. Table 7.4-1, Releases and Exposures from Projected Accidents During WIPP Facility Operations, Page 7.4-3.

(a) We agree with the release values for the VOC's (based on the assumptions) except for Freon. The Freon values are high by a factor of about 14, however, the amount of Freon inhaled by both the worker and off-site individual is consistent with the correct release value (assuming that the fraction of release inhaled is the same for all VOC's). It is of interest that the No-Migration Variance Petition, February 1989, DOE/WIPP 89-003, Table 5-10, has a consistent value for Freon.

(b) Based on the assumptions presented, the lead release and inhalation values cannot be reproduced. The value of "potentially vaporized lead" is not given. Also the fraction of release that is inhaled is only about 1.5% of that for the VOC's after adjusting the amount removed by filters and that plated out. Credit should not be taken for the HEPA filters being in operation and reducing a release, because credit is not taken in other accident scenarios due to the fact that the filtration system is only operative following an alarm and therefore may not engage in a timely manner. Also a lead release could occur without releasing enough radioactivity to trigger an alarm.

(c) The fraction of the release assumed to be inhaled by a worker is unusually high, about 1.3% of the total release. The fraction for radionuclide inhalation in this chapter is less than .01% of the release. Also Table 5-10 in the No-Migration Variance Petition referred to above shows a worker's intake to be only 5.3E-03% of the release. Therefore, the 1.3% inhalation value is obviously in error and should be corrected.

(d) The effective X/Q values at the location of the maximum off-site individual for the VOC releases are 1200 times greater than the X/Q values used for the radionuclides. Please explain the basis for this difference.

CHAPTER 8

Long Term Waste Isolation Assessment

A. General Comments

1. In our October 14, 1988 review of the Draft FSAR, EEG strongly objected to the deletion of 159 pages of detailed discussion, summary, and tabulations estimating the consequences from long-term waste isolation and pointed out that this violated the 1981 DOE/State Consultation and Cooperation Agreement which specified content of the SAR. This Draft FSAR responded to our objection by reinstating 18 pages of summary statements, conclusions and tabulations heavily referencing Amendment 9 of the SAR.

This re-insertion of consequence analyses in Chapter 8 by reference to an earlier SAR could be claimed to have resolved the issue of non-compliance with the C&C Agreement. However, it is a superficial outdated effort. None of the tabulations and figures are more recent than March, 1983. There have been drastic changes in the inventory since that time and the method of calculating radiation dose has been changed. EEG considers this long-term Waste Isolation Assessment to be inadequate.

2. Failure to Meet 1981 C&C Agreement

The text begins with the statement "The purpose of this Chapter is to discuss the long term isolation assessments that will apply to the WIPP facility" (emphasis added). While the text does provide a minimal discussion, that is not the purpose mutually agreed upon by DOE and New Mexico in the July 1, 1981 Stipulated Agreement, Appendix B, Working Agreement that specified the contents of the Safety Analysis Report, Chapter 8, Long Term Waste Isolation Assessment. It was agreed that the document would analyze the long term impact on public health and safety following decontamination and site control termination and would include consequence analyses. This chapter does not discuss the 1981 commitment by DOE to perform consequence analyses or even reference the Working Agreement.

3. Failure to Provide Comparable SAR to DOE HLW SAR

DOE has agreed to complete their SAR for the HLW repository in Nevada before they begin construction of the repository. That SAR will include an evaluation of the performance of the proposed geologic repository for the period after permanent closure and give the rates and quantities of releases of radionuclides to the accessible environment as a function of time and a similar evaluation which assumes the occurrence of unanticipated processes and events. Why can the Department agree to provide this detailed information in their SAR for HLW in Nevada and not provide it in the FSAR for TRU waste in New Mexico? Note that this issue is independent of whether the facility is a repository or is a research and development facility. Both are analyses of the safety of a proposal to place unwanted radioactive materials in a mine.

4. It is stated that until the decision is made regarding the use of the WIPP facility as a permanent repository, compliance with Subpart B of 40 CFR 191 is not required. The following reasons are advanced for not demonstrating compliance at this time:

- Possibility of Revision of Subpart B by EPA.
- Further experiments and analyses are needed to complete a performance assessment.

Since it is not expected that there will be any major changes in Subpart B, and an agreement with New Mexico to adhere to the vacated standards is in effect, anticipation of a revision is not a justified reason for non-compliance. The FSAR should be more specific as to the analyses involving the collection of data. What is the specific data that must be collected to refine assumptions? What are these assumptions? If undefined assumptions have been formulated, then they should be stated in this report, as well as any supporting analyses. If experiments are to be performed, then they should be described and schedules presented.

5. The issue of demonstrating compliance with Subpart B of the EPA Standards for the disposal of transuranic waste and performing long term waste isolation assessment of consequence analyses is separate and administratively unrelated as the following chronological sequence indicates.

- 7/81 DOE agrees to conduct consequence analyses in the SAR (Ref. W.A.)
- 11/84 DOE agrees to meet any future EPA disposal standards (Ref. 1st Mod.)
- 9/85 EPA promulgates standards for disposal of TRU waste.

Since there is nothing in the C & C Agreement and subsequent modifications to relieve the Department of its obligation to conduct these SAR Analyses, on what basis does the Department contend that the obligation to demonstrate compliance with Subpart B of 40 CFR 191 relieve DOE of the 1981 SAR obligation?

B. Detailed Comments

1. Section 8.1, Summary of Initial Consequence Analyses

Performed for WIPP, Page 8.1-2. This section references Amendment 9 of the Safety Analysis Report. Since the FSAR will supersede all previous amendments to the SAR, it does not seem reasonable to adopt or take credit for passages in earlier versions by reference. As previously recommended, the long-term consequence analyses should be included in the FSAR, Chapter 8.

2. Page 8.1-2, "These standards now exist in 40 CFR 191..." - Subpart B of the standards does not now exist.

"The WIPP facility must demonstrate compliance to these new standards..." - They were promulgated in September 1985 and are not new.

3. Section 8.1-12. While the issues of compliance with the EPA standards and performing consequence analyses in the SAR are mutually unrelated events, the discussion of EPA standards contains a number of misleading and incorrect statements.

The text states that compliance with Subpart B of 40 CFR 191 is not required until the decision is made to use the WIPP facility as a permanent repository. Two reasons are provided for not demonstrating compliance at this time:

A) Possibility of Revision of Subpart B by EPA, and B) Further experiments and analyses are needed during the Pilot Plant Phase to complete the performance assessment.
Neither are correct.

With respect to A), a formal agreement exists between New Mexico and DOE to evaluate the expected performance of the proposed repository with the vacated standards. Hence, the possibility that the standards may change is not germane. Additionally, anticipation of a revision of the standard is not a justified reason for non-compliance, particularly when all parties agree that most of the standard will be salvaged. With respect to B), to date there are no experiments nor analyses that have been identified that are needed for performance assessment.

4. Section 8.1, Tables 8.1-1-6. It is noted that all doses in these Tables are from Amendment 6 (March 1983) or earlier versions of the SAR. The inventories used have been changed significantly. Also, old dose conversion factors and the pre ICRP-26 & 30 method of dose calculation is still used.

5. References for Section 8.1. Other than a 1986 revision of the SAR, the remaining references are 1978 or earlier.

6. Section 8.2.1, Performance Assessment, Page 8.2-3. As stated in our earlier comments, DOE-WIPP 86-013 requires that sensitivity and uncertainty analysis be carried out. This section again fails to recognize the need to include uncertainty analysis in the performance assessment methodology. Also, the final scenario report has not been published as of April 1, 1989.

7. Section 8.2.1.1, Scenario Development and Screening, Page 8.2-4. As previously recommended, the discussion on human intrusion modeling should include consideration of the possibility of Castile brine reservoirs under the repository. (See EEG reports EEG-11 and EEG-15).

8. Section 8.2-3, 8.2.1.1, "A final scenario report will be published in 1988..." - It is now May 1989, the report has not yet been published, and the future tense should not be used to describe a 1988 publication date.

9. Section 8.2-2, "Activity to address each of the assurance requirements is scheduled to begin in FY88..." - FY89 is now over half over and the sentence should be rewritten as, "Activity began..." or will begin in FY89.

10. The following paragraphs "summarize the progress to date" - What progress has occurred since September 1985? Nothing but a schedule has been published.

Section 8.2-7, 8.2.1.5. Our October 14, 1988 comments on the internal Peer Review Panel have been ignored and are reprinted again.

11. The text states that DOE is the only implementing agency responsible to determine compliance with the standards and an internal Peer Review Panel will provide assurance to state officials can be assured that DOE's conclusions are credible. That philosophy virtually guarantees a loss of credibility with the New Mexico EEG if the intent is merely to ask us to review the results. The authors appear unfamiliar with the 1978 contract between DOE and the State of New Mexico.

12. Section 8.2-10. The schedule shows completion of Subpart B compliance in October 1992. No indication is provided of the amount of time between completion by DOE and review by EEG and others. Contrary to the text, the Compliance Strategy (Plan) does not provide such a schedule.

13. What does "major" and "supporting" mean in the diagram? For example, will scenario development be completed in April 1990? That is not consistent with the plan to publish scenario development before October 1988.

CHAPTER 9

Conduct of Operations

A. General Comments

1. This chapter contained several significant improvements, and evidences considerable response to previous EEG comments and recommendations.

"Although DOE is responsible for all aspects of the WIPP facility, it delegates those functions to various contractors." The chapter is silent on the responsibility to protect the workers and the general population except for identifying the Safety, Security, and Environmental Protection Department as being responsible for "health and safety related programs which satisfy the requirements of the DOE and other...agencies." The philosophy and tone of the responsibilities and authorities of the various officials do not convey a strong commitment to health and safety matters.

B. Detailed Comments

1. Section 9.1.1, Owner Organization. The text states that the functions, responsibilities, and authorities of DOE and its contractors are discussed in Section 11.1.1. They are not.

2. Section 9.1.2.2.1, Page 9.1-2, General Manager. The General Manager has overall responsibility for the operation, maintenance, and modification of the WIPP facility. Is the General Manager ultimately responsible for the health and safety of WIPP personnel or has this authority been delegated to a lower level?

3. Section 9.1.2.2.7, Page 9.1-4, Safety, Security, and

Environmental Protection Department. This paragraph assigns the responsibility of health and safety to the "department." The department should have "functions," and responsibilities should be assigned to an individual, such as the Department Manager. This comment also applies to other sections in the chapter where the "department" is assigned responsibilities.

4. Figure 9.1-1, Page 9.1-8, Management & Operating Contractor Organization Diagram. The management diagram does not reflect a communication line between the General Manager and the Radiation Safety Manager. The WIPP "Radiation Safety Manual," WP 12-5, assigns the responsibility for interpreting the radiation safety program to the Radiation Protection Manager, yet the FSAR, Section 6.1.5.2, assigns responsibility for the radiation safety program to the Safety, Security, and Environmental Protection Manager.

The radiological safety program responsibilities should be clearly defined and reflected in the formal organization structure. Please clarify the reporting and communication lines.

5. Section 9.1.3.2, Page 9.1-6, Staff Managers. Although there is reference to staff manager's qualifications, there are no requirements specified. The words "typically have" should be replaced with "as a minimum requirement shall have." The importance of qualifications should be reviewed with respect to guidance found in ANSI/ANS-3.1-1987, "American National Standard for Selection, Qualification, and Training of Personnel for Nuclear Power Plants." Although this document is not a general DOE requirement, the overall guidance should be followed at WIPP. Chapter 9 should state commitments to high level management qualifications, and specifically to appropriate technical experience of the Radiation Protection Manager. As per ANSI/ANS-3.1-1987, the collective qualifications of management and technical managers shall be reviewed and supplemented, as

necessary, with personnel with applicable qualifications.

6. Section 9.2, Acceptance Testing, Page 9.2-1. This section refers to the "WIPP Procedure Manual." Presumably this is a reference to "Standard Operating Procedures," WIPP-DOE-103. If so, this title should be correctly presented. EEG does not have a document entitled "WIPP Procedure Manual."

7. Sections 9.2.2, 9.3.5, and 9.4.1, Acceptance Tests, Administration and Records, and Plant Procedures, Pages 9.2-3, 9.3-5, and 9.4-1. These sections refer to Sections 11.1.11, 11.1.12, and 11.1.17. There are no such sections. They should refer to Sections 11.11, 11.12, and 11.17.

8. Section 9.4.4, Operational Occurrences, Page 9.4-2. The text discusses compliance with U.S. DOT regulations in the transportation of TRU wastes, but fails to discuss compliance with U.S. NRC regulations.

9. Section 9.4.4, Operational Occurrences, Page 9.4-3. This section refers to DOE Order 5484.2 which has been superceded by DOE Order 5000.3.

10. Section 9.4.4.1, Page 9.4-3. The assumption that a contaminated drum, box, or canister would not contaminate the interior of the Internal Containment Vessel on the TRUPACT may not be valid and can result in reduced worker safety.

CHAPTER 10
Operational Safety Requirements

A. General Comments

1. There have been substantial improvements in this chapter, and it has been responsive to many of EEG's comments and recommendations.

2. The introduction states that RH-TRU waste handling is not covered and that, "This document will be expanded to include those OSRs (Operational Safety Requirements) prior to receipt of RH-TRU." EEG agrees that this supplement will be necessary.

B. Detailed Comments

1. Section 10.1, Introduction, Page 10.1-1. We disagree that, "It is inconceivable that non-radioactive hazardous materials would be released from containers without the simultaneous release of radioactive materials." Our reasons include:

(a) the VOC's are much more volatile than the transuranics;

(b) in some containers there may be heavy concentrations of hazardous chemicals and low amounts of radioactivity; and

(c) the amount of radioactivity released may not be enough to trigger an alarm.

This assumption should not be made before sufficient operational experience is obtained to verify it.

2. Section 10.1.4, Definitions and Acronyms, Page 10.1-4. The following acronyms should be added: AC (Page 10.6-4,5), OSR (Page 10.6-3).

3. Section 10.3.1.1, Continuous Air Monitors, Page 10.3-2. This section implies that only two CAMs are mandatory, and therefore the CAMs used for Effluent Monitors, as discussed under Section 10.2.1.2, are not required. This is incorrect. Also, the title of this section should be amended to "Continuous Air Monitors for Waste Handling Building."

4. Section 10.3.1.2, Effluent Monitors, Page 10.3-4. The second paragraph under LCO should be amended to include activity alarm limits for the Station B CAM. Since Station B represents filtered exhaust from the storage horizon, it should have the same alarm limits as Station C from the Waste Handling Building. Such an alarm system would provide an alert to defective filtration in the event of a release followed by an alarm at Station A (also see discussion on page 10.3-11). Furthermore, there is a reference to the LCO for Station B under "Applicability" on page 10.3-5.

On page 10.3-5, it is recommended that this discussion be amended to indicate that portable equipment would only be acceptable for use at Station C if it were connected to the isokinetic probe. The use of batch sampling for monitoring of this effluent point should be used only as a last resort, and for a very short time period.

5. Section 10.3.2.1, Waste Handling Building Differential Pressures, Page 10.3-6. Normal differential pressure ranges for the four WHB areas were given in the first Draft FSAR, but deleted here. Why? Is the system in the WHB able to meet these previously mentioned differential pressures? On page 10.4-2 this draft still takes credit for listing the pressure differentials.

6. Section 10.3.2.3, Underground Exhaust Air Filtration System, Page 10.3-11. The last paragraph on this page discusses

the HEPA filtration system provided for the underground exhaust. It states that periodic verification of the efficacy of the filters is required to maintain confidence in their ability. This discussion should refer to Section 10.4 for information on how verification will be provided. Section 10.4 indicates that the filters will be verified by local examination at each shift. A local visual examination may not be sufficient to determine that a filter system is ineffective. A more definitive description of "local examination" is needed here. At the present time, there is no alarm if the exhausted air exceeds prescribed radiation limits; therefore, the filters could be defective throughout an entire shift, or longer, if the "local examination" is not adequate. See comment 3 above.

The CAM at Station A would be sampling a significant dilution of the radioactive particulates if there should be a release. Consideration should be given to initiating filtration of the underground effluent based upon alarms from CAMs located inside the RMAs of the underground. Dilution of the contaminated air would be less and the air being monitored would be comparatively free of interfering salt dust.

7. Section 10.4.1.2, Effluent Monitors, Page 10.4-2. This section also uses the ambiguous phrase "local examination." This phrase should be more definitive. For example, it could refer to a specific WIPP procedure. In Section 10.4.2.3, the requirements indicate that the filter banks will be tested only annually. Therefore, it is essential that the "local examination" can actually determine effectiveness of the effluent monitors.

8. Section 10.4.2.3, Underground Exhaust Air Filtration System, Page 10.4-4. This section requires only annual verification of the effectiveness of the HEPA filter banks. Because of their importance, it would seem desirable to increase the frequency of such verification. Please provide the basis for

such infrequent verification.

9. Section 10.5.4, Ventilation Systems, Page 10.5-3. The first paragraph on this page states that, "All effluent air streams from areas that contain radioactive materials are filtered <u>and</u> monitored for activity." It should be made clear that the normal operating mode is to exhaust unfiltered monitored air from the exhaust shaft. All air effluents at WIPP are not filtered.

10. Sections 10.6.1, 10.6.2 and 10.6.3, Training, Design and Procurement, and Document Control, Pages 10.6-2, 10.6-3 and 10.6-4. The references listed on these pages should include the "Radiation Safety Manual," WP 12-5.

11. Section 10.6.4, Audit Program, Page 10.6-4 to 10.6-6. The references listed on this page should include the "Radiation Safety Manual," WP 12-5, since there are several important limits which are set forth only in this manual.

12. Section 10.6.8.2, Area Radiation Monitors, Page 10.6-10. This section allows the ARMs to be reset to higher levels for an indefinite period if a higher radiation source is in the area. This seems to defeat the purpose of the ARMs and could allow indiscriminate violation of the established limit of 10 mr/hr. The section should be revised to more definitively establish criteria for resetting to a higher level, and limiting the time at which it may remain at the higher level. Also resetting to a higher level should be permitted only if authorized by a health physicist.

CHAPTER 11
Quality Assurance

A. Detailed Comments

1. Table 11.1, Applicable Quality Assurance Standards, Page 11.1-4. Part B of this table and associated discussions should be revised to include reference to ANSI/ASME NQA-2, Current Editions, "Quality Assurance Requirements for Nuclear Power Plants." NQA-2 is applicable to the operations phase of work at nuclear facilities and is to be used in conjunction with applicable portions of ANSI/ASME NQA-1.

2. Section 11.2.2, General Responsibilities, Page 11.2-5. Documentation should be added to describe the implementation of the Quality Code Classification work described in Guidelines for Requisitions to Determine Quality Code Classification for Purchase Requisitions and Purchase Requisitions Change Notice Attachment 2 of Westinghouse Procedure 15-009, Revision 2. Documentation should also be added to describe the Quality Surveillance work required by the Westinghouse Procedure 13-011, Revision 0, Quality Assurance Surveillance.

CHAPTER 12

Decontamination and Decommissioning of the WIPP Facility

A. General Comments

1. Chapter 12 assumes that the facility will meet the EPA Standards for disposal of TRU waste during the five-year demonstration period and that the removal of 65,000 drums will not be required. A safety analysis should reflect conservative assumptions on matters affecting the health and safety of workers and the general public. Hence, this chapter should contain plans and safety analyses of potential radiation doses to workers and the public from operations and transportation if the wastes need to be retrieved, returned to the generating sites, sent to the high-level waste repository, left indefinitely on the surface at WIPP, sent to a new site, or left in place.

B. Detailed Comments

1. Section 12.1, General, Page 12-2. In the first paragraph of page 12-1, the reference to "DOE Order 5280.2A" should be 5820.2A.

2. Section 12.2, Decontamination and Decommissioning, Page 12-3. This section lists the sequence of future planned events for decontamination and decommissioning, but does not provide meaningful information either in this section, or the chapter, to permit a safety evaluation of the processes. Additional detail is needed for a safety analysis.

3. Section 12.5, Post Closure Physical and Environmental Surveillance, Page 12-5. As previously indicated, additional detail is needed. For example, further information should be

included on how mining will be controlled. Furthermore, the plans for surface environmental surveillance do not appear to address the intent of the NRC in 10 CFR 60 which requires subsurface early warning detection. The National Academy of Science report also recommended subsurface surveillance.

APPENDIX:

OCTOBER 1988 COMMENTS

ENVIRONMENTAL EVALUATION GROUP

AN EQUAL OPPORTUNITY / AFFIRMATIVE ACTION EMPLOYER

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October 14, 1988

Mr. Jack B. Tillman
Project Manager
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U. S. Department of Energy
P. O. Box 3090
Carlsbad, NM 88221-3090

Dear Mr. Tillman:

Our review, which contains 77 pages of detailed comments and recommended changes, of the draft DOE Final Safety Analysis Report (FSAR) is attached. Several of the SAR chapters reflected a conscientious response by the WIPP Project Office (WPO) to EEG's December 1986 and January 1987 comments on Amendment 9. The Final SAR, however, does not contain an adequate analysis of the safety of the WIPP project as required by the July 1, 1981 Working Agreement for Consultation and Cooperation, as well as DOE Order 5481.1B. A considerable amount of work needs to be documented and risks quantified before the SAR can be considered acceptable.

We have repeatedly requested that the SAR include a forthright statement of the purpose of the WIPP project, which is designed to serve as a repository for permanent isolation of defense transuranic waste from the environment. Also, the purpose of the SAR has been downgraded from ". . . the most comprehensive document . . . on public health and safety . . ." (DOE/NM C & C Agreement) to ". . . to support the construction and operation of the WIPP." (Draft FSAR, page 1.1-1)

The "draft final" document contains serious deficiencies, misleading information, omissions of sufficient detail, failures to respond to our previous comments, and minor errors. The more serious deficiencies involve primarily Chapter 1A, 6, 8, 10, and 12. Chapter 1A fails to address the criteria used as a basis for the summary and conclusions; Chapter 6 does not respond to our previous comments on Amendment 9 as you agreed to do in your letter of November 19, 1987; Chapter 8 fails to provide a long-term waste isolation assessment as required by the 1981 DOE/New Mexico Consultation and Cooperation Agreement and the 1988 DOE Order DOE/AL 5481.1B; Chapter 10 needs to provide considerably more detail to permit us to evaluate the operational safety; and Chapter 12 should contain detailed plans for decommissioning and decontamination, if retrieval of nuclear waste becomes necessary.

Due to the substantive nature of our objections to the Final SAR, EEG requests reconsideration of the position taken in your September 15, 1988 letter that you will not respond to our comments prior to publishing the Final Safety Analysis Report. Your early response to this request is needed to insure that our concerns are addressed.

Sincerely,

Robert H. Neill
Director

RHN:ML:lsb

Enclosure

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Comments and Recommendations

on

DOE Draft Final Safety Analysis Report

Waste Isolation Pilot Plant

Prepared by

Environmental Evaluation Group

New Mexico

October 1988

SUMMARY

The preliminary Safety Analysis Report was first published by the Department of Energy's WIPP Project Office (WPO) in 1980. The New Mexico Environmental Evaluation Group (EEG) reviewed this five volume document shortly after publication and transmitted detailed comments and recommended changes to the WPO. Following such review and comments, and on some occasions, meetings between representatives of respective agencies, the report has been revised nine times. These amendments have been based upon both DOE initiated changes in design, criteria, and planned operations, as well as EEG recommendations.

The present DOE draft Final Safety Analysis Report reflects a favorable response to many of EEG's previously recommended changes, but there remain some serious deficiencies, some misleading information, omissions of sufficient detail, failures to respond to previous comments, and minor errors. The more serious deficiencies are summarized below, with the more detailed observations and recommended changes itemized under each Chapter heading.

1. The SAR does not provide an adequate safety analysis of WIPP including the quantification of risk and documentation of calculations and analyses envisioned in the 1981 Consultation and Cooperation (C & C) Agreement between DOE and the State of New Mexico. Even the purpose of the SAR has been downgraded from "the most comprehensive document . . . on public health and safety . . ." agreed to by DOE and the State in the 1981 C & C Agreement to the present "to support the construction and operation of the WIPP."

2. The purpose of the WIPP Project is to provide a facility to permanently isolate the defense TRU waste from the environment. It should be clearly stated in the first paragraph of Chapter 1 of the FSAR. Statements such as, "The WIPP facility is designed to receive, inspect containers for damage and contamination, emplace, and store unclassified defense-generated transuranic wastes in a retrievable fashion . . ." (Chapter 1, page 1.1-1) and "The WIPP is designed as a full-scale facility to demonstrate the technical and operational principles for the permanent isolation of defense-generated transuranic waste in salt" (Chapter 3, page 3.1-1) are misleading.

3. The draft FSAR violates the 1981 DOE/State Consultation and Cooperation Agreement (Appendix B, Article III), and the requirements of the 1988 DOE Order AL 5481.1B, both of which require the FSAR to have a long-term waste isolation assessment, identifying potential communication modes, modeling methods, and consequence analyses. Earlier drafts of the SAR did attempt to evaluate long-term waste isolation (159 pages in the previous edition), but such analyses have been replaced in the Final SAR with a nine page general discussion of how performance assessment will be conducted. Consequence analyses must be included.

4. Although the Department has informally indicated that there is no intent to conduct experiments at WIPP with high level waste, there are numerous references in the SAR to high level waste experiments. They should be deleted since the SAR contains neither technical justification nor radiological risk evaluation of bringing high level waste.

5. The SAR takes credit in Chapter 8 for a Peer Review Panel providing assurance on suitability of WIPP as a repository. Since the Department has never involved EEG with any of the Peer Review Panels, nor provided us with agenda, minutes or recommendations, we believe that the committees do not provide credibility as stated in the SAR, but in actuality detract from it. In order to take credit, EEG must be involved.

6. According to the August 4, 1987 Second Modification to the C & C Agreement, DOE agreed to document compliance with Subpart A of 40 CFR 191 in the Final SAR prior to the receipt of waste. Such compliance has not been adequately shown nor specifically identified.

7. Chapter 1A is important because it is intended to provide a summary of more detailed information contained in other chapters for final conclusions on the safety of the WIPP design, criteria and plans for operations, and for long-term stability. Unfortunately, Chapter 1A fails to present the basic criteria used in coming to the conclusion that WIPP can be operated safely.

8. While the SAR invokes frequent comparisons with the NRC safety regulations for nuclear reactors, it would be far more appropriate to make comparisons with the NRC health and safety standards for high-level waste disposal (10 CFR 60).

9. It is noted that all references to backfilling the waste storage rooms have been deleted from the FSAR. We know that the Department has decided to emplace the experimental CH-TRU waste without backfill to avoid crushing the drums during the retrieval period. The FSAR should clearly state this decision and the reason for it and should state that when the waste is emplaced for disposal, a properly selected tailored backfill will be used to fill the space between the drums, above the drums and between the walls and the drums. The FSAR should also state that only the amount of waste expressly needed for conducting experiments to help in Performance Assessment (to show compliance with the EPA Standards 40 CFR 191 Subpart B) will be emplaced in a temporary mode without backfill.

10. While DOE made a conscientious response to EEG's December 16, 1986 comments on Amendment 9 of the SAR, an important exception was Chapter 6, Environmental Safety and Health Protection, in which it appeared that the authors were neither aware of our previous comments nor the commitments contained in the November 19, 1987 response by the WIPP Project Manager. Chapter 6 needs to be extensively revised by addressing our comments.

11. The Operational Safety Review (Chapter 10) lacks sufficient detail to permit us to evaluate the operational safety of WIPP. EEG's specific comments describes the areas in which extensive expansion and revision are needed.

12. Since it is not apparent that a Design Basis Accident (DBA) assessment has been performed, it is strongly recommended that such an assessment

addressing the requirements of DOE Order 6430.1 and the guidelines to "A Guide to Radiological Accident Consideration for Siting and Design of DOE Non-Reactor Nuclear Facilities," LA-10294-AC, be performed and summarized in Chapter 7.

13. Chapter 12 assumes that the facility will meet the EPA Standards for *disposal of TRU waste during the five year demonstration period and that* the removal of 125,000 drums will not be required. A safety analysis should reflect conservative assumptions on matters affecting the health and safety of workers and the general public. Hence, this chapter should contain plans and safety analyses of potential radiation doses to workers and the public from operations and transportation if the wastes need to be retrieved, returned to the generating sites, sent to the high level waste repository, left indefinitely on the surface at WIPP, sent to a new site, or left in place.

CHAPTER 1

Introduction and General Description

1. Section 1.1, Page 1.1-1. The purpose of the WIPP project to provide a facility to permanently isolate defense TRU wastes from the environment is not stated anywhere in this document. We understand that the Department's data needed for the analysis to show that the project can accomplish that purpose is not yet available, however, the purpose should be clearly stated in the document. Statements such as on page 1.1-1, "The WIPP facility is designed to receive, inspect . . . " are misleading and raise unnecessary questions as to the intent of constructing the repository.

2. The text states, "The final SAR has been prepared by DOE to support the construction and operation of the WIPP . . . ." This stated purpose appears to be considerably less comprehensive than that agreed to by DOE and New Mexico in Article III of the Working Agreement For Consultation and Cooperation (1981) which states, "The Safety Analysis Report (SAR), as amended from time to time, constitutes the most comprehensive document concerning WIPP both in general and specifically as related to public health and safety as well as other matters." Use the definition in the C & C Agreement since DOE and New Mexico devoted four pages in that Agreement to delineate the expected scope of the SAR. It would also be helpful to state in this section that the Final Safety Analysis Report (FSAR) is required by the 1981 State/DOE Consultation and Cooperation Agreement, and the 1988 DOE Order 5481.1B, and its purpose is to provide analyses of the risks associated with the location, design, and operation of the facility, a summary of applicable standards and criteria, and to

demonstrate through such documentation that it meets applicable standards and requirements for public health and safety.

3. The last line of the first paragraph of this section should be amended to indicate that the facility will not become a permanent disposal facility through "successful demonstration of the acceptability," but through successful demonstration of compliance with the EPA Standards 40 CFR 191, followed by a decision by DOE to make it a permanent disposal facility.

4. All references to the high level waste experiments at WIPP should be deleted from the SAR since DOE has not developed any plans for such experiments nor intends to do so.

5. Section 1.1.1, Page 1.1-2. A reference to the presence of "three mines are located between five and ten miles of the site" should be expanded with a description of lease holdings at the WIPP site and the distance of nearest mining activity from the edge of the site. A more recent and reliable estimate of resources at WIPP than the information contained in the FEIS is a report by the New Mexico Energy and Minerals Department, entitled "Natural Resources at the Waste Isolation Pilot Plant," January 1984.

6. Section 1.1.2, Page 1.1-2. Please enunciate the "technical and operational principles" to be demonstrated. Describe the "studies and experiments . . . to extend the understanding of the behavior of high-level waste in salt" or cite a reference where these are described. Describe the "operating and scientific data" that is expected from

temporary emplacement of waste or provide reference to a document that describes it. Finally, provide the basis(es) on which "DOE will make a decision regarding whether to dispose permanently of transuranic waste at WIPP." The role of the State of New Mexico in this decision should be indicated since the text implies that it is a unilateral decision by DOE.

7. Section 1.1.3, Page 1.1-3. The text improperly states that the CH-TRU storage capacity is 6.3×10^6 cu ft based on the assumed drum-box split. The capacity of 6.3×10^6 cu ft is specified in the 1980 WIPP FEIS.

8. While the text states, "A specific WIPP storage capacity has not been established for RH-TRU waste," the C & C Agreement (Modification 1, 11/30/84) specifies that the limit of RH-TRU waste is 5.1×10^6 curies.

9. The current concept of disposal of decommissioned, contaminated surface facilities of WIPP should be expanded to include plans for the disposition of these contaminated facilities.

10. Section 1.1.3, Page 1.1-4. "The design accommodates the time required to reach the waste and retrieve it if such a decision is made." Please provide specific time periods for the emplacement and retrieval of each waste form.

11. Section 1.1.3, Page 1.1-4. The definition of when WIPP becomes a permanent waste facility on page 1.1-4 (after decommissioning) differs from the definition on page 1.1-1 (upon successful demonstration of the acceptability). Actually, WIPP becomes a permanent facility when the

waste is emplaced with no intent of recovery (40 CFR 191.02 1). The SAR should describe plans for review and approval by EPA, EEG, and the State of New Mexico, before WIPP becomes a permanent facility.

12. Section 1.1.4, Page 1.1-4. The schedule should be amended to reflect recent changes. Also, please provide a basis for the planned schedule.

13. Section 1.2.3.3, Page 1.2-6. Please identify the location of the waste experimental area and provide a brief description of these experiments.

14. Section 1.3, 2nd Paragraph, Page 1.3-1. This paragraph discusses the possible need for allowing exception to the WIPP Waste Acceptance Criteria. The Environmental Evaluation Group (EEG) has participated extensively in reviews of the original WAC and the various revisions. We recognize the importance of the criteria to the safety of WIPP operations and to public health and safe transportation of WIPP wastes. Therefore, it is our firm conviction that the State and EEG should be informed in advance of proposed revisions or exceptions to the WIPP WAC, and that we should be provided the opportunity to make a determination of the safety impact independent of the WPO. This policy would be consistent with Amendment 1 of the DOE/State Consultation and Cooperation Agreement, which states ". . . the DOE will, prior to granting such exceptions for such waste and prior to the shipment of such waste: (1) perform analyses to ascertain the impact of such on the public health and safety, (2) consult with the State of New Mexico, including providing the State with a copy of the analyses for review and comment, and (3) provide to the State a period of forty-five (45) days to review and comment on such

analyses prior to granting any such exceptions. In no instance will such an exception to the WAC be granted if it would cause a significant increase in the impacts on public health and safety discussed in the WIPP FEIS." The EEG is not insisting that such a policy be stated in the FSAR, but it should be made a part of the Standard Operating Procedures (SOP) for amending or allowing exceptions to the WIPP WAC. The failure to include such a policy in the SOP would represent a failure to adhere to the spirit of the commitment reflected in the WIPP WAC and the C & C Agreement.

Also, it would be desirable to include in this section a reference to the need to meet the requirements of 40 CFR 191.

15. <u>Section 1.3.1, Page 1.3-2</u>. It is noted that all references to backfilling the waste storage rooms have been deleted from the FSAR. We know that the Department has decided to emplace the experimental CH-TRU waste without backfill to avoid crushing the drums during the retrieval period. The FSAR should clearly state this decision and the reason for it and should state that when the waste is emplaced for disposal, a properly selected tailored backfill will be used to fill the space between the drums, above the drums and between the walls and the drums. The FSAR should also state that only the amount of waste expressly needed for conducting experiments to help in Performance Assessment (to show compliance with the EPA Standards 40 CFR 191 Subpart B) will be emplaced in a temporary mode without backfill.

16. Section 1.3.4, Page 1.3-3. This section on defense high level waste experiments should be deleted since there are no plans to conduct such experiments.

17. Section 1.5.1, Page 1.5-1. The second paragraph indicates that site characterization was completed in December 1978. As indicated in the title of a Sandia Report (SAND 88-0157) published in May 1988 (received by EEG on July 1, 1988), "Summary of Site-Characterization Studies conducted from 1983 through 1987 at the WIPP Site," site characterization is ongoing. Also, Mr. Troy E. Wade II, Acting Assistant Secretary for Defense Programs, in his testimony before the Subcommittee on Procurement and Military Nuclear Systems of the Committee on Armed Services of the U. S. House of Representatives on September 8, 1988, said, "Formal WIPP site characterization activities will end in December 1988." Only the first phase of site characterization was completed in 1978. The first sentence on page 1.5-2 is a description of the site characterization studies performed since 1983, but the attempt appears to have been made to not use the phrase "site characterization" and thus the description is meaningless. We suggest using the appropriate language from the summary of SAND 88-1057 to describe this effort.

18. Section 1.5.2, Page 1.5-2, 1.5-3. It should be made clear that the experimental programs described in this section do not require emplacement of any radioactive waste. In order to avoid confusion, it would be appropriate to clearly separate the R and D that requires waste from experiments that are performed to better design the repository.

19. Section 1.5.2.1, Page 1.5-3. The discussion of the tests that have been performed for several years should include at least the preliminary results of those tests. What have the plugging and sealing studies shown to date? When is the decision on plugs and seals design expected to be made? What assumptions on plugs and seals performance will be used for showing compliance with the EPA Standards? Please indicate when room-scale seals will be evaluated.

20. Section 1.5.2.3, Page 1.5-5. This section does not describe experiments with waste and, therefore, the title is misleading. Please change the title to "CH TRU Waste Container Stability."

21. Section 1.5.2.4, Page 1.5-5. Please change the title of this section to "RH TRU Waste Container Stability."

22. Section 1.5.3, Page 1.5-8. This section refers to "the design modification alternatives." These alternatives should be listed and the one that was selected should be justified. Also, describe which of the "follow-on studies" are being performed and why, and include a summary of the results to date.

23. Section 1.5.3.1, Pages 1.5-8, 1.5-9, 1.5-10. Please provide references for the studies described in this section and at least a brief synopsis of the results.

24. Section 1.5.4, Page 1.5-12. As previously indicated, please delete references to high-level waste experiments.

25. Table 1.5-1, Pages 1.5-16, 1.5-17. New dates are needed for publishing the "Interim Sorbing Tracer Test Report", "Hydrogeochemical Facies in the Rustler Formation", "Groundwater Modeling Study of the Rustler Water-Bearing Zones", and the "Facies Variability and/or Evaporite Dissolution Within the Rustler Formation" reports.

CHAPTER 1A

Summary Safety Analysis

1. This Chapter attempts to summarize the entire FSAR in order to present the conclusion that it is a safe facility. It does in fact summarize the radiation doses to the worker and the public as a result of normal and abnormal operations and accidents. It then concludes that there is no significant impact on the public health. It fails, however, to summarize the criteria that would provide the basis for such a conclusion. These also should be summarized, either as a table or narrative. For example, the FSAR must provide reasonable assurance that the facility will meet Subpart A of 40 CFR 191, i.e., the combined annual dose equivalent to any member of the public in the general environment resulting from (1) discharges of radioactive material and direct radiation from such management and storage shall not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other critical organ.

2. Section 1A.1, Page 1A-1. It is recognized that Chapter 1A is a Summary Safety Analysis, however, the attempt to summarize in the first paragraph leads to some confusion and ambiguity. For example, the definition of Design Class I in the first paragraph is a serious distortion of the more detailed definition in Sections 3.1.7.1.1. To refer in the first paragraph to "a leak" from the WIPP facility, and then discuss effluents and controlling radiation doses off site in the second paragraph, will almost certainly lead to confusion for some. Please also see our comments on the definition of Class I items in Section 3.1.7.1.1.

3. Section 1.A.1.2.1.2, Page 1A.1-6. The first section describes a potential problem which would be resolved by means of an inexpensive test. It is recommended that the types of clay minerals present in the Dewey Lake Redbeds be determined to resolve the question referred to.

The finite element model mentioned in the third paragraph of this section predicted the closure rates that were 3 to 4 times slower than the actual observations. This section should include the discrepancy between the predicted and actual creep rates and what changes in the design and operations plans have been made to accommodate the faster rates of closure.

4. Section 1.A.1.2.2, Page 1A.1-7. The first sentence of this section is incorrect. There is plenty of evidence of infiltration below the Mescalero Caliche. The second sentence should be more explicit. The water-bearing zones are at depths of approximately 608 to 632 feet, 714 to 740 feet, and 850 to 860 feet. In the third sentence, because grouting of the shafts had to be performed three times before leakage was stopped, it should be indicated that frequent checks and maintenance will be provided to ensure that the shafts remain dry. The fourth sentence, "No groundwater forces in salt are experienced because there are no connected saturated pore spaces" is incorrect. (See Bredeholft, 1988; and Beauheim, 1987, page 4, lines 1 to 4.) Finally, the last word of this section should be "important" and not "significant."

5. Section 1.A.1.3, Page 1A.1-7. Potential damage from an aircraft crash should not be indicated as "very small." While the probability of a

scheduled airliner crash may be very small, a number of small aircraft and military aircraft are seen flying very low over the site. In fact, a small private plane crash occurred at the site in 1982. Efforts should be made to safeguard the site from such incidents in the future. Also, please note our comment 5 on Chapter 2.

6. Section 1A.2.3.1, Page 1A.2-5. The last paragraph of this section states that the gamma source strength was used to calculate shielding for RH-TRU rather than neutron dose rates. Please indicate a reference for information which provided a basis for this conclusion.

7. Section 1A.2.3.2, Page 1A.2-6. The last paragraph of this section implies that the doses to the public for normal operations are developed assuming use of HEPA filters for the exhaust from underground. It should be mentioned that this is a valid assumption only for accidents.

8. Section 1A.2.4.1, Pages 1A.2-8 and 1A.2-11. The units used in Table 1A.2-1 are confusing. From Table 6.1-8, it is apparent that doses due to "direct radiation" (external radiation is preferred terminology) are average individual doses and should be labeled rem/year. The doses due to inhalation are called population doses in Table 6.1-10 (total dose received by all exposed persons), which would be 50 year dose commitment in person-rem.

9. Section 1A.5, Page 1A.5-1. This section states, "The facility operation will include in situ experiments addressing technical issues for defense waste programs and storage of defense related contact-handled (CH) and

remote-handled (RH) transuranic (TRU) waste." At least a brief description of experiments and technical issues to be resolved should be provided to support receipt of waste at WIPP for the R and D purposes. References should be provided of documents in which a detailed description of the experiments may be found.

The statement, "This section provides conclusions with regard to the adequacy of the WIPP site," is incorrect. Either remove the statement or provide the conclusions with appropriate rationale.

10. Section 1A.5.1, Pages 1A.5-1, 1A.5-2. Please provide appropriate references for the "conceptual design" and the "preliminary design."

Page 1A.5-2, first paragraph, mentions keeping a minimum clearance for five years. It should be changed to at least ten years since the retrieval would take at least as long as emplacement. The same paragraph discusses the models to predict the rate of closures without mentioning that these predicted rates were three to four times lower than the rates observed after excavation.

Before reaching the conclusions stated in the last paragraph of this section, it is necessary to discuss the changes in the plans for retrievable emplacement of waste which became necessary due to rates of closure three to four times higher than predicted. For example, it is planned to emplace the waste without backfill during the period when retrievability needs to be maintained to minimize the possibility of the drums being crushed. Also, the rooms will be cut an extra foot higher and trimmed before emplacement of waste. The original design criteria were, therefore, not suitable. This section should discuss why these changes became necessary, what were the options available, why was an option chosen, and why the changes are not likely to affect the operations in the facility adversely.

Reference 1 cited at the end of this section is not listed at the end of the Chapter. There are no references listed.

11. Section 1A.5.2, Page 1A.5-3 to 1A.5-5. The last paragraph on page 1A.5-3 should be expanded to include the plans for disposal of excavated salt.

Before concluding (last paragraph of this section on page 1A.5-5) that, "Under no circumstances will the public health and safety be subjected to significant risks," this section should provide references to detailed information on the accident scenarios which were analyzed, and potential releases from malfunctioning or inadequate design of shafts and underground facilities. (Also, please note comment one on this Chapter.)

CHAPTER 2

Site Characteristics

In response to many EEG comments on previous versions of SAR, this chapter has been extensively revised and is much improved. A few questions that remain are listed below.

1. Section 2.1.1.2, Pages 2.1-4 through 2.1-5. This section refers to DOE Order 5480.1A which has been superseded by DOE Order 5480.1B. Also, it is noted that the dose limits on page 2.1-5 exceed the limits of the EPA Standard 40 CFR 191.03(b). Under 40 CFR 191.04(a), DOE may establish alternative standards for WIPP provided EPA has approved an application for such alternative. If DOE has made such application, please provide EEG with a copy of the application and EPA approval notice. DOE Order 5480.1B references DOE Order 5480.11 for radiation protection standards, however, this order indicates that the "Requirements for Exposure of Individuals and Population Groups in Uncontrolled Areas" is to be added at a later date. Therefore, if no alternative standard has been approved by EPA, the FSAR should adhere to the exposure standard prescribed in 40 CFR 191.03(b).

2. Section 2.1.2.1, Page 2.1-6. Please update paragraph two of this section since the land exchange of State-owned sections has been completed.

3. Section 2.1.2.1.2, Page 2.1-7. Settlement of potash leases inside the WIPP site should be completed before a permanent decision is made to store waste at WIPP.

4. Section 2.1.2.2, Pages 2.1-8 and 2.1-9. The last paragraph of this section refers to "low level of radioactive releases . . . ." Please include references to the analyses of postulated accidents which support this statement.

5. Section 2.2.3.1. EEG personnel have witnessed very low flying military aircraft directly over the WIPP site, almost on a daily basis during certain periods in summer, 1988. Either such flights should be banned or their potential impact on WIPP should be considered in Section 2.2.9, and evaluated in other Chapters of the FSAR. One crash has occurred already at the WIPP site.

6. Section 2.1.3.4, Page 2.1-14. The reference to "population centers" as defined in 10 CFR 100 is no longer appropriate. Those regulations apply to siting of nuclear reactors, not nuclear waste repositories. A more appropriate reference would be 10 CFR 60 or 40 CFR 191. With respect to exposure to members of the public off-site, it would be preferable to refer to the limits of 40 CFR 191.03(b).

7. Figure 2.1-7. The location of the potash leases of the International Minerals and Chemical Corporation are not shown on this map.

8. Section 2.5.3.5.2, Page 2.5-23 through 2.5-27. This section is very well written, but needs to be updated.

9. Section 2.5.4, Pages 2.5-29 through 2.5-34. This section needs a thorough updating in view of the recent publications by Bredeholft, Nowak, McTigue, Beauheim, etc.

10. Section 2.5.5.1, Page 2.5-37. The last paragraph of this section on page 2.5-37 refers the reader to Chapter 8, but the new Chapter 8 of FSAR is devoid of any technical evaluations.

11. Section 2.5.6, Page 2.5-46. The first sentence on page 2.5-46 is incorrect. In a karst region, such as the WIPP area, lack of a near-surface regional water table does not preclude a significant quantity of recharge. The fact is that in spite of several suggestions by EEG over the past five years, the WIPP Project Office has chosen not to perform systematic studies to determine the rate of recharge at and in the vicinity of the WIPP site. It is more correct to say that the information is not available rather than assuming it to be "negligible."

12.. Section 2.5.7.4, Page 2.5-58. In view of the discussion in this and the preceding subsections, it is recommended that Table 2.5-21 not be included in the FSAR. This table and the last paragraph on page 2.5-58 should be replaced by a discussion of the program to determine more reliable values of Kd being performed currently.

CHAPTER 3

Principal Design Criteria

1. Section 3.1, Page 3.1-1. This section refers to experiments and studies to understand the behavior of waste in salt. Please add the reference to reports or chapters in the FSAR where these experiments are described.

2. Section 3.1.1, Page 3.1-2. Experimental (high-level) waste as one of the types of waste to be emplaced should be deleted.

3. Section 3.1.1.1.1, Page 3.1-3. This section should clearly indicate that the boxes described in Table 3.1-2 are not compatible with TRUPACT-II. Therefore, there should be an indication of how these boxes will be transported, i.e., whether they will be repackaged into a TRUPACT-II compatible box, or whether another type B container, certified by NRC will be used. Also, Table 3.1-2, page 2, should be revised to indicate the type of "standard waste container" to be used.

4. Section 3.1.1.1.2, Page 3.1-3. Radionuclide composition of waste for WIPP has been calculated and presented in Table 3.1-4, based on a March 1987 report (Ref. 4). To date, the WIPP office has refused to provide us with this report. In order for EEG to conduct its evaluation, the report must be provided.

5. Section 3.1.1.1.2, Page 3.1-4. This section states that the average Pu-239 equivalent is 7 g for a drum and 110 g for the most common box.

Table 3.1-3 shows 14 g of Pu-239 in drums and 79 g in "standard waste containers." It is recommended that this section, or Table 3.1-3, be revised to reflect consistency and the basis for the values presented.

6. Section 3.1.1.1.4, Page 3.1-5. This section also should indicate that the thermal power will be limited by the PE-Ci limits and the Watt limits of TRUPACT-II. Please also add a reference to the data which reflect the fraction of heat source plutonium to be shipped to WIPP. According to EEG information, the SRP heat source wastes alone comprise about 10% of the total volume and 60% of the total alpha curies that will be coming to WIPP.

7. Section 3.1.1.2, Page 3.1-5. This section is misleading in that it implies a very small fraction of the WIPP waste is RH-TRU. State that RH-TRU waste comprises 36% of the total radioactivity.

8. Section 3.1.1.2.2, Page 3.1-6. The first paragraph of this page contains incorrect reference designations. On line 2, the reference to the current data base probably should be 6 rather than 7. Also, the reference designation in the last line should 8 rather than 9.

9. Section 3.1.1.2.3, Page 3.1-6. This section also designates 9 as reference for surface dose rate limits, and it should designate 8 (the first modification of the C & C Agreement).

10. Section 3.1.2.2, Page 3.1-7. In this section, it would be helpful to state how many TRUPACTS could be stored outside and how many drums inside

(in both surge storage and shielded CH-TRU area) and the basis for the limitation.

11. Section 3.1.3.1, Page 3.1-9. This section states that the RH throughput would be two canisters per shift, which indicates a throughput of 500 canisters per year, which is greater than 250 canisters per year. Which is the maximum?

12. Section 3.1.3.3, Page 3.1-11. In the fourth line from the bottom, the reference designation should be 9 rather than 10. Also, the designation 10 CFR (c)(ii) is incomplete and, therefore, ambiguous. It should designate which subparagraph of (c) is applicable, i.e., (c)(2)(ii) or (c)(6)(ii) or both.

13. Section 3.1.3.3, Page 3.1-12. The reference designation in the first paragraph is in error. Please see previous comment.

14. Section 3.1.3.3, Page 3.1-13. The second paragraph on this page describes movable shielding in the floor hatch which mates with the bottom of the facility cask to allow access to the cask loading room while the cask is being loaded. Is there a control or alarm provided to preclude access when the shield is not in place? If so, this should be described here.

15. Section 3.1.6.2, Page 3.1-16. This section indicates radioactive waste generated on-site will be disposed at WIPP. Compliance with the EPA disposal standards must be completed before any wastes can be disposed at

WIPP. Please provide the design for solidification of liquid wastes at WIPP. EEG has not received any information on this.

16. Section 3.1.7.1.1, Pages 3.1-17 to 3.1-18. The first paragraph defines the Design Class I items and relates these items to a "basic component" as defined in 10 CFR 21.3 (a) (2) as follows:

"'Basic Component,' when applied to other facilities (than nuclear power reactors) and when applied to other activities licensed pursuant to Parts 30, 40, 50, 60, 61, 70, 71, or 72 of this chapter, means a component, system or part thereof . . . in which a defect . . . could create a substantial safety hazard . . . ." "A 'substantial safety hazard' means a loss of safety function to the extent that there is a major reduction in the degree of protection provided to public health and safety for any facility licensed . . . pursuant to Parts 30, 40, 50, 60, 61, 70, 71, or 72 of this chapter."

The only one of the listed parts of Title 10 which would have provisions somewhat comparable to the WIPP facility would be Part 60, "Disposal of High Level Radioactive Wastes in Geologic Repositories." In that Part, Section 60.1 defines "important to safety" as follows:

"'Important to safety,' with respect to structures, systems, and components means those engineered structures, systems, and components essential to the prevention or mitigation of an accident that could result in a radiation dose to the whole body, or any organ, of 0.5 rem or greater at or beyond the nearest boundary of the unrestricted area at any time until the completion or permanent closure."

Therefore, the definition of Class I in this paragraph of the draft FSAR is not consistent with "a basic component" as defined in 10 CFR 21. As EEG has previously maintained, the Class I definition should be amended so that it is consistent, and so that it will not appear that the design criteria for WIPP provides less protection than that which will be imposed on DOE for high-level waste repository. Perhaps the reason that the WPO has resisted this change is because there would then exist some Class I items at WIPP, just as there are likely to be some Class I items at a high-level geological waste repository. If not, then there should be no reason for not making the two definitions identical.

17. Section 3.1.7.1.1, Page 3.1-18. The third paragraph on this page states that "each WIPP item was evaluated against the design classification criteria." It is presumed that such evaluations are documented, however, no reference is cited to this documentation. Please provide this reference in order that EEG and others may obtain copies.

18. Section 3.1.7.3, Page 3.1-21. This section lists several design factors which provide a basis for the design class. Among these is included the phrase "importance to safety," which is not defined. If this phrase also has the same meaning as in 10 CFR 60.1, it further substantiates the need to modify the Class I definition as discussed in comment 11 above. In any case, this phrase should be defined and if it is not the same as in the NRC regulations for high-level waste repositories, the EEG would like to know the rationale for the difference.

19. Section 3.1.7.5.1, Page 3.1-22. The cited reference 13 in this section should be changed to 11.

20. Section 3.1.7.5.2, Page 3.1-22. The cited references in this section are also in error.

21. Table 3.1-3, Page 3.1-27. This table has two errors, as follows:

  a. Th-282 should be Th-232,
  b. The activity for Pu-238 should be 1.0E+01

22. Table 3.1-3, Page 3.1-28. This table also has two errors, as follows:

  a. The Ci/container of Pu-239 should be 4.9 E+00,
  b. The total activity should be 83.

23. Table 3.1-5, Page 3.1-30. If the average canister contains 1000 curies, then the first modification to the C & C Agreement (which limits total curies in RH-TRU to 5.1 million) will limit the number of canisters to 5100 and to 162,000 cubic feet of waste, rather than 250,000 as stated in Section 3.1.1.2.3. It is also noted that the WIPP Final Environmental Impact Statement (FEIS) shows 510 Ci/canister, 170 Ci of Cs-137, 160 Ci BA-137m, and 145 Ci of Pu-241.

24. Section 3.3.1.1, Page 3.3-1. The last sentence on this page is misleading. A significant fraction of the WIPP waste may be mobile since

the Waste Acceptance Criteria (WAC) allow one percent of the particulates to be less than 10 microns in particle size.

25. Section 3.3.3, Page 3.3-17. Paragraph (1) of this section indicates some "minor exceptions" to the general rule that "all buildings and their support structures are protected by fixed, fire suppression systems . . . ." Please add to this paragraph some examples of such exceptions. Of particular interest is whether any fixed permanent structures lack such fire suppression systems.

26. Section 3.3.4, Page 3.3-19. This section discusses radiological protection design considerations. In the second paragraph, it states that the plant is designed so that under normal operating conditions, "the radiation exposure to the general public is negligible as compared to the natural background radiation." It then references section 6.1.6.4. This reference section does not clarify the meaning of "negligible," but instead merely discusses the effluent and environmental monitoring program. For the FSAR, it is necessary that the criteria forming the basis for the "negligible" conclusion be clearly stated, and that this section should reference the relationship between potential doses to the public and the design criteria. These criteria and relationship are clarified for occupational exposure, but not for the general public.

CHAPTER 4

Plant Design

1. This chapter contains many improvements and a considerable amount of additional important information. With only a few exceptions, the information also was well presented. The few exceptions concerned some of the figures which were not always legible in their newly condensed form.

2. Section 4.2.1.5, Page 4.2-15. The last paragraph of this section states the liquid waste produced at WIPP will be solidified prior to disposal at WIPP. Additional details should be added here on the plans, designs, method of processing, and radiation protection procedures, since it could be a factor in evaluating radiation safety.

3. Section 4.2.2.3, Page 4.2-19. The first paragraph erroneously refers to Figure 4.2-7 for the air intake shaft headframe. It should reference Figure 4.2-6.

4. Section 4.2.5, Page 4.2-20. This section refers to Figure 4.2-10 for a display of the pumphouse and contents. Figure 4.2-10 is a pictorial of the east and south elevations of the Support Building. There is no figure in the 4.2 series which displays the pumphouse.

5. Section 4.2.2.6, Page 4.2-20. The first paragraph refers to Figures 4.2-12 through 4.2-15. The correct references are Figures 4.2-7 through 4.2-10. There are no Figures 4.2-12 through 4.2-15.

6. Figure 4.2-4, Page 4.2-30. This figure is an unacceptable representation of the configuration and operation of the EFB for the following reasons:

a. The effluent monitoring station locations are improperly identified. The reduction in size and extension of the duct at Station B is not represented. Station A is now to be down the exhaust shaft, not after the bend as shown.

b. The normal operating position of the dampers of the EFB is improperly identified, e.g., the EFB isolation dampers should be normally "closed" not "open," to allow normal discharge to occur by the new main fans (which, incidentally, are not identified in the figure).

7. Section 4.3.2.1, Page 4.3-10. This section describes the subsurface facilities and refers to Figure 4.3-5. This figure does not indicate the location of the area for plug-in battery charging. The plug-in area should be indicated since it is a location of potential fires or explosion should ventilation be inadequate.

8. Section 4.3.2.1.2, Page 4.3-9. This section states that vapor from diesel fuel constitutes the principal risk of an underground explosion. Other areas warranting consideration are those for vehicle battery charging as discussed in Section 4.3.2.1, and the waste storage area when filled with waste. The latter deserves consideration unless the emplaced waste will be covered with backfill following emplacement. Audits of the

WIPP Waste Acceptance Criteria do not verify absence of pyrophoric wastes or those materials which tend to produce explosive gas mixtures.

9. Section 4.3.2.2, Page 4.3-14. Please provide a reference to the procedure to be used for retrieval of contaminated and uncontaminated waste packages. Such procedures are essential to an adequate radiation safety analysis.

10. Section 4.3.2.3, page 4.3-14. In the last paragraph on this page, there is a discussion of the dose rate from emplaced RH-TRU. It is stated that the maximum loaded canister would be 100 rem/hr. This is not correct. Pursuant to Modification 1 of the DOE/State Consultation and Cooperation Agreement, up to 5% of the RH-TRU canisters may have a surface dose of 1000 rem/hr. Also, please provide the reference or more detail in the last paragraph on this page on the calculation that concludes the highest radiation dose rate around the shield plug will be only 3 mrem/hr.

11. Section 4.4.1.2.1.2, Page 4.4-13. The first line on this page indicates that "if excessive airborne contamination is detected at the air intakes, the outside air supply is directed through HEPA filters." It is not clear in Figure 4.4-7 (the Legend page is not legible) if a separate CAM is provided for the intake, or will the air be monitored elsewhere? Please clarify.

12. Section 4.4.1.3, Page 4.4-16, third paragraph. This paragraph indicates that "a small quantity of air is drawn down the waste

shaft . . . ." What is meant by "a small quantity"? Has an analysis been performed of the potential radiological health consequences of an airborne release incident in the WHB which results in contaminants being drawn down the waste shaft and exposing workers below?

13. Section 4.4.3.1.2.3, Page 4.4-34. Please provide a reference to figures which display the location and other details of the "separate exhaust system" provided for venting hydrogen from the battery-charging process.

14. Section 4.4.3.1.6, Page 4.4-37. Please include a reference to the report of the study done to evaluate public fire fighting capability and level of mutual aid response in case of a fire emergency at WIPP.

15. Section 4.4.3.2, Page 4.4-37. This section refers to Table 4.4-10 which provides a considerable amount of new and helpful information on the fire suppression equipment throughout the plant.

16. Section 4.4.4.1, Page 4.4-47. The first paragraph of this page refers to Figure 4.2-10 for a schematic of the pumphouse. As indicated in comment 4 above, this is an incorrect reference. There is no figure showing the pumphouse.

17. Section 4.4.6, Page 4.4-51. The second paragraph of this section refers to Section 5.4 for details on process operations, however, Section 5.4 fails to provide details on the solidification process for liquid waste. As previously stated, information on this solidification process

is necessary for an adequate safety evaluation. The Failure and Affects Analysis (Table 4.4-13) does not consider this subject. Furthermore, such processing should be clearly defined prior to the receipt of WIPP wastes.

18. Section 4.4.10.4, Page 4.4-74. This section describes the breathing air supplies available for fire fighting and normal WIPP operations. More detail should be added on the equipment and procedures used for producing the Class D breathing air for SCBA cylinders. Information also is needed on the inventory of SCBA tanks. No breathing air compressor systems are indicated.

19. Section 4.5.2.5, Page 4.5-6. This section describes the canister shuttle car used to transfer waste canisters from the port in the floor of the hot cell to the floor of the cask loading room. Please add a scale drawing of the shuttle car.

20. Section 4.6.5, Page 4.6-2. More detail is needed on the criteria to be used to determine when reinforced canopies will be used to protect operators of mobile mining equipment.

CHAPTER 5

Process Description

1. Page 5.1-1. If DOE decides to ship waste by rail to WIPP, EEG requests six months prior notification in order to address education of the public and rail workers to potential doses and problems.

2. Section 5.1, Page 5.1-1. Following the sentence, "The shipping containers are DOT Type B containers certified by the NRC," please add the sentence "These containers are designed for shipments exceeding 20 curies of plutonium and are, therefore, doubly contained."

3. Table 5.1-3, Accidents 15 and 16. The stated consequences are not consistent with the information provided in Chapter 7, and the consequences as stated for Accident 18. How can an accident be bounded by another accident which is not considered credible, and therefore the consequences were not analyzed?

4. Section 5.2.1.2, Page 5.2-3. The second paragraph on this page should contain a reference to the Standard Operating Procedure to be used for this and subsequent operations. These procedures are necessary for an adequate safety analysis.

5. Section 5.5.2, Page 5.5-2. The first paragraph of this section refers to DOE Order 5480.1A, Chapter V, but references DOE Order 5480.1B, Chapter XI. Please clarify. Since DOE 5480.1B superseded 5480.1A, references to 5480.1A should be deleted.

CHAPTER 6

Environmental Safety and Health Protection

1. In general, Chapter 6 appeared to have been prepared hastily. There were few improvements, and there was no evidence of response to EEG's December, 1986 comments on Amendment 9 of the SAR. The Bibliography for Chapter 6 was poorly done, containing several duplications and inaccuracies.

2. Section 6.1.1.1, Page 6.1-1. Credit is taken for periodic ALARA reviews of design documents by nuclear and health physics specialists from the architect-engineer organization. EEG has not received any of their reports, analyses or recommendations. Please provide this information.

3. Section 6.1.1.3, Page 6.1-3. This section refers to the WIPP Radiation Safety Manual (WP 12-5) as the basis for the WIPP ALARA programs. EEG agrees that this manual will impact substantially on the radiation safety aspects of WIPP, and we recently transmitted comments and recommendations for the improvement of the policies, procedures and criteria contained in that manual. We are pleased that most of our recommendations were adopted in the July 1988 revision of the manual.

   The SAR states that the WIPP ALARA program is described in Section 2.0 of the WIPP Radiation Safety Manual (WP 12-5). Section 2.0 of that document contains only generalized responsibilities of management, personnel and radiation workers. Hence, the SAR does not adequately describe the WIPP ALARA Program as claimed and should do so.

4. Section 6.1.2.1.1, Page 6.1-4. Please add a table in support of this section to show the estimated number of 55 gallon drums of waste and the number of each type of boxed waste to be shipped to WIPP.

5. Section 6.1.2.1.2, Page 6.1-5. This section refers to Table 6.1-2 for the design basis gamma source strengths for RH-TRU waste, however, this table provides only average source strengths. The description should include the maximum source strengths of 1000 rem/hr.

6. Section 6.1.2.1, Pages 6.1-4, 5. The CH-TRU and RH-TRU gamma source strengths presented in Tables 6.1-1 and 6.1-2 are not derived from the current radionuclide content of RH-TRU waste presented in Table 3.1-5. The Mev/s-canister total in Table 6.1-2 should be less than one-quarter of the value given, and the peak energy group area should be in 0.4-0.8 Mev, not 0.8-1.3 Mev and 1.3-1.7 Mev. While the values used probably give conservative results for shielding and external dose considerations, it would be desirable to directly determine the gamma spectrum on representative drums. An assumption that external radiation does not contain significant quantities of low energy radiation can lead to the selection of instruments or TLD badges that fail to detect the radiation present.

The comment was made that the allowed neutron dose rate is much smaller than the allowed gamma dose rate. A table similar to Table 6.1-1 should be provided for neutron energy group and surface flux.

7. <u>Section 6.1.2.2, Pages 6.1-6 through 6.1-9</u>. The procedure used to estimate resuspended radionuclide concentrations, quantities of radionuclides inhaled, and the resulting radiation doses from handling undamaged, surface contaminated containers is difficult to follow. We also question some of the assumptions and are unable to arrive at similar conclusions. Also, the reference to the August 19, 1981 version of DOE 5480.1B may not be appropriate in view of the 1988 draft version of 5480.11, if it has been approved.

The surface contamination concentrations given in Table 6.1-4 are only about 52% of the WAC limits for both drums and boxes. This will, of course, impact subsequent calculations. In our comments on this table in Amendment 9, we pointed out that the values were incorrect and were told the table would be completely revised in the FSAR. The numbers are unchanged from Amendment 9.

The expression on Page 6.1-7 used to calculate the concentration in room air is difficult to check because we are not given the volume of the room used. Using only the volume of the inventory and preparation area (that was scaled from Figures 4.2-1 and 4.2-3) of 1.80 x 10^{10} cm^3, we arrive at total alpha concentrations of about 1 x 10^{-13} $\mu Ci/cm^3$, about 0.2 of those in Table 6.1-3. Also, the concentrations in Table 6.1-3 are mislabeled; it should be $\mu Ci/cm^3$ (not mCi). Furthermore, the MPC fraction assumes the radionuclides are insoluble form. If they are soluble, the combined MPC would be about 0.17.

However, either concentration results in doses received by the work force that are somewhat greater than the values shown in Table 6.1-10. The concentrations in Table 6.1-3 lead to an annual dose to a worker in the Waste Handling Building (with 2400 m^3/y inhalation) of 0.43 to 0.54 rem, depending on solubility assumptions. Yet in Table 6.1-10, it is stated that the total dose from air contaminants to the 16 waste handlers and 7 radiation control workers in the Waste Handling Building is 0.22 person-rem. Even with an occupancy factor of 50% for these workers, there should be a dose of at least 5 person-rem. And if 100% of the WAC contamination limit had been used in Table 6.1-4, the dose would have been at least 10 person-rem. Is it intended that the doses be average individual doses? (Note our comment on Table 1A.2-1.)

Furthermore, it is questionable if use of a "resuspension fraction" to calculate airborne concentrations is the most appropriate approach. Other concepts such as the "resuspension factor" (units of Ci/m^3 per Ci/m^2) or "resuspension rate" (units of Ci/sec) have a larger data base and usage. Your reference (Sutter) gives data for these other concepts. Also, it is probable that most exposure will occur to workers near the contaminated drum, rather than other parts of the Waste Handling Building where the aerosol concentration is much more dilute. If a "resuspension factor" of 10^{-6}/m is used (commonly accepted value for PuO_2 resuspension in the work place, from page 83 Jones and Pond in "Surface Contamination," Pergamon Press, 1964), one calculates that one person-year in proximity to containers would lead to a 50-year effective dose commitment of 6 rem.

In summary, we believe that the assumptions and methodology used in calculating airborne concentrations are questionable, that the calculated doses presented are much lower than they should be for the assumptions used, and that worker exposure to airborne contaminants is probably a much greater fraction of potential occupational exposure than is concluded in Chapter 6. This entire calculation should be carefully reviewed.

8. Section 6.1.3.1.1, Page 6.1-9. Credit is taken for minimizing personnel radiation exposures by limiting access in the plant. Reference and document this claim.

9. Section 6.1.3.2.2, Page 6.1-13. This section discusses use of Respiratory Protective Equipment. The section does not provide any detailed information on the SCBA equipment to be used. There have been several recent improvements in the design of such equipment, and the WIPP should use these improved design criteria. For example, in none of the WIPP documents is there an indication that SCBA equipment to be used will be positive pressure demand type, equipment which will maintain a positive pressure in the face mask (even during high breathing rates), and provide fresh air on demand. It is only recently that the value of such positive pressure equipment has been demonstrated. (Some WIPP documents have referred to Pressure demand SCBA's but this could be a reference to the Negative-pressure respirators, which only provide air on demand.

10. Section 6.1.3.3, and Table 6.1-7. This section refers to Table 6.1-7 which indicates design contamination zones. Based on this Table, the CH waste handling area is a Contamination Zone B which has a maximum contamination of 50 pCi/100 cm^2 loose alpha, contamination which would be equal to the WAC contamination limits. It may be difficult, therefore, to detect contamination at or in excess of the WAC limits if the room in which the package is located has contamination levels equal to those limits. Also, it is noted that the Radiation Safety Manual (July 1988) calls Contamination Zones I, II, III, with Zone I having limits of 20-100 dpm/100 cm^2 (9-45 pCi/100 cm^2) removable alpha contamination. The SAR terminology should be identical to the RSM and we recommend that the Zone I limits apply to the CH waste handling area.

11. Section 6.1.3.4.2.1, Page 6.1-16. What is the "derived average source strength," and how was respiratory protection considered in the result (i.e., how was the NRC manual on respiratory protection used)? This should be clarified in the FSAR.

The use of special shielding in separate enclosed area should be based on 1 rem annual dose or 100 mrem/h contact dose rate and ALARA considerations. For example, an ALARA evaluation might consider worker dose resulting from installation of temporary shielding as compared to worker dose from moving drums to a specified location. Other ALARA considerations might be potential contamination problems, existing radioactive inventories in shielded areas, or worker activity in controlled areas. In other words, the criteria is too simplistic and could result in a greater dose to workers rather than less.

12. <u>Section 6.1.3.4.2.4, Page 6.1-19 to 6.1-21</u>. This section fails to provide information on the basis for the underground shielding for RH-TRU canisters. For example, in calculating the shielding provided for emplaced canisters, was consideration given to those canisters which may have dose rates up to 1000 rem/hr? Information should be added to the FSAR to indicate the criteria used for shielding of emplaced canisters.

13. <u>Section 6.1.3.5, Page 6.1-21</u>. "The design and operation of ventilation systems assure that doses to personnel and the general public . . . are below limits specified in the appropriate regulatory guidance." Please include the data used, an illustration of the methods and the assumptions used for calculations, and results.

14. <u>Section 6.1.3.5.1, Page 6.1-22</u>. Please provide more detailed information or data to support the ALARA assumptions of this section.

15. <u>Section 6.1.3.6, Page 6.1-26</u>. This section refers to Figure 6.1-13 which consists of 11 sheets, none of which is legible. Please provide legible copies.

16. <u>Section 6.1.3.6, Page 6.1-26</u>. The Continuous Air Monitor (CAM) description here no longer correctly describes the CAMs (now alpha CAMs). What is needed is a figure and detailed description which fully explains the marriage of the NRC and Eberline equipment added later. A proper description of all these instruments would involve a statement - really a commitment - to a certain DAC-hr response capability in a specified

radon/thoron daughter background. A step in this direction is provided later for the Pu CAMs, but it still is flawed. There should be an estimation of performance of the alpha and beta CAMs in above-ground applications, and another in the salt dust-laden below-ground applications. It is likely that the beta-gamma CAMs as engineered will not be adequate in either case. The Pu CAMs may be adequate in the above-ground applications. It is difficult to know how the area Radiation Monitors should be required to be specified, except in terms of the ability to detect a gamma field producing a given exposure rate at 1 meter from a remote position typical of the installation.

17. Section 6.1.3.6.2, Page 6.1-28. Reference to the "posting requirements" of 5480.1B is not an adequate way to reference CAM performance requirements. Continued reference to "alpha equivalent" detectors is probably incorrect. If not, this needs some clarification.

The concept of airborne radioactivity monitoring is simplistic and not in accordance with the intent of DOE Order 5480.11. As an example, NUREG/CR-4033 and NRC Regulatory Guide 8.21 suggest that air samples should be collected that are representative of the air in the worker's breathing zone. Sampling of radioactivity shall be in areas known to be of a greater concentration than that of the worker's breathing zone. This section should be revised to reflect this fundamental concept.

18. Section 6.1.3.6.2, Page 6.1-29. On what basis is an alarm setting at 10 MPC-hrs an acceptable performance standard for CAMs? It should not be larger than 4 MPC-hrs (as is stated later in the chapter). The

underground CAMs might have a severe problem meeting 4 MPC-hrs in a reasonable radon/thoron background and outfitted with a long transport line. The FSAR should specify exactly (based on appropriate tests) what MPC-hr performance can be expected from both types of CAMs, in both types of settings.

References to the CAMs "operating" in "expected" environmental conditions hardly seems a satisfactory specification, particularly with reference to background suppression, for both alpha and beta-gamma CAMs. Furthermore, if the internal aerosol transport system of the CAM heads has not been changed to match TAMU design specifications, then from an aerosol sampling perspective the CAMs in the WHB and below ground are substandard, and would not be expected to meet reasonable response standards under accident conditions.

"Calibration" of the CAMs with plated sources, as stated here, can really only provide an indication that detector response continues to be the same as before. With an MCA-based count collection and analysis system and microprocessor based algorithm for background suppression, a more exacting calibration should be done, and explained here. The periodic demonstration of the proper functioning of such a sophisticated system will require careful development.

19. <u>Section 6.1.3.6.3</u>. The SAR states that no credible criticality hazard exists. References please.

20. Section 6.1.4, Page 6.1-30. More current data for the waste forms for WIPP may be found in revision 3 of reference 22.

21. Section 6.1.4.1, Page 6.1-30. The design objective should be less than 1 rem/year/person and ALARA.

22. Section 6.1.4.2, Page 6.1-31 and Table 6.1-8. The external doses calculated for routine operations use the February 1985 report, WTSD-TME-009, as a basis for calculating external doses received by workers. This report uses older inventory data and time-motion study based on TRUPACT-I and drums being packaged as six-packs. The WPO has a July 1988 report, DOE/WIPP 88-012, which uses actual time and motion data obtained in a June 1988 Preoperational Checkout that was specific to TRUPACT-II and used the latest inventory data. The later report estimates annual external radiation doses from CH-TRU of 13.7 person-rem for normal operation and 0.64 person-rem for "off-normal" waste handling, compared to 9.19 and 0.132 person-rem in Chapter 6. Although EEG has not critically reviewed DOE/WIPP 88-012, the methodology is more specific, contains real data, and uses newer inventories. We believe it should be used in place of WTSD-TME-009.

23. Section 6.1.4.3.2, Pages 6.1-33, 6.1-34. The whole analysis of the handling of damaged drums seems to presuppose that the workers instantly recognize that drums or boxes are damaged before they could possibly be exposed, and don respirators. The experiences recently at the SWEPP facility at INEL involving a damaged drum show otherwise. Two people were exposed apparently before anyone donned respirators. Thus, it is

likely that there will be some delay in discovery of damage unless TRUPACT itself was visibly damaged.

There are several additional questions or observations on this scenario:

a. The origin of the number 66 for contaminated seven-packs is not clear. From Table 6.1-15 one would expect 34,000/7 = 4860 seven-packs/year and 1% of this would be 49 seven-packs.

b. From the information given here, the estimate of 1.0 mrem/hr seems low. A 6 mrem/hr dose rate at 4 inches would be about 1.2 mrem/hr at 2 feet, and an exposure to two drums would be about 2.4 mrem/hr during hands-on operations. Furthermore, DOE/WIPP 88-012 uses average surface dose rates of 14 mrem/hr for drums and 5 mrem/hr for boxes.

c. The fraction of the waste assumed to be aerosolized and respirable (FA&R) is 10^{-5}. If it is intended that this fraction apply to all drums in the seven-pack, then the FA&R is equivalent to 7×10^{-5} of one drum. In contrast, the accident scenarios in Chapter 7 have FA&R values for one drum of 1.25×10^{-5} (C2) and 2.23×10^{-5} (C3). Is this consistent? Should an average overpacking and decontamination operation release as high or higher FA&R as the accidents?

d. We believe the assumption of 10^{-5} release of one average drum's contents is sufficiently conservative. But this is not a negligible release and it is not clear how this could lead to a dose as low as 0.04 person-rem. Consider the following:

(1) amount released from an average drum (11.9 PE-Ci) would be 1.19 $\times 10^{-4}$ PE-Ci;

(2) this would be released in 6 volumes of Overpack and Decontamination Room air, or 1.98 $\times 10^{-5}$ PE-Ci/volume;

(3) the volume of air (from Figures 4.2-2 and 4.2-3) seems to be about 130,000 ft^3 (3.6 $\times 10^9$ cc);

(4) thus the apparent concentration in air is 5.5 $\times 10^{-15}$ PE-Ci/cc;

(5) a worker would inhale about 6.6 $\times 10^{-11}$ PE-Ci/hr (after allowing for a decontamination factor of 10^{-2} from use of respirators);

(6) for 132 person-hours per year this would be an intake of 8.73 $\times 10^{-9}$ PE-Ci/year;

(7) for a 50 year committed effective dose equivalent (CEDE) of 430 rem/µCi, this becomes 3.8 person-rem.

This calculation needs to be carefully rechecked since the results are potentially significant.

e. We checked the doses in Table 6.1-9 for RH-TRU casks decontamination within 5% and believe the assumptions are conservative.

24. Section 6.1.5.2, Page 6.1-37. This section refers to Figure 6.1-13, which should be Figure 6.1-14.

25. Section 6.1.5.4.5, Page 6.1-49. This section refers to "pressure demand self-contaminated breathing apparatus." Please note Comment 4 above. WIPP should use only POSITIVE pressure demand SCBA's.

26. Section 6.1.5.4.4, Page 6.1-50. The last paragraph refers to WIPP 12-006, "Respiratory Protection Equipment," Reference 31. EEG has been unable to locate such a report. It probably should refer to WIPP 12-106, "Respiratory Protection Program."

27. Section 6.1.5.5.1, Page 6.1-51. The first paragraph on this page states that "Radiation contamination survey stations are indicated on Figures 6.1-1 through 6.1-6." There are no survey stations indicated on these figures, except for the underground area (Figure 6.1-5).

28. Section 6.1.5.5.8, Page 6.1-53. What is the criteria for considering clothing contaminated? The level of contamination in anti-contamination clothing is important in minimizing skin dose and as an indicator of contamination problems. The WPO Radiation Safety Manual does not provide for how contaminated anti-contamination clothing will be handled. It should be made clear whether anti-contaminated clothing will be disposable clothing or laundered. Information on the processing of anti-contaminated clothing should be added to the Radiation Safety Manual.

28. Section 6.1.6.1.1, Page 6.1-56 and Table 6.1-13. When using 100% of the WAC surface contamination limit and the other assumptions in this chapter and χ/Q value of 1×10^{-5} s/m^3 at the site boundary, there results a maximum adult dose of 6.2×10^{-7} rem/y from resuspension of surface contamination. Although this is a significant increase from the value presented in Table 6.1-13, it is still a negligible dose.

29. Section 6.1.6.3, Page 6.1-63 through 6.1-65. In our comments on Amendment 9 of the SAR, we noted that Table 6.6-5 (now Table 6.1-13) did not provide data on doses from the several ingestion pathways, nor does it compare these doses with those from pathways which directly involve the plume as claimed on (Page 6.1-66). The WPO response stated that this section is being reevaluated for the FSAR to be consistent with the previous discussion. It appears that with only one minor exception, this section is identical to the previous one, therefore there appears to have been no response to our earlier comment.

30. Section 6.1.6.4.2, Pages 6.1-68 through 6.1-70. This section contained no changes from Amendment 9 of the SAR. Therefore it was totally unresponsive to our previous comments on Amendment 9 as contained in our letter to the WPO of December 16, 1986. It also did not reflect a peer review of the plans for stack monitoring at WIPP held on November 14, 1986, in Santa Fe. The entire discussion of the effluent monitoring probe design and operation here is written with little or no resemblance to the reality of the present stack monitoring system and facility monitoring system, which was to be completely redesigned following extensive EEG review. More specifically:

a. At present it appears that the alpha CAMs in the stack systems have a vastly improved aerosol transport system of TAMU design when compared to the facility monitoring systems built around an Eberline supplied alpha detector apparently replacing the L X-ray detector in an otherwise unmodified NRC CAM head. Neither here nor in the discussion of the other probes is there any mention of aerosol transport capabilities.

b. The shrouded Texas A & M University (TAMU) stack monitoring probe is not designed to be an isokinetic probe as stated here, for example, the flow rate is kept constant, so there is no "sample flow rate controller" associated with the TAMU probes, as stated here. A more nearly correct description is found later in Chapter 6.

c. There is no discussion at all of the expected response time of the effluent monitoring system, whether triggered by a CAM underground, or in the stack. This is a significant omission of an assessment of accidental releases to the environment.

31. Section 6.1.6.4.2, Page 6.1-69. The statement that the sampling period and volume for the FAS are "maximized to provide a reasonable lower limit of detection" is unacceptably vague. There are limits on time and sample rate for each FAS setting set by the conditions of sampling and the choice of filter size, filter medium, etc. It should be stated what the lower limit of detection will be for the major TRU radionuclides from the various FAS locations.

32. Section 6.1.6.4.2, Page 6.1-70. With regard to the response characterization of the beta CAM (11 cpm after 4 hrs at 60 lpm), it is almost certainly true that this level of activity could never be seen after a relatively short sampling period (about 1 hr) in the beta-gamma noise of the radon-thoron background on the filter. As was pointed out in EEG-38, the background sensing GM tube is not sensing the appropriate background for this instrument. Based on the stated sampling rate and

MPC, using the filter activity equation, the implied efficiency of the system at the stated 11 cpm is 34%, which is reasonable for a low-background GM detector counting a Sr-90 standard source. But that is totally inappropriate as a measure of the LLD for the system with an equilibrium load of radon and thoron daughters on the filter. The FSAR should specify the LLD of both the beta-gamma and alpha CAMs under realistic background conditions.

With regard to the alpha CAM response, it is quite adequate to specify an MPC-hr response of 4 MPC-hrs for Pu-239. However, it is totally unacceptable to add the proviso: ". . . when no other radionuclides are present." There is no basis for such a provision in DOE Orders, ANSI Standards, or any other authority that is known to EEG. There will <u>always</u> be background radionuclides present on the filter during monitoring. The FSAR should state the MPC-hr response without qualification.

33. <u>Section 6.1.6.4.3, Page 6.1-74</u>. The summary of the preoperational program in Table 6.1-15 should include data collected by the EEG.

34. <u>Section 6.1.6.4.7, Page 6.1-77</u>. As is evident throughout Chapter 6, there is no response to EEG's comments on Amendment 9 of the SAR. The EEG had recommended that mention be made in this section of the agreement to conduct intercomparison and verification of environmental data with the State of New Mexico as provided in the Consultation and Cooperation Agreement. In response, the WPO committed to "Appropriate words will be included in the FSAR, referring to the arrangement outlined in the

Supplemental Stipulated Agreement through which the State and DOE Environmental Programs are coordinated and through which the State is to provide independent environmental monitoring verification services to DOE."

35. References for Section 6.1, Pages 6.1-79 through 6.1-84. This bibliography contains numerous duplications and inaccuracies. For example, it has five listings of DOE Order 5480.1B, Chapter XI; three listings of WIPP Radiation Safety Manual; it refers to a 1981 version of DOE Order 5480.1B, whereas Chapter 4 refers to a 1986 version. We believe the Chapter 4 listing is correct.

36. Table 6.1-12, Page 6.1-98. We commented on this Table when it was presented in Amendment 9 of the SAR. At that time, we were informed by the WPO that this data was based on the data in Section 3.1 of the SAR, but that new source term data will be used for the FSAR and an example calculation will be provided for clarification as to how the data in Table 6.1-12 was derived. The data in Table 6.1-12 is unchanged from the previous Table, and no example was provided.

37. Section 6.2, Page 6.2-1. The material on non-radiological surveillance programs, relevant to agreements, laws and regulations, is a new addition to the SAR. Its inclusion is desirable. However, the amount of detail is inadequate. Three omissions are noted in the Section.

38. Table 6.2-1, Page 6.2-8 through 6.2-10. The Resource Conservation and Recovery Act is appropriately noted in the Table. However, the extensive

effort and problems concerned with obtaining a RCRA permit for disposal of the hazardous waste component contained in much of the TRU waste is nowhere discussed or evaluated. This is an important effort which is necessary for the FSAR.

39. Table 6.2-2, Page 6.2-11. List the contract establishing EEG in 1978. Same for Table 6.2-3, Page 6.2-14.

40. Table 6.2-3. The Second Modification to the DOE/State Agreement for Consultation and Cooperation was signed August 4, 1987, and should be listed and summarized in this Table.

41. Section 6.3, Page 6.3-1. The last sentence of this Section refers to Figure 6.3-1. This figure was not included in EEG's copy of Chapter 6.

42. Section 6.3.1.1, Page 6.3-2, 6.3-3. This Section should provide greater detail for the various training and indoctrination programs discussed, or each program described should reference the documents which provide greater detail.

43. Section 6.3.3, Page 6.3-5. This Section also should provide more detailed descriptions of the emergency preparedness, or it should reference other sections of the FSAR or other documents where more information is available.

44. Section 6.3.3, Page 6.3-6, 2nd Paragraph. The discussion of emergency medical technicians should indicate the number of EMT's per 100 employees.

45. <u>Section 6.3.4, Page 6.3-7</u>. Please provide appropriate references to the Emergency Preparedness Plan.

CHAPTER 7

Accident Analysis

1. There does not appear to be a "Design Basis Accident" identified in this Chapter. The category "limiting incident" may be considered by the WIPP Project Office to be an acceptable alternative to the DBA (both have an associated probability such that they are credible, but not expected to happen over the life time of the project).

The requirements for identification and discussion of DBAs are set forth in DOE Order 6430.1, Chapter 1. Both internal and external (e.g. earthquake) initiating events must be considered. It is not apparent from the text of this Chapter that a DBA assessment has been performed. It is strongly recommended that such an assessment be performed and summarized in Chapter 7. It should meet the requirements of 6430.1 and the guidelines of related documents such as "A Guide to Radiological Accident Consideration for Siting and Design of DOE Non-reactor Nuclear Facilities," LA-10294-AC, January 1986. The advantage of the DBA assessment is that it provides a perspective for evaluating the significance of the potential mitigators which are presently described as limiting impacts to inconsequential outcomes. Moreover, the DBA assessment would reflect conditions which might enable structures, systems and components to be evaluated with respect to their importance to safety. In a suitable DBA assessment, degraded performance of all mitigators must be considered, and a release of radioactivity described associated with the DBA which causes radiological exposure. This release event must be shown to result in doses which are not in excess of the guideline doses in DOE Order 6430.1, Chapter I, or associated guidance.

Another problem in not performing a rigorous DBA analysis is that all possible failure modes are not systematically considered. The following two scenarios were apparently not considered:

a. The contamination of the underground by releases from several accident scenarios in the CH-TRU portion of the WHB from the ventilation air flow down the Waste Handling Shaft;

b. Any scenario involving contamination of the radiation control area, or carrying contamination off-site by workers, visitors, or equipment. This is perhaps the most likely pathway for radionuclide contamination from the WIPP Site to reach surrounding communities. It has been a problem in various nuclear facilities over the years and considering the difficulty in detecting alpha contamination, is a potential problem at WIPP. There is no indication in the SAR that this threat has been adequately addressed by the WPO.

2. There are significant numerical errors and inconsistencies in this chapter, and serious questions are raised in the comments that follow, concerning the appropriations of the assumptions and methodologies used.

3. Section 7.2.1, Page 7.2-1. All of the significant CH-TRU accidents are considered moderate frequency, which is defined as accidents assumed to occur once a year or up to 25 times during the project lifetime. Yet all these accidents are assumed to occur only with an average drum (apparently 11.9 PE-Ci). We believe that occupational dose commitments

for all of these moderate frequency accidents should be calculated for the drum loading with the maximum PE-Ci level. These doses would be significant. For example, with the proposed 1000 PE-Ci limit (which EEG is objecting to in our letter of June 22, 1988) the 50 year EDE to a worker in the C2 accident would be about 420 rem and 15 rems would be delivered in the first year for W category wastes. If the waste were Y category the 50 year EDE and the 1 year EDE would be about 275 rem and 24 rem. In either case, these are very undesirable doses that are possible and should not be ignored in the Chapter 7 tabulations. Furthermore, the realization that very high occupational doses are possible should affect the choice of PE-Ci limit as well as the operational health physics procedures employed.

4. Page 7-3. Please indicate the basis for the statement that the relative radionuclide abundance per cubic foot is greater for drums than for any of the alternative containers. If this is true, is the probability of release necessarily higher for drums in the various accident contexts given the weight and presence, for example, of heavy, hard wastes in boxes? It is worth pausing to consider that the most spectacular release of TRU has occurred with an accident involving a box and not a drum.

5. Section 7.2.2.1, Page 7.2-2. The second paragraph on this page states that "three" individuals were considered in the analysis. In Section 7.2.2.1.2, second paragraph, "four" individuals were located within a single sector. Also Table 7.3-2 provides dose estimations to a worker, but fails to show the location of the worker. Was the worker also considered to be "outside the facilities?"

6. Table 7.2-1, Page 7.2-9. This table from Chapter 3 also has an error in the Ci/drum of Pu-238. The value should be 1.0E + 01 rather than 1.0E + 02. The PE-Ci should be 11.9 rather than 8. This will affect most other calculations.

7. Section 7.3.1, Page 7.3-1. This is a new scenario necessitated by the changed design for TRUPACT-II which requires unloading outside of the Waste Handling Building. Any release would be to the site and the environment from a ground level release without HEPA filtration. It is important that this scenario be completed and releases and inhalation values calculated.

8. Section 7.3.1, Page 7.3-2 through 7.3-3. This accident assumes that a bundle (7 drums) are dropped from a fork lift. Also it assumes that the drop "causes the lids of the drums to be knocked off and an inner plastic liner to tear." It is also assumed that 25% of "the drum contents (8 PE-Ci) is spilled, and 5% of the total activity is contained in the allowed one weight-percent." Therefore these assumptions imply that the total activity released is

$$(8 \times 7) \times .25 \times .05 = .7 \text{ PE-Ci}$$

If .001 is resuspended this results in 7E - 04 being released, a factor of 7 higher than indicated. Perhaps it was intended to state that the lid of only one drum fell off, releasing 25% of its contents. Regardless, this is an excellent candidate for the above-ground facility DBA if analyzed properly. Unfortunately, the opportunity is not adequately considered. First, it is assumed that all workers who could potentially be exposed in the immediate vicinity of the accident instantaneously leave, so there is no exposure. In effect 100% credit is taken for safety features of the facility and equipment, and for worker training. This is not valid unless the circumstances and consequences of this accident are considered in more detail. The exposure "allowed" is that to a worker located in a remote location (and this cannot be evaluated since Appendix 7B is not complete). Why is it incredible (probability 10^{-6}) that a worker might not instantly leave the accident scene? What if he is injured or stunned by the falling drums? What if he is uncertain about whether or not a release actually happened? What if he is trapped momentarily by the equipment and drums?

Although, the scenario description did not state residency time for the nearby worker it was estimated that it would take about 25 seconds for the "cloud" to travel 20 feet and about 1¼ minutes of breathing to obtain the stated inhalation quantity. The forklift operator, at about 5 feet distance, would get the "cloud" in about 6 seconds and in the next 10 seconds would inhale about 4.5×10^{-8} PE-Ci (7 times that of the worker in a 2 minute residency time). We believe the assumption is non-conservative and that a dose to the forklift operator should be calculated. Incidentally, we note that the 5/86 version of this section used a "cloud" velocity of 5 ft/min, which is only 1/10 of that listed here.

9. Table 7.3-1, Page 7.3-14. This table has several serious errors and inconsistencies. For example, it is noted that the numbers in both 50 year Effective Dose Commitment columns are unchanged from the May 1986

draft FSAR even though there are substantive changes in the PE-Ci values released or inhaled for most scenarios. As an illustration, the 6.5 x 10^{-9} PE-Ci inhaled in the C2 accident (using 520 rem/uCi inhaled) the 50 year Effective Whole Body Dose would be 3.4 rem. If this is further corrected by using the correct 11.9 PE-Ci average per drum (rather than 8.0) the dose would be 5.0 rem. Also, the 50 year EBD for R4 is not consistent with that for C3.

10. Table 7.3-2, Page 7.3-15. This table has errors similar to those in Table 7.3-1. Although the intake for the scenarios is significantly different in the 1986 draft, the doses in the Table have not been changed. Accident C3 uses the C2 model to relate resuspended radioactivity to inhaled radioactivity. With 1.8 times the resuspended activity the amount inhaled would be 1.2 x 10^{-8} PE-Ci. This would result in an occupational dose of 6.1 rem in Table 7.3-2. With the use of an 11.9 PE-Ci per drum the dose would be 9.0 rem.

In scenario C4 the calculations check although its not clear why 15 seconds inhalation time was used when the cloud volume would pass a point in slightly over 2 seconds. The occupational dose commitment in Table 7.3-2 would be 3.2 rem with an 8.0 PE-Ci drum and 4.8 rem with an 11.9 PE-Ci drum.

When the C6 scenario is modeled as the C4 scenario the worker would inhale 1.1 x 10^{-8} PE-Ci and the dose would be 5.6 rem for an 8.0 PE-Ci drum and 8.4 rem for an 11.9 PE-Ci drum.

There are two separate observations on the R4 scenario. One is that if the maximum canister had 1000 PE-Ci of TRU with the same relative composition shown in Table 3.1-5 there would be 17.3 Ci/l of TRU only. Thus it would not be possible to have the 17.1 Ci/l of fission and activation products in the same canister and remain under the 23 Ci/l maximum concentration permitted by agreement with the State of New Mexico. See also the preceding comment on Table 7.3-1, which relates to the R4 scenario.

11. Section 7.3.2, Page 7.3-7, Accident C7. The first paragraph of this section refers to DOE-AL Order 5484.1A. There is no such reference in Chapter 7. The only DOE Order referred to is DOE-AL Order 5481.1B, on Page 7.1-2. Perhaps this is the Order intended here. See also a reference to DOE-AL Order 5481.1A in the first paragraph on Page 7.3-8. As discussed in Comment 1 above, EEG does not agree that this accident fulfills the DBA assessment requirements of DOE Order 6430.1.

12. Section 7.3.2, Page 7.3-8, Accident C9. The requirements for diesel vehicle safety were upgraded years ago following discussions with EEG, so that this scenario could be considered incredible. Please provide the procedures to be used to insure that these upgraded requirements are followed throughout the lifetime of the project.

13. Section 7.3.2, Page 7.3-9, Accident C10. This accident has some conservative assumptions, however, the last sentence in this description assumes that no worker is located downstream of the fire. This does not seem to be conservative. What is the basis for such an assumption? Note

that Accident C4 assumes that a worker is downstream when the accident occurs. A new employee or a worker excited in the presence of smoke could conceivably violate established policy and be located downstream from the fire. Also, is there available experimental evidence to support such a large depletion in a mine environment? Reference 4 does not provide such evidence.

This accident becomes the limiting scenario for off-site releases. It is noted that the postulated release from a 1000 PE-Ci drum is calculated to deliver a 50 year effective dose commitment of 1.4 rem. This intake would also result in a one year dose of 0.51 rem if the release is in soluble form or 0.67 rem if it is insoluble. Thus the WIPP system components pertinent to this scenario would be classified as "important to safety" if this were a commercial repository to which 10 CFR 60 applied. Important to safety items require special quality assurance procedures which are not presently required of WIPP items.

Also, while the choice of a 1000 PE-Ci drum in this scenario is very conservative, the χ/Q value used is not. If maximum possible χ/Q values were used along with appropriate effective stack height correction factors one could calculate a dose greater than 0.5 rem from a 30 PE-Ci drum. So, such doses are clearly possible.

14. Section 7.3.2, Page 7.3-11, Accident R4. There appears to be a slight error in the calculated fission and activation products released for this accident. The result should be 7.8×10^{-9} Ci.

CHAPTER 8

Long Term Waste Isolation Assessment

The Long-Term Waste Isolation Assessment in Chapter 8, Amendment 9, contained 159 pages of text, figures, and tables. EEG was in basic agreement with the format presented in Amendment 9, although we responded with over 10 pages of questions and comments on details of the assessment. Now, in the Draft FSAR, all of these scenarios and evaluations are omitted and replaced with 9 pages of general discussion on how performance assessment will be conducted.

The deletion of the analyses presented in Amendment 9 and failure to provide consequence analyses is unacceptable to EEG. We understand that DOE is not prepared to do the Performance Assessment now and have never considered Chapter 8 to be the Performance Assessment. However, the SAR is supposed to analyze the ability of the project to be operated safely in all areas including long-term waste isolation. How can EEG and others reviewing the SAR conclude that the facility is adequate for long-term waste isolation when the SAR is completely silent on this?

The inclusion of the compliance strategy in Chapter 8 along with the long-term waste isolation assessment is desirable. However, the strategy presented is very brief and largely avoids mentioning specific dates or other details. This compliance schedule should be included in the FSAR. Also, on page 8.1-2, the last sentence refers to "data collection and development during the Pilot

Plant Phase will be required to complete the predictive models being used for the long-term performance assessment." Please describe in more detail the data and predictive models referred to. Other comments on specific sections of this Chapter are provided below.

1. Section 8.1.1, Page 8.1-3. As stated on Page 14 of DOE-WIPP 86-013, the Compliance Strategy will include Sensitivity AND UNCERTAINTY (emphasis added) analysis. The third item on this page failed to include the uncertainty aspect of the analysis. It is particularly important that the DOE analyze the parameter uncertainties, i.e., uncertainties about the numerical values in or resulting from data, and uncertainties in the conceptual model and its mathematical representation.

2. Section 8.1.1, Page 8.1-3. This section indicates that the final set of scenarios to be modeled for inclusion in the CCDF will be chosen from 73 scenarios examined during the PA. Because of lack of data on probabilities from actual experience, we urge that the DOE have a Peer Review of the scenarios and utilize the recommendations resulting from such review for the selection of the final set. EEG should participate in such Peer Review. Although the last paragraph on Page 8.1-7 indicates that a Peer Review Panel will evaluate the PA, there is no indication of the timing of such review or of what aspects will be reviewed by the Panel.

3. Section 8.1.1, Page 8.1-3. The last bullet on this page concerning human intrusion modeling should include Castile brine reservoirs. (See EEG reports EEG-11 and EEG-15.)

4. Section 8.1.3, Pages 8.1-4 to 8.1-6. This section completely ignores human intrusion scenarios that result in waste being brought to the surface (which is also the accessible environment). This is likely to be the most serious single pathway.

5. Section 8.1.6, Page 8.1-7. The last paragraph of this section states that "a Peer Review Panel will provide assurance to the DOE/WPO that the performance assessment is well conceived and being carried out with professional competence, and so that scientists and state officials can be assured that DOE's ultimate conclusions as to the suitability of WIPP as a repository are credible." In the past, the DOE/WPO has refused to include the State Environmental Evaluation Group (EEG) as a participant or observer of such Peer Review Panels. Until EEG is routinely included, and given reasonable advance notice of such reviews, with agenda and background information on proposals, the ultimate conclusions are not likely to be considered credible by state officials, nor by other scientists having no organizational ties to DOE. If the DOE/WPO plans to establish a new policy with respect to these Peer Review Panels, such that they will include full participation by EEG, it should be indicated in this section.

CHAPTER 9

Conduct of Operations

1. Section 9.2, Page 9.2-1. The first paragraph indicates that "formal test procedures are prepared for complex and critical systems as discussed in the Operations Program Plan." The FSAR should list those complex and critical systems, and should provide more detail on the test procedures.

2. Sections 9.2.1 through 9.2.2, Pages 9.2-1, 9.2-2. These sections should provide more detail on the acceptance testing programs. To what extent are equipment and systems tested at the factory? What fraction are found to be defective? What fraction of systems checked at the WIPP Site are found to be defective? Where are such testing records maintained? What documents contain the testing procedures? What documents contain the procedures for handling nonconformance? This type of additional detail should be provided or this section should reference where such detail is documented.

3. Section 9.3, Page 9.3-3. The first paragraph on page 9.3-3 refers incorrectly to "regulations numbered 48, 49, and 74 in 30 CFR 57 . . . ." The correct reference should be to "parts 48, 49, 57, and 74 in Title 30 of the CFR," however, Part 74 is applicable to coal mines only.

4. Section 9.3, Page 9.3-6. Reference 2 is also incorrect in that it refers to only one Part (i.e., 57) of Title 30, whereas it should refer to Title 30, CFR, without specifying parts.

5. Section 9.4.1, Page 9.4-1. Please provide a reference to the formal written operating procedures.

6. Section 9.4.2, Page 9.4-2. The third paragraph of this page refers to 30 CFR 57, whereas a more appropriate reference is 30 CFR 48.

7. Section 9.4.4, Page 9.4-2, 9.4-3. The last paragraph of 9.4-2 refers to "abnormal" occurrences. To be consistent with the terminology of other DOE and WIPP documents, the word "unusual" should be used instead of "abnormal." For example, see the definition of "unusual occurrence" in DOE order 5484.2. The word "unusual" should also be used in the first and last paragraphs of page 9.4-3 instead of "abnormal" and "internal."

8. Section 9.4.4.2, Page 9.4-4. The discussion in the first paragraph of this page should include a requirement that the WIPP operating contractor shall notify appropriate state authorities to assist in determining the impact of the violation on public health and safety. For example, the New Mexico/DOE C & C Agreement requires that "DOE shall keep the State currently and fully advised . . . so that the State may make independent reviews on public health and safety concerns relative to WIPP." To maintain credibility, it should be considered essential by WPO to involve the State authorities at an early stage in the public health evaluation. Furthermore, the WPO must meet the public exposure requirements of 40 CFR 191, Subpart A. These regulations should be referenced in Section 9.4.4.

CHAPTER 10

Operations Safety Requirements

1. This chapter lacks sufficient detail to permit EEG to adequately evaluate the operational safety at WIPP. It begins by defining safety limits but then states that there are no variables which require safety limits (see Sections 10.2). However, there are provided sections called "Surveillance Requirements" for the safety limits. The references in some cases are so general as to be of little value. In all instances, the references do not provide the complete title, nor do they cite the applicable section of the referenced documents. It is recommended that this Chapter be extensively revised and specific sections be revised as indicated in the following comments.

2. Section 10.1.4, Page 10.1-3 through 10.1-4. Please add and define the following ACRONYMS which are used in the Chapter, or should be cited in the Chapter:

   MOC - (See page 10.3-9)

   HVAC -

   WAC - Waste Acceptance Criteria

3. Section 10.2, Page 10.2-1, Safety Limits. This paragraph states that there are no measurable process variables which could result in an unfiltered release of radioactive material that exceed the DOE guidelines at the plant boundary. It would seem that the DOE Waste Acceptance Criteria should be construed as such a set of variables. Although unlikely, it should be considered credible that a waste shipment could be

received which has external contamination well in excess of the WAC. Furthermore, the DOE radiation exposure limits should be construed as safety limits or measurable process variables.

4. Section 10.3, Page 10.3-2. It is recommended that the word "activities" in Item 3 be amended to "activities, equipment or services".

5. Section 10.3.1.3, Page 10.3-3. In the first and second paragraph, the language should be amended to preclude, without exception, any operation with radioactive material when the CAMs and ARMs are not operating. These devices must be considered as essential to a central monitoring system. When not operational, the operations with radioactive materials should be suspended until these devices, or substitute equipment, are again operational. Therefore, in the first paragraph, please delete the words "except during calibration and change out." In the second paragraph delete "unless otherwise noted" and "(within a one hour limit)". The "Exception" on page 10.3-4 is quite reasonable and proper, however it is recommended that the words "continuously monitored by HP personnel . . . " be changed to "continuously monitored with equivalent equipment."

6. Section 10.3.1.3, Page 10.3-3, Item F. "50 ft" should be revised to "50 ft or less."

7. Section 10.3.1.4, Page 10.3-4. The language under "Basis" is so general as to be useless. It should be expanded, or replaced, to state the applicable sections of specific standards or guides.

8. Section 10.3.1.5, Page 10.3-4. To avoid confusion, please provide specific and complete references.

9. Section 10.3.2.5, Page 10.3-5. The reference "Westinghouse O and M Procedures" is inadequate. Please provide specific references.

10. Section 10.3.3.3, Page 10.3-6. Please revise the mid-page notation to state that the HVAC systems for the above ground facilities in the WHB are independent. The underground ventilation systems do not provide independent operation in the CH and RH areas.

11. Section 10.3.3.3, Page 10.3-6, Paragraph 2. Item 2 needs to clarify whether all (above ground and underground) ventilation will be shutdown, or whether it will only be shutdown in the affected work area.

12. Section 10.3.3.3, Page 10.3-6, Paragraph 3. Item 3 needs to be amended to state what minimum air flow is needed when normal operations are stopped. What air flow is required when HP surveys are being made to determine the area affected by an unplanned radiological incident or release, or when an air monitoring instrument is not operable.

13. Section 10.3.3.5, Page 10.3-7. The references should cite the applicable sections of the referenced documents. Also the referenced documents should be complete, including reference number, etc.

14. Section 10.2.3.4, Page 10.3-8. The referenced citations should be complete and should cite specific sections applicable.

15. Section 10.3.5.1, Page 10.3-8. The applicability should include portable fire suppression devices such as extinguishers, fire hose and stand pipe equipment.

16. Section 10.3.5.3, Page 10.3-8. This paragraph should be more specific to include minimal water pressure of sprinkler and hose systems.

17. Sections 10.3.5.4 and 10.3.5.5, Page 10.3-9. Cite specific sections of the referenced documents and include document numbers.

18. Section 10.4.1, Page 10.4-1. Please cite specific sections of the WIPP operating procedures and maintenance instructions.

19. Section 10.4.2, Page 10.4-1. Cite specific sections of reference documents which apply.

20. Section 10.4.2, Page 10.4-1, Paragraphs 1 and 2a, b and c. These paragraphs should be revised to assure that records of each inspection will become a part of the central records system.

21. Section 10.4.2, Page 10.4-2.

Paragraph 1 - The local monitoring should be equivalent to the CMS capability.

Paragraph 2 - Should be revised to assure that the air quality is checked frequently and to document the air quality standards.

Paragraph 4 - Should be titled "Exhaust Filter Building Equipment," and paragraphs 4a and b become subparagraphs. Paragraph 4b should require a monthly demonstration of the ability of the equipment to shift automatically to the filtration mode.

22. Sections 10.4.4 and 10.4.5, Page 10.4-3. Please include specific sections of the WIPP Safety Manual which apply to inspection and testing. Also include the requirement that the records of the testing be included in the Central Records System. Furthermore, the equipment to be tested or inspected should include portable fire extinguishers and stand pipe systems.

23. Section 10.5, Page 10.5-1 through 10.5-3. This section seems superfluous since it does not include limiting conditions of operations. It should be edited to be consistent with other sections to include specific LCO's, or it should be eliminated. Chapter 10 is not the chapter for descriptions of systems.

24. Section 10.6, Pages 10.6-1 through 10.6-16. This section should be revised to include the role of the Quality Assurance (QA) program. The QA manager's role is indirectly referenced in 10.6.5.3. Specific QA responsibilities should be stated, or referenced, relative to such items as 10.6.1 Training, 10.6.2 Design and Procurement, 10.6.3 Document Control, 10.6.4 Auditing, and 10.6.7, 10.6.8, and 10.6.9 on radiological protection. Quality Assurance is essential to operational safety.

25. Section 10.6, Page 10.6-1. The paragraph entitled "Administrative Controls for Operations" states that "Administrative Controls shall define the mechanisms and interfaces necessary (emphasis added) to insure adherence to the Safety Limits and LCO's, DOE orders and WIPP Standards Practices." If this statement is referring to the Administrative Controls of Section 10.6, these controls do not seem to meet this definition. The Administrative Controls of Section 10.6 do nothing more than refer to other documents in such general terms as to be of minimal value. Also, in some cases, the "controls" are nothing more than a restatement of previous sections of Chapter 10. As examples of the foregoing, Section 10.6.2.3 does not state a "control;" it states that a control shall be established. Similarly, Section 10.6.3.3, Paragraph 2 states that the operation manager shall establish a control. Section 10.6.7.3 is a restatement of portions of Section 10.3.1.3.

CHAPTER 11

Quality Assurance

EEG has not reviewed the quality assurance plans and procedures of various aspects of the project and is, therefore, not in a position to evaluate these adequately. Quality assurance relative to the waste acceptance criteria and waste certification at the generator sites have been performed and the comments are contained in other chapters of draft FSAR.

CHAPTER 12

Decontamination and Decommissioning

While it would be unreasonable to expect DOE to provide detailed analyses of decommissioning procedures at this time, it is reasonable to expect some indication that the Department is addressing the problems involved as shown in the following:

1. Section 12.1, Page 12.1-1. There is no commitment here to meet the D & D requirements of EPA's Standards for the disposal of TRU waste, 40 CFR 191, which should be included. This section should be expanded to include specifics on the regulations of 40 CFR 191, as they relate to the preparation for Decontamination and Decommissioning. For example, pursuant to DOE's "A Plan for the Implementation of Assurance Requirements in Compliance with the 40 CFR 191.14 at the Waste Isolation Pilot Plant," DOE/WIPP 87-016, the WIPP will become a disposal facility if the decision is made (5 years after receipt of the first waste) not to retrieve the wastes. The WPO must then begin to implement the WIPP active institutional controls program as required by 40 CFR 191, Subpart B, and DOE/WIPP 87-106. This program includes four important steps, which are listed on page 8 of DOE/WIPP 87-016, and should be listed in the FSAR, Section 12.2. These steps relate to the advance preparation for Decontamination and Decommissioning. Furthermore, this section states that Chapter 12 is written with the assumption that WIPP is shown to be acceptable as a repository and, therefore, decommissioning activities begin near the end of the operational life (25 years) of WIPP. Such an assumption reflects a bias in favor of the acceptability of the

five year pilot phase. If the five year phase is to provide a valid test, then such a bias should not be condoned. Also, if the demonstration does indicate that permanent disposal is unacceptable, there should be available, well-in-advance, a detailed plan for removal of the waste, decommissioning of the facilities, and decontaminations and environmental evaluation. This chapter does not provide this degree of detail. This degree of detail is needed to allow for sufficient budgeting, agencies and facilities, and to provide a base for post decommissioning activities such as the disposition of the land.

2. Section 12.2, Page 12.1-1. The text states that all the waste will be retrieved if the site proves to be unacceptable during the five-year demonstration period. Then the text states that this Chapter is written with the assumption that WIPP will be acceptable. Hence, it will not be necessary to retrieve the waste. Since DOE has consistently insisted that it is necessary to emplace 125,000 drums during this five-year period, specific plans and consequence analyses should be provided as to whether the 125,000 drums will be returned to the generating sites, sent to the high level waste repository, left on the surface at WIPP or be held underground before a new site is selected.

3. Section 12.2.1, 12.4, and 12.5. The term "Decommissioning Plan" in Chapter 12 includes varying adjectives of "final" and "detailed." Are they different?

4. Section 12.3, Page 12.1-2. Since the Department has requested the Congress to assign exclusive responsibility to DOE to prevent future

mining during the post-decommissioning phase, Section 12.3 should state whether the Department plans to reassign those authorities to the BLM, Department of Interior, State of New Mexico or establish a DOE organization to prevent mining rather than merely rely on records and documents.

5. Section 12.4, Page 12.1-4. While the three goals of closure are laudable, no indication is presented of how they are to be completed. The text should provide some indication of plans for active and passive controls, how long DOE will maintain a fence, employ watchmen and actively prevent mining permits in the area. Also, the various regulations and orders that must be met should be mentioned and discussed. These include DOE Order 5820.2A, 40 CFR 91, 40 CFR 265 Subpart G, and NMHWMR 206.C.2.

6. Section 12.5, Page 12.1-5. Post-closure environmental surveillance within the repository should be determined before the disposal mode begins in order to allow installation of sensors at the time of emplacement.

CHAPTER 13

Glossary

1. "Aquifer" - This definition contains a misspelled word "aquiclide", which should be "aquiclude."

2. This glossary should be expanded to include additional terms used in several chapters and other WIPP documents, such as:

   a. Radiation area

   b. High radiation area

   c. Unusual occurrence

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EEG-13 Spiegler, Peter., Analysis of the Potential Formation of a Breccia Chimney beneath the WIPP Repository, May, 1982.

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EEG-15 Bard, Stephen T., Estimated Radiation Doses Resulting if an Exploratory Borehole Penetrates a Pressurized Brine Reservoir Assumed to Exist Below the WIPP Repository Horizon, March 1982.

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EEG-21 Faith, Stuart, et al., The Geochemistry of Two Pressurized Brines From the Castile Formation in the Vicinity of the Waste Isolation Pilot Plant (WIPP) Site, April 1983.

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EEG-34 Chaturvedi, Lokesh, (edi), The Rustler Formation at the WIPP Site, January 1987.

EEG-35 Chapman, Jenny B., Stable Isotopes in Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP Area, October 1986.

EEG-36 Lowenstein, Tim K., Post Burial Alteration of the Permian Rustler Formation Evaporites, WIPP Site, New Mexico, April 1987.

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EEG-37 Rodgers, John C., Exhaust Stack Monitoring Issues at the Waste Isolation Pilot Plant, November 1987.

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EEG-39 Chapman, Jenny B., Chemical and Radiochemical Characteristics of Groundwater in the Culebra Dolomite, Southeastern New Mexico, March 1988.

EEG-40 Review of the Final Safety Analysis Report (Draft), DOE Waste Isolation Pilot Plant, May 1989.

EEG-41 Review of the Draft Supplement Environmental Impact Statement, DOE Waste Isolation Pilot Plant, July 1989.

ENVIRONMENTAL EVALUATION GROUP

REPORT NUMBER EEG-41

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EEG-41

REVIEW OF THE DRAFT SUPPLEMENT ENVIRONMENTAL IMPACT STATEMENT, DOE WASTE ISOLATION PILOT PLANT, APRIL 1989

Environmental Evaluation Group
New Mexico

July 1989

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EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volumes I and II, December 1978.

EEG-3 Neill, Robert H., et al, (eds.) Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U. S. Department of Energy, August 1979.

EEG-4 Little, Marshall S., Review Comments on the Report of the Steering Committee on Waste Acceptance Criteria for the Waste Isolation Pilot Plant, February 1980.

EEG-5 Channell, James K., Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, November 1980.

EEG-6 Geotechnical Considerations for Radiological Hazard Assessment of WIPP. A Report of a Meeting Held on January 17-18, 1980, April 1980.

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EEG-11 Channell, James K., Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, January 1982.

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DOE/AL/10752-41

REVIEW OF THE DRAFT SUPPLEMENT ENVIRONMENTAL IMPACT STATEMENT, DOE/EIS-0226-DS, VOLUMES I AND II DOE WASTE ISOLATION PILOT PLANT, APRIL 1989

Environmental Evaluation Group
7007 Wyoming Boulevard NE, Suite F-2
Albuquerque, New Mexico 87109

July 1989

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FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure protection of the public health and safety and the environment. The WIPP Project, located in southeastern New Mexico, is being constructed as a repository for permanent disposal of transuranic (TRU) radioactive wastes generated by the nation's defense programs. The EEG was established in 1978 with funds provided by the U. S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and provided for continued funding from DOE through Contract DE-AC04-79AL10752.

EEG performs independent technical analyses of the suitability of the proposed site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria and the generator sites' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP. EEG also performs environmental monitoring for background radioactivity in air, water, and soil, both on-site and in surrounding communities.

Robert H. Neill
Director

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SUMMARY

The Draft Supplement Environmental Impact Statement (SEIS) for WIPP does not provide adequate justification to support the proposed action of shipping up to 620,000 cubic feet of transuranic (TRU) waste to WIPP before demonstrating compliance with the Environmental Protection Agency's (EPA) Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR 191). The "alternative action" of shipping no waste to WIPP prior to demonstrating compliance with the EPA Standards has been dismissed without sufficient discussion and justification. The document contains mistakes in calculations, reflects an erroneous knowledge of the history of the project, presents tables without units, and displays an indifference to the statistical precision of predictions. It also does not adequately address the environmental impacts of the potential failure to complete the demonstration of compliance with the EPA Standards by October 1993. By comparison, DOE plans to complete the demonstration of compliance with the same standards before starting construction of the high-level waste repository in Nevada. These two diametrically opposed approaches by DOE, for WIPP and for the Yucca Mountain repository, need to be addressed.

There is insufficient time for EEG to check all the calculations and to evaluate the public health and safety implications of the errors found in the calculations. EEG will pursue these when time permits, since they may be substantial. The following is a summary of our main concerns with the document.

1. <u>Lack of Compliance with EPA Standards</u>

The SEIS is silent on the observed lack of progress by DOE in demonstrating compliance with the Standards for safe disposal of transuranic waste which were promulgated by EPA in September 1985, and had been circulated in draft for several years prior to that.

New Mexico's position on the Standards was expressed as early as January 15, 1979, in a letter from the Secretaries of the New Mexico Health and Environment Department and the Energy and Natural Resources Department, to the U.S. Department of Energy:

> "We feel that DOE should clearly state that EPA Standards will take precedence over any interim standards established by DOE."

Unfortunately, DOE still has not published any probabilistic risk assessment studies as required by EPA, and DOE continues to issue deterministic analyses of the type used in the 1980 Final Environmental Impact Statement (FEIS) for WIPP.

The NM Secretaries' letter further stated:

> "Also, the DOE should state that they will move quickly to come into conformity with any EPA Standards developed for nuclear wastes." "...we feel that a permanent TRU repository should be conceived and designed to allow for timely compliance with new standards developed in the future." - January 15, 1979

The work has not moved quickly nor has the DOE committed to timely compliance.

Preliminary calculations of performance assessment by the DOE's scientists since 1987 have indicated that the repository may not meet the EPA Standards under human intrusion scenarios. This issue must be addressed by the SEIS directly and explicitly, and its impact on the proposed action should be evaluated.

2. Incomplete NEPA Documentation

The October 1980 FEIS stated that the necessary National Environmental Policy Act (NEPA) documentation had been completed for two of the ten waste generating sites. The April 1989 SEIS states that the necessary NEPA documentation has been completed for two more sites in the intervening 8.5 years. The SEIS states that DOE may propose that TRU wastes generated at six other facilities be shipped to WIPP, and appropriate site-specific NEPA documentation would be prepared for such a proposal. Why hasn't site-specific NEPA documentation been completed for the other six sites? An explanation of the lack of progress of documentation for each of these six sites and the proposed schedule for compliance should be included.

3. Incomplete Information

While the SEIS does address bounding calculations for the environmental impact of 10% of the waste (83,000 drum-equivalents), it does not identify the quantities of CH-TRU waste associated with the various alternatives. Since the amounts of waste are an intrinsic component of any evaluation, the document neither provides nor permits a meaningful comparison of the alternatives. The reader must rely on other documents to obtain estimates of the quantities of TRU waste. They include the April Draft Test Phase for Performance Assessment and Operational Demonstration, the June 6, 1989 Addendum to the Test Phase, and the June 7, 1989 Draft Test Phase for the Bin and Alcove Experiments, all of which contain conflicting and inconsistent information.

4. Unexplained Changes in Radioactive Inventories

While estimates of the expected amounts of waste to be produced are continuously changing, we are concerned with the very wide differences from those shown in the FEIS. For example, the amounts of remote handled transuranic (RH-TRU) waste have changed from 250,000 cubic feet to 93,000 cubic feet. The estimated actual radioactivity in each canister dropped from 510 curies in the 1980 FEIS, to 47 curies (adjusted for daughter radionuclides) in the 1989 draft Final SAR, and has now increased to 177 curies in the 1989 draft SEIS. The total amount of RH-TRU radioactivity has been reduced from 5.1 million curies to 0.51 million curies, a ten-fold reduction without any explanation.

5. Uncertainty Estimates

EEG recommended in September 1979 (EEG-3) that DOE include estimates of the uncertainty associated with the radionuclide inventories. This has not yet been done. Instead, the document shows seven-place accuracy in the projections in which two-thirds of the CH-TRU waste has yet to be generated.

6. Incorrect Dosage Estimates

The calculations of human exposure from the stock water well to beef pathway are incorrect. The correct dose to an individual would be over two orders of magnitude greater than reported. The corrected doses (15.7 rem committed effective dose equivalent in the Case IIC scenario) are very significant and will most likely violate the EPA Standards when probabilities are assigned.

7. U.S. Department of Transportation Preferred Routes

While there is agreement in the routes to be followed in New Mexico for the 34,000 truck shipments to WIPP, they are not "Preferred Routes" in the context of regulations issued by the U.S. Department of Transportation (49 CFR 171 and 173) and it is misleading to imply that they fulfill the DOT requirements.

8. Shortcomings in the FEIS

Of fundamental concern is whether DOE will properly and adequately address concerns expressed in this review of the SEIS. The following issues identified by EEG in January 1981 (EEG-10) in our review of the 1980 Final Environmental Impact Statement (FEIS) were then rejected by DOE (WIPP-DOE 81 and 81A). Subsequently, all the following problems identified in EEG-10 have been encountered or have yet to be resolved.

A. We recommended that DOE evaluate a scenario of a connection between the WIPP, a high-pressure brine reservoir and the surface (EEG-10, pages 20, 23). DOE refused to do so, stating it appears extremely unlikely and the only pressurized brine pocket in a deep drill hole in the Delaware Basin away from the Capitan Reef was associated with an anticlinal structure. EEG then published two scenarios (EEG-11, EEG-15). After a brine reservoir estimated to be 17 million barrels was encountered 1,000 feet from the then proposed waste location, DOE finally published an analysis and has now updated it for the SEIS.

B. In EEG-10, we repeated our August 1979 recommendation on the DEIS review (EEG-3) that a scenario evaluating the effects of high pressure gas formation, generated by organic decomposition of the waste, acts as a driving mechanism in bringing wastes to the surface.

DOE rejected the hypothesis and did not consider the effects of human intrusion. EEG raised the issue of the retardation on room closure at a meeting with the NAS WIPP Panel in January 1988, and presented an extensive discussion in a paper at the waste management conference in March 1988. While the 1989 SEIS does not address this issue, gas generation has been recognized as a major problem associated with a human intrusion scenario.

C. EEG questioned why there was no consideration of gas generated from CH-TRU waste decomposition.

DOE stated that it would not be expected to be released to the atmosphere because of the overburden and slow rate of gas production. Today, gas is recognized as a major problem.

D. EEG raised the concern whether the CH-TRU waste drums could contain explosive gas mixtures at the time of retrieval, if retrieval proved necessary.

DOE responded "The amount of time between waste emplacement and retrieval is expected to be too short to allow significant generation of gas in the CH-TRU waste containers ("Gas Generation from Radiolytic Attack of TRU-Contaminated Hydrogenous Waste," LA-7674-MS, Los Alamos Scientific Laboratory, 1979)."

The amount of time between waste emplacement and retrieval could be 10 years. We now know that hydrogen gas generation can be a problem in the transportation of CH-TRU wastes which involves a period of only several months (EEG-24).

E. EEG recommended that the FEIS provide an estimate of the total radioactivity expected to be emplaced in WIPP.

DOE did not do so and part of the confusion that exists today on the proper source term to be used in dosage estimates stems from that fact.

F. We recommended that an effective control period of 400 years be established.

No further progress has been reported by DOE on this request.

G. EEG stated that the information was not adequate on large brine reservoirs.

DOE stated that the information was adequate for an assessment of the WIPP site. A large reservoir was subsequently encountered at WIPP-12 on November 22, 1981.

H. EEG recommended that estimates of the uncertainties of waste quantities be included.

DOE ignored the recommendation and it has been ignored in the SEIS.

I. EEG asked what would be the ultimate disposal site if wastes had to be retrieved.

DOE responded that the specific site has yet to be determined. Today, that is still true.

J. EEG expressed concern that DOE did not incorporate an analysis of ingesting contaminated food after a transportation accident. The SEIS still does not address this concern.

K. DOE stated that "the SPDV program has been planned to confirm the geologic adequacy of the site..."

We did not agree. DOE's response was to insist that it was adequate and subsequent events have confirmed that the SPDV program was not adequate.

L. EEG stated (EEG-10, p. 39) that WIPP-12 was at the edge of an anticlinal structure in the Castile, and was also at the southern edge of one of the zones of anomalous seismic reflection.

The response of DOE was to ignore the comment. Later, brine was encountered when the hole was deepened in November 1981.

SPECIFIC COMMENTS ON SEIS SUMMARY CHAPTER

1. Page S-2, Changes in Waste Package. The TRUPACT-I design was not a Type A package. It was a single-contained, vented, Type B package that could not have met NRC requirements for shipments of plutonium in excess of 20 curies.

2. Page S-2, Implementation of a Test Phase. The Test Phase, which is part of the proposed plan, is not presented with any detail in the Draft SEIS nor has it yet been evaluated in detail by the National Academy of Sciences (NAS) WIPP Panel, or the Environmental Evaluation Group (EEG). Nonetheless, reviewers of the SEIS are asked to accept the proposed plan rather than the Alternative Plan or the No Action Plan without being able to evaluate the efficacy of the proposed Test Plan.

3. Page S-3, New Information. The following should be included in the section titled "New Information":

   A. State that there is much better understanding of the Rustler Formation hydrology, including higher transmissivities in the central and southeastern part of the site, geochemical zonations, sorption, and salt dissolution.

   B. Add to the last item (salt creep), "and fracturing would make it difficult to retrieve the waste after five years, without rock-bolting in the roof of the waste rooms." Add "3 times faster."

   C. Also add, "It is now assumed that a large quantity of pressurized brine exists in the upper part of the Castile Formation, approximately 800 feet below the repository."

4. Page S-5, First Sentence. It is stated that all TRU waste emplacement would be conducted so as to maintain retrievability for a reasonable time period. This statement is not definitive enough and should discuss more specifically the effect of room closure, fracturing and other anticipated problems on the ability to retrieve and the amount of time to emplace and retrieve.

5. Page S-7, No Action Alternative. This alternative is given very little attention in the Draft SEIS and the reason(s) given for not accepting it are not persuasive. The section on Pages 5-168 to 176 does give estimated doses to persons on and off-site from very low probability events. The consequences of those events are similar to those postulated for WIPP during the transportation and operation phase and it is not known how the degree of conservation or the probability of occurrence would compare. However, there are <u>expected</u> consequences from the WIPP Project which are delineated in the Draft SEIS (e.g., 8.3 traffic fatalities, 106 injured in traffic, about 1.1 Latent Cancer Fatalities from transportation and operation radiation exposure to workers and the public) and none are mentioned for the No Action Alternative. There is one good reason for not choosing the No Action Alternative, but it is not invoked in the SEIS. Congress has passed laws to dispose of TRU and high-level radioactive wastes in geologic repositories and, thus, ruled against reliance on long-term storage. It appears that the Draft SEIS was written with a predetermined conclusion to accept the proposed plan and that alternatives were not seriously considered.

6. Pages S-8 to S-13, Summary Table. The inclusion of a summary table is an effective way to give the reviewer a

quick overview of projected environmental consequences. Most entries in the table will be discussed elsewhere in our comments, but the following comments are offered here:

A. The expected number of fatalities and injuries from transportation accidents are the greatest projected impacts of the project. Yet the Draft SEIS says very little about this impact and does not even attempt to explain why the plans are to ship all (or virtually all) wastes by truck and incur 5.3 (179%) more fatalities and 72 (212%) more injuries than by train. The failure to thoroughly evaluate the transportation mode is a major shortcoming in the Draft SEIS.

B. Since several effects are not listed in the table or in the SEIS, the document fails to fully reflect the consequences of WIPP. For example:

   (1) The irreversible and irretrievable commitment of resources (said to be similar to the FEIS in Chapter 9, but fails to list any numbers);

   (2) The numbers of deaths and injuries expected from industrial accidents, both at WIPP and the generating/storage sites;

   (3) Any updating of the quantity and value of mineral resources located in the proposed 16-square-mile withdrawn area since 1980 and their impact on national markets.

C. Table 5.1 uses both per year and per project lifetime health effects and the footnotes do not always reflect the correct units. This is confusing and should be clarified and made consistent.

7. Page S-14, Alternatives Considered but Rejected. It is not clear what synergistic mechanisms would require radioactive waste emplacement at WIPP, given the time frame of the experiments, and why these experiments cannot be performed at the generator sites. More documentation is needed to evaluate the "unreasonableness" of this alternative than has been presented.

It is stated that another alternative to conduct performance assessment without collecting any data was rejected for reasons related to the rejection of using non-radioactive simulated wastes. Why is it necessary to obtain additional data? Has performance assessment with existing data shown non-compliance? If so, then this information should be made available to evaluate the need for additional data.

8. Page S-14, Existing Environment. The Draft SEIS should explain why DOE determined that Zone IV was unnecessary (the change is mentioned on Page 2-1).

9. Page S-15, Transportation. The calculation of 34,144 truck shipments of TRU waste or 18,467 rail shipments is one that affects most calculations pertaining to transportation doses throughout this document. Unfortunately, those numbers are based on an incorrect assumption of the volumes of waste coming to WIPP.

Waste volumes listed in the Integrated Data Base (IDB) represent total volumes of various containers instead of the actual volume of waste contents. The IDB for 1987 (Table

3.9, Page 110) and the IDB for 1988 (Table 3.10, Page 97) indicates that the projected volume accumulation to move to WIPP through the year 2013 is 156,613 m^3 (5.53 x 10^6 ft^3). This is comparable to the total in SEIS Table 3.1, (5.60 x 10^6 ft^3) compiled from Tables 3.5 and 3.16 in the IDB of 1987.

The 6.2 x 10^6 ft^3 design capacity of WIPP is based upon the total volume of emplaced containers and not their contents. Attachment 1 to this review provides an informal analysis of WIPP capacity for CH and RH wastes. If the projected mix (per DOE/WIPP 88-005) of 65% by volume in drums and 35% by volume in Standard Waste Boxes (SWB) is used, and if the SWBs are emplaced three tiers high, 6.16 x 10^6 ft^3 can be accommodated. Scaling up slightly to 6.20 x 10^6 ft^3, this corresponds to 843,537 drum equivalents. Each drum represents a value of 208 L (0.21 m^3). The SEIS makes a fundamental error that permeates the entire document. The SEIS takes the 6.2 x 10^6 ft^3 waste capacity at face value, assumes this represents the volume of container contents, and generates a fictitious number of drums that cannot fit into the WIPP. They assume the average drum is 80% full, round off the total drum volume to 0.2 m^3, and obtain 6.2 x 10^6/(0.2 x 0.8 x 35.31) = 1.10 x 10^6 drums (where 35.31 is ft^3/m^3). This is 256,463 drums more than the capacity of WIPP! For the 10% of waste capacity assumed for the Test Phase, the SEIS correctly uses 6.2 x 10^5 ft^3, but because of the interpretation error, uses 110,000 drums and 22,000 drums per year instead of 84,354 and 16,870 drums per year, respectively. For the Disposal Phase, they use 990,000 drums and 49,500 drums per year instead of 759,183 drums and 37,959 drums per year. The effects of using the 0.8 "fullness" factor on results are as follows:

A. The number of required shipments are overstated by

23%.

B. The number of transportation accidents are overstated by 23%.

C. The radioactive control per shipment should also be affected. However, it does not appear to be, since Table D.3.3 (average curies per shipment) values don't agree with the total inventory (Table B.2.1) either with or without the 0.8 factor.

D. The chemical content per shipment and for the total campaign are not affected, since these calculations are done on a per drum basis, not a total inventory.

These calculated transportation consequences affect several portions of the SEIS and it is disturbing that more care was not taken in setting basic parameters at the outset.

10. Page S-15, Transportation. EEG comments on Incident-Free Conditions and Accident Conditions are included under Chapter 5 and Appendix D. We concluded that the population doses (person-rem) calculated for both routine transportation and accidental releases were conservative. However, the maximum exposures to a member of the public from routine operation and the bounding accident were non-conservative by at least an order of magnitude.

11. Page S-17, Long Term Performance. It should clearly be stated at the beginning of this section that these calculations neither provide a basis for assessment of compliance with the long-term performance part of the EPA Standards (40 CFR 191), nor do they substitute for those

calculations. The failure to include any work to date in showing compliance with these 4-year-old standards is distressing.

12. The reference to "usual guidelines" in the last paragraph on Page S-17 is sloppy. State the guidelines that apply to WIPP - EPA Standards, DOE Orders, etc. - and judge compliance with them.

13. Page S-18, Last Paragraph. The statement, "Nevertheless, the results suggest that appropriate Performance Assessment methods and likely values of parameters would show that the WIPP would comply with the Standard. They also indicate the efficiency of potential engineering modifications..." is without basis and should be deleted. The official position of DOE is that compliance with standards for safe disposal cannot be shown until October 1993. Hence, conjecture such as "likely values would show that WIPP would comply" is misleading.

14. Page S-20, Mitigation Measures. EEG believes the presentation of mitigation measures in the Draft SEIS is incomplete and preliminary and is a major shortcoming. Some of these measures will be required by the project, and the Draft SEIS implies that those that are needed will be used and they will automatically work in a satisfactory manner.

Much more careful thought and consideration needs to be given to these measures than is contained in the SEIS or other documents published by the project. Too many decisions regarding mitigation measures are yet to be made, yet credit already appears to have been taken for several of these measures.

15. Both the Proposed Action and Alternative Action reveal a

serious shortcoming concerning waste treatment mitigation measures. They indicate that construction of waste treatment facilities will be in abeyance until after the Test Phase and pursued only if a determination is made that noncompliance with EPA regulations would result if additional treatment is not done. If the Test Phase must be followed by a study of options, design facilities, a budget cycle, construction, and tests prior to start of waste shipment to WIPP, a delay of many years will be introduced. DOE may argue that commencing such work now would be interpreted that treatment must be done, while tests may indicate it is not needed. The risk is that there can be a serious interruption of WIPP operations if waste treatment is required. A counter argument may be that selected stored waste, plus certain newly-generated wastes, may be "complying" and can be shipped during the interim while facilities are constructed. If DOE had vigorously pursued waste processing as recommended by EEG, oversight committees and other organizations, instead of following a stated minimal processing policy, much of the current debate over gas generation and brine inflow may have been resolved. An up-to-date discussion of the impact on the program of possible waste processing needs should be provided in the Final SEIS.

SECTION 1

1. Page 1-1, First Paragraph. It is not correct to say that "most of the underground experimentation rooms and waste rooms for initial waste emplacement have been excavated." Excavation for the alcoves began in late June, 1989.

2. The Salado Formation is 1700 to 2000 feet thick. What is a "3000-foot-thick bedded salt and anhydrite formation?"

3. "The volumes and characteristics of TRU wastes are discussed in Subsection 2.4..." Should this be Subsection 2.3?

4. Page 1-1, Third Paragraph. There is no Subsection 10.3.1 in the Draft SEIS. Subsection 10.2.5 appears to be the appropriate reference.

5. The SEIS fails to identify the role of EEG, created in 1978, as the only full-time, external, review agency on WIPP subsequently mandated by Congress in the National Defense Authorization Act, Public Law 100-456, September 29, 1988, Section 1433 (a).

6. Page 1-1, Last Full Paragraph. In the list of items requiring completion prior to testing, add "an EPA Permit to receive mixed wastes at WIPP."

7. Page 1-2, First Paragraph: It is stated that, "In addition, the delay of the WIPP Project holds the potential to adversely affect the nation's production of nuclear weapons." This sentence should be amplified to explain the delay of any progress in demonstrating compliance with the EPA Standards for disposal of TRU waste, which were

promulgated by EPA almost four years ago in September 1985. The lack of progress toward showing compliance and the resulting delay is the factor that may well impact on weapons production.

8. Page 1-2, Last Paragraph. DOE's Record of Decision of January 28, 1981 was challenged in a court by the NM State Attorney General. Describe that challenge and the resulting "Stipulated Agreement" between DOE and the state here.

9. Page 1-4, NEPA Documentation Since the FEIS. In 1980, DOE completed NEPA documentation for shipment of waste from INEL and RFP. Since that time, DOE has completed NEPA documentation for transportation of radioactive wastes from only Hanford and SRP. Why? Section 1.2.2 does not contain any information on NEPA documentation since the FEIS.

10. The discussion of the 1982 cost-reduction measures that were subsequently reinstated is not included. For example, DOE maintained that the deletion of the fourth shaft would not pose problems for air circulation. In 1988, DOE acknowledged that the fourth shaft was required for adequate air circulation underground.

11. Page 1-4, Purpose and Need for Supplement. The statement that DOE may be proposing disposal of wastes from six additional facilities is puzzling since DOE has publicly acknowledged that the mission of WIPP is to include wastes from LANL and five other facilities.

12. Page 1-4, "The analysis in the 1980 FEIS considered only TRU wastes from INEL and Rocky Flats Plant".

The FEIS never explained why the transportation of wastes from all other sites was included in the 1979 Draft

EIS and deleted in the Final EIS. Please explain, including the impact of hydrogen gas generation from radiolysis on the unvented TRUPACT-I.

13. Page 1-4, Fourth Paragraph. Also state EEG's response to DOE (1983) and the recommendations that were accepted by DOE and implemented during 1984-89 period.

14. Page 1-5, Changes in the TRU Waste Inventory. Provide an explanation for the 10-fold reduction of RH TRU from 5.1 x 10^6 curies to 0.51 x 10^6 curies.

15. Page 1-5. In the list of new data and significant geotechnical information, include the presence of a brine reservoir in the uppermost anhydrite of the Castile Formation below the proposed repository. The significant change in the withdrawal area of the WIPP site should also be an important reason for a SEIS, as is compliance with 40 CFR 191.

16. Page 1-5. The text states that experiments would be conducted to reduce uncertainties associated with the prediction of several natural processes (e.g., gas generation, brine inflow, and salt deformation).

There are no experiments requiring the use of waste to measure brine inflow. There are no experiments requiring waste to measure salt deformation since they are mutually independent events. Gas generation is the <u>only</u> parameter proposed to be measured that requires waste.

17. Page 1-5, Proposed Action. It is stated that operations are needed to "show the ability of the TRU-waste management system to safely and efficiently certify, package, transport, and emplace waste in the WIPP." This claim is misleading for the following reasons:

A. The certification of waste for WIPP is independent of operational demonstration and is currently underway at the generating and storage sites.

B. The packaging of waste has been studied and perfected since 1970 and is independent of any operational demonstrations.

C. The transportation of these wastes has been demonstrated in the past with packages other than TRUPACT-II and experience with TRUPACT-II could be obtained (once it is certified by NRC) by shipments from RFP to INEL and from LLNL to NTS.

D. No justification has been provided for the emplacement of 83,000 drums (up to 10% of the WIPP capacity). Emplacement is occurring today at INEL.

18. Page 1-6, Line 9. It is stated that, "At the conclusion of the Test Phase, the DOE would decide...whether WIPP would comply with EPA disposal standards." No mention is made of receiving input or requiring concurrence by other organizations. Does DOE plan to make this determination unilaterally?

19. Page 1-6, Line 14. "If there is a determination of non-compliance, a number of options would be considered (e.g. waste treatment) and the required NEPA documentation would be prepared." We believe it would be prudent for DOE to begin evaluating options at this time and not rely completely on the hope that the Proposed Action will be found to be satisfactory. It is irresponsible to plan on deferring action on a potential problem for 4 years and then say that the required NEPA paperwork would deal with it.

20. Page 1-6, Alternatives Considered in the SEIS. The SEIS is not able to adequately justify the alternative chosen

because of the lack of a detailed, DOE-approved, Five-Year Test Plan to review.

21. Page 1-6, Content of the SEIS. "...it is not the purpose of this SEIS...to demonstrate compliance with regulatory requirements." Unfortunately, it is also not the purpose of the Final Safety Analysis Report to do so either, nor has any other document been prepared by DOE to demonstrate regulatory compliance. By comparison, DOE will provide that documentation in the FSAR in Nevada. Why the difference?

22. Page 1-6, Section 1.5. The first paragraph of this section gives the impression that assessment of compliance with 40 CFR 191 was not done because the Standards were vacated. This is not true and is misleading.

23. Page 1-7, Footnote. The SEIS uses numerical values and projections made in the December 1988 draft of the FSAR. EEG has extensively reviewed the Draft FSAR and believes many of these calculations are flawed (see EEG-40, May 1989).

24. Page 1-17 & 18, References. The reference list does not include the following documents referred to in the text:

A. 1978 Contract establishing EEG

B. Public Law establishing EEG

C. C&C Agreement

D. Five-Year Test Plan

SECTION 2

1. Page 2-1, Location, Fourth Paragraph. Provide the reference for the justification for DOE eliminating "the requirement to control the land identified as Zone IV in the FEIS"? This is a significant change that should be explained.

2. It is misleading to merely state the percent reduction (from the FEIS) of desirable mineral resources resulting from the reduced site area since this does not mention that the amount of these resources is so significant. For example, the FEIS stated that the (old) WIPP site contained 20.2% of the free world's langbeinite resources and reserves. If 35% of this is still within the present WIPP site boundaries, this would still be 7.1% of the free world total. The resource issue needs to be addressed directly, not by reference to the FEIS.

3. Describe the status of private leases being held.

4. Page 2-3, Exclusive Use Area. The location of the Exclusive Use Area and the proposed expanded area should be shown in Figure 2.2 or elsewhere. Also, the rationale for choosing a 640-acre or a 1,454-acre exclusive use area should be explained.

5. Page 2-5, Figure 2.3. Buildings numbered 364 and 365 are missing from this figure and from the listing of building names on the next page. These buildings are significant since they house Station A and Station B of the Effluent Monitoring System.

6. Page 2-7. Although the definition of TRU wastes

excludes actinides with half-lives less than 20 years, DOE has committed to including Cm-244, with a half-life of 18 years, and Cf-252, with a half-life of 2.6 years, in the TRU wastes coming to WIPP. DOE has also committed to include U-233 with a half-life of 150,000 years which does not have an atomic number greater than 92. This commitment by DOE to include these three radionuclides should be shown in conjunction with the definition.

7. Page 2-7, "Wastes with TRU concentrations between 10 and 100 nCi/g are expected to be reclassified as low-level wastes which would not be sent to the WIPP."

They are classified as low-level wastes. Our understanding is that waste with TRU concentrations between 10 and 100 nCi/g <u>will</u> (not may) be classified as low level wastes and not be sent to WIPP. This is an important distinction. What are the plans?

8. Page 2-9, "CH-TRU waste is packaged in sealed steel drums and boxes."

They are not and must be vented to avoid the generation of mixtures of flammable gases during shipment.

9. Page 2-9, "Approximately 3% by volume of defense TRU waste is RH TRU waste,..."

It is about 5.3% by curies (a more meaningful measure than volume) and 1.6% by volume (see Appendix B-2 and 3). The text should be specific about the volume percentage that is being quoted and should also give the radioactivity percentage. Also, the maximum dose rate limits for RH-TRU should be listed.

10. Page 2-9. The use of units of volume to characterize transuranic waste is misleading. The discussion should describe typical concentration in nanocuries/gram for both weapons grade plutonium and heat source plutonium.

11. Page 2-9, Waste Acceptance Criteria. The statement, "The DOE established the WAC in consideration of DOT and NRC regulations" is incorrect. The purpose of the WAC was to delineate the criteria that waste packages must meet in order to permit safe handling and disposal at WIPP.

12. Page 2-9, "The NRC will be asked to issue a certificate of compliance for the TRUPACT-II shipping container...".

Add "... and the yet to be built RH-TRU waste shipping cask."

13. The SEIS does not discuss the two sets of additional criteria that must be met in transporting and disposing of wastes at WIPP, including:

A. Those issued by the NRC as a condition for licensing the use of TRUPACT-II for CH-TRU waste.

B. Those issued by EPA to meet the requirements of 40 CFR 261 and 262 for hazardous waste.

The SEIS should explain how these criteria differ, how each is implemented, and if there are potential conflicts in meeting all three sets of criteria simultaneously.

14. Page 2-9, Section 2.3.1 (WAC). Although Revision 3 of the "TRU Waste Acceptance Criteria for the Waste Isolation Pilot Plant," January 1989 (WAC), reflected many improvements over Revision 2, it still contains certain serious deficiencies, some of which EEG had called to the attention of the WIPP Project Office following publication of Revision

2. (See letter to Mr. W. R. Cooper, WIPP Project Manager, from R. H. Neill, Director, EEG, January 15, 1986.) These and other comments are addressed below:

A. Does the gas generation criterion allow the waste generators to make a decision on the need for venting? There is no definition of what is considered an "overpressure," nor an "explosive mixture." The criterion also specifies that the "TRU waste shipper" must provide data on the total alpha activity, waste form, and organic content, but this language appears redundant, since such information is already required by the Data Package Certification criterion. If it is to be provided in two separate places, it should be clarified and justified. The provision of such information does not preclude the possibility of judgmental or careless errors on venting due to lack of sufficiently definitive criteria.

   Also, the technical justification for the gas criteria has not been updated and fails to recognize current data on gas permeabilities and gas generation levels of concern now being expressed by Sandia. The gas criteria needs to be completely reevaluated and rewritten.

B. The immobilization criterion fails to recognize the potential for increases in particulates with time due to breakdown of cellulosic material. Packages containing such material should be subject to a lower limit.

C. The criterion applicable to radioactive mixed waste mandates that hazardous waste as defined in 40 CFR 261 be included only as co-contaminants with transuranics (and presumably fission products). The last line of the criterion as stated in Revision 3 indicates that such hazardous materials "are to be reported," however, no further details are indicated on such reporting. It is not clear whether such reporting is in reference to the Data Certification information, or whether it is an additional reporting pursuant to 40 CFR 262. This latter RCRA regulation requires reporting to EPA and also requires that the waste shipment be accompanied by a detailed manifest on a specific EPA form. This manifest requirement is not mentioned in the WAC, Revision 3, and should be added. The entire subject of the RCRA regulations is treated in excellent detail in "Radioactive Mixed Waste Compliance Manual," 1989, WP-02-07, and could be included in the WAC by reference.

D. The EEG has been objecting to the use of a maximum Plutonium-Equivalent Curie (PE-Ci) limit of 1,000 since November, 1985, and considers it to be unacceptable. For our latest comments on the PE-Ci limit, see EEG-40 (May, 1989).

15. Page 2-10, "The WAC do not require detailed characterization of chemical constituents because waste sampling and analysis would result in increased radiological exposure of personnel."

The WAC does not and was never intended to specify how a waste generator demonstrated compliance, and suggests a lack of familiarity by the author with the intent of those criteria. By that rationale, the WAC would never have required characterization of radiological constituents.

16. References should include the review by Marshall S. Little, "Evaluation of the Safety Analysis Report for the Waste Isolation Pilot Plant Project," May 1985, EEG-29.

17. Page 2-10. In the discussion of "plutonium-239 equivalent activity," , mention should be made of the long-standing disagreement by EEG of the 1,000 PE-Ci limit chosen by DOE.

18. Page 2-12, "Gas generation considerations for transportation have resulted in the introduction of vented waste packages at some generation facilities."

The WAC needs to be modified to require filters in all packages prior to shipment.

19. Various DOE documents describe the fraction of stored mixed waste as 60% (SEIS) to 90%. Is 60% the agreed upon value?

20. Page 2-14. Clearly state that it is planned to emplace waste during the first five years without backfill, and that backfill will be added later by moving the waste to new rooms. Also, state the reasons for not backfilling during the test phase.

21. Page 2-14. The decision on retrieval fails to specifically describe what DOE would do with 83,000 drums if it were necessary to retrieve them. This is different from DOE's commitment in Nevada to include a detailed discussion in the Final SAR. (See DOE planned Table of Contents for the HLW repository, 10 CFR 60.21, SAR Content.)

22. Page 2-15. The reasons cited for possibly not returning wastes to the generating sites due to "costs of double

handling and transportation impacts" should be addressed in evaluating the alternative of showing WIPP can meet the safety standards first.

23. Page 2-15, Third Paragraph. Serious consideration to the feasibility and problems of various engineered modifications should be given now rather than postpone it for several years. The problems are fairly well defined already.

24. Page 2-15, Fourth Paragraph. Where will the waste be shipped if the drums are to be compacted, incinerated, etc.?

Too many DOE documents have claimed the possibility of in-place installation of backfill without describing and demonstrating the process. "It could possibly be installed" is not good enough for making decisions.

This section (2.5) should also describe the changes (roof rock-bolting, for example) that have been introduced in the design due to fracturing observed in the SPDV rooms, and analyze the effect of these design changes on the assurance of retrievability and long-term performance.

26. Page 2-20, Section 2-9. This section does not describe any of the independent environmental surveillance conducted by EEG. It is suggested that this section be changed to read as follows:

> "Since 1985, DOE has funded independent environmental and effluent studies at WIPP which are conducted by the Environmental Evaluation Group. Measurements of radioactivity include atmospheric, terrestrial, hydrologic and biotic baselines. EEG will also conduct radiological analyses of particulate samples from the effluent air exhaust system which serves the underground portion of the facility."

SECTION 3

1. Page 3-1. The SEIS identifies the Proposed Action of bringing 83,000 drums (10% WIPP capacity) to WIPP prior to demonstrating compliance with the EPA Standards on the basis that it is needed to demonstrate compliance with those Standards. The authors appear unfamiliar that the quantity of wastes identified by DOE in providing information useful to assess compliance with those Standards amounts to <u>4,500</u> drums (650 for bin and 3,850 for alcove tests as described in M. Molecke test plans.) The discussion in comparing alternatives without any reference to the amounts involved is meaningless.

2. Page 3-2. Why has DOE completed the necessary NEPA documentation for only two additional sites since 1980? The SEIS should specify the status of such documentation for six other facilities, including the expected dates of completion.

3. Page 3-2, Paragraph Three. Stating that "DOE may propose that TRU waste stored and/or generated by six additional facilities should be transferred to the WIPP for permanent emplacement" after the expenditure of 3/4 billion dollars is not only surprising, but, if true, illustrates that DOE has not made any plans for alternative disposal.

4. Page 3-2. For the past 11 years, DOE has repeatedly issued estimates of RH-TRU waste of about 250,000 cubic feet at 5.1 million curies. This document shows a ten-fold reduction to 0.51 million curies. Why? What is the explanation?

In 1984, the DOE Inspector General recommended (DOE/IG-0207) that there was insufficient justification to build a hot-cell at WIPP for RH-TRU waste only, and those unwanted residuals should be sent to the HLW repository. The reduction of RH-TRU from 36% of the WIPP radioactive inventory to 5.3% suggests that the recommendation of the IG had merit.

5. Page 3-2. The text suggests that the purpose of WIPP can be modified to accommodate up to 1.65 million cubic feet of TRU waste from new facilities ($6.45 \times 10^6 - 5.8 \times 10^6$). Is this correct? Is DOE suggesting that buried TRU wastes or unidentified stored TRU wastes could be brought to make up the difference? Also, what information is available on the Special Isotope Separation Facility?

6. Page 3-4, Table 3.2, RH-TRU Quantities. These values are reported in Chapter 3 and Appendix B. Both the expected volume and curies of RH-TRU waste continue to change drastically as shown in the following table:

	FEIS(1)	FSAR(2)	SEIS
Ci/canister	510	47(3)	177(4)
Volume, feet^3	250,000	88,285 - 176,570	93,000
Total, Curies	5.1×10^6	$5 \times 10^4 - 1 \times 10^6$	$.52 \times 10^6$

1 Expected Average Conditions
2 Representative Radionuclide Content (see EEG-40, p. 19)
3 Includes Daughter Radionuclides
4 Equals the Ratio of Total Curies/ft^3 x 31.8 ft^3/canister.

There is no documentation or justification for these changes. How certain are these estimates in which half the RH-TRU has yet to be generated (Table B.2.3)? Provide an explanation for these substantive differences. Also, there are internal inconsistencies within Appendix B; the average curies per trailer load in Table B.2.7 is not consistent with that calculated from Tables B.2.1 and B.2.3.

7. Page 3-3. Only 1/3 of the total TRU waste to be shipped to WIPP now exists with 2/3 yet to be produced. Table 3.3 shows seven-place accuracy in the estimates of future waste ($1 \div 5{,}598{,}397 = 10^{-7}$). Either DOE can make astonishingly accurate predictions, or the authors are unaware of the statistical limitations of future projections. The same comment applies to Table 3.2 on Page 3-4.

8. EEG requested a discussion of uncertainties in the RH-TRU inventory in our review of the FSAR and has not had a reply. We suspect there is still considerable uncertainty in volumes, curies, and distribution of radionuclides in RH-TRU waste. We are aware that a questionnaire is now being conducted by the WPO on RH-TRU inventories, and have heard that there are wastes that are high in activation products that may have a problem meeting the 1,000 rem/hour surface dose rate limit. Although calculations in the FEIS, FSAR, and SEIS indicate that RH-TRU wastes should be less of a problem than CH-TRU wastes, we cannot conclude this because of the apparently greater uncertainty in the data base.

9. Page 3-5. "The design of the CH-TRU waste package has been changed from a Type A (TRUPACT-I) container in 1980 to Type B..."

While EEG has called the original design a lot of things, we never called it a Type A container. Change it to Type B. Also, the decision to abandon the rectangular TRUPACT-II design in favor of a right circular cylinder TRUPACT-II design was not made in 1980, but in 1987.

10. Page 3-5, Brine Inflow Studies. Although there are

plans to measure brine inflow in a cylindrical room to be mined in the WIPP repository, the study will not involve the use of radioactive waste. Hence, the statement inferring that radioactive TRU waste is needed during the Test Phase to reduce uncertainties associated with brine inflow is incorrect and should be changed.

11. Page 3-6, Last Paragraph. This paragraph states that the average Pu-238 activity content has increased from 1.2% in the FEIS (correct) to 17%. This does not agree with the tabulation in Table B.2.13, Page B-19, in Volume 2, which indicates that 42% of the total radioactivity and 81% of the alpha-emitting transuranic radioactivity is Pu-238.

12. Page 3-7, Table 3.3. Change "Curies" to "Radioactivity" to be consistent with the other entries and list all units (including curies) in the table.

The table should indicate maximum values. For example, the maximum surface dose rate of RH-TRU is 1,000,000 mrem/hour. The failure to provide units results in this confusion.

Fill in the blanks in the table on RH-TRU waste characteristics. Since the Final Safety Analysis Report (FSAR) has not been published, include the information in both documents.

13. Page 3-10, Table 3.4. EEG has expressed concern previously (see EEG-40) about the extent that concentrations of hazardous chemicals at RFP could be considered as conservative for all other sites. There is now an additional uncertainty with the RFP wastes since we understand that the FBI and EPA are currently investigating the RFP characterization of mixed wastes. Thus, it is possible that

the RFP waste constituent data are flawed.

14. Page 3-16, Transportation Modes. It is stated that the requirements of the trucking contract in all these areas are highly specific and demanding with respect to the transport of TRU waste to WIPP. Does the contract include alternate route restrictions to safeguard against arbitrary selection by the driver/company? If so, then it should be documented in the text.

15. Page 3-19, Transportation Routes. DOT regulations contained in 49 CFR, Parts 171, 174, and 177, are characterized as requiring that the interstate highway system be used whenever possible to transport highway route controlled quantities of radioactive materials to WIPP and that appropriate state agencies can require other routes if less risk can be demonstrated.

This analysis of 49 CFR, Parts 171, 174, and 177, is misleading and inaccurate. The requirements of 49 CFR, Part 177.825, are that highway route controlled quantities of radioactive materials can be transported over "preferred routes" which are selected by a state routing agency when an interstate highway system or bypass is not available. As of this date, there have been no "preferred routes" designated by the State of New Mexico as required by the DOT regulations in 49 CFR 177.825 dated May 8, 1988.

16. Page 3-25, Integrated Operations Demonstration. The emplacement of TRU waste at WIPP for operational demonstration purposes is being proposed before compliance with 40 CFR, Part 191, Subpart B. What is the advantage of initiating such a demonstration before compliance with the Standard where the possibility exists that the waste may have to be removed, treated, etc.? What are the disadvantages of

delaying this activity until compliance is demonstrated? If the reasons are political, economic, training, etc., then a justification for overriding a health and safety standard should be incorporated into the SEIS. Also, why is it not possible for some operational demonstrations external to WIPP to be conducted without actual transport and emplacement of waste at WIPP prior to compliance?

17. Page 3-26, Performance Assessment. DOE and the State did not agree to proceed with performance assessment <u>planning</u> as if the Standards were in effect. We agreed to proceed with the documentation. Unfortunately, nothing except a schedule has been published by DOE since those Standards were promulgated in September 1985.

18. Page 3-26, Performance Assessment. It is stated that the SEIS describes the proposed Test Phase activities that will enable DOE to ascertain whether the repository can meet the Standards (Subpart B). An alternative to the Test Phase is to proceed with performance assessment without gathering any more data (Page 3-32). It is stated that under these circumstances DOE would not have "sufficient" data for conducting a performance assesssment that would provide a basis for determining compliance with Subpart B. Yet it may be possible to perform an assessment with the available data that would be bounding, and could be compared with the Standard to justify additional data gathering in critical areas of uncertainty and sensitivity. If such assessments have already been performed, then they should be incorporated into the SEIS.

19. Page 3-27, Bin-Scale Tests. Because the bin-scale tests would involve the emplacement of TRU wastes at WIPP before compliance with Subpart B of 40 CFR, Part 191, then a justification for such action should be stated. Other

locations for these tests have been presented as an alternative with little impact on the health and safety of the public or on the environment. The preference to conduct these experiments at WIPP are guided by economics and delays expected due to permitting at other facilities. But these economics have not been demonstrated, nor has it been explained why permitting would be much easier at WIPP. In fact, due to the expected delay in obtaining a permit for mixed wastes, the date to begin starting bin-scale experiments at WIPP may be considerably delayed.

20. Page 3-28, Second Paragraph. Why are treated wastes such as incinerated, cemented, charred, asphalted, etc., not part of the experimental design since some of the alternatives to retrieval (under non-compliance) involve treatment of wastes? If treatment of some or all wastes is found to be necessary, the lack of experiments now may result in considerable delay.

21. Page 3-28, Room-Scale Tests. Room or alcove experiments are designed without consideration of possible future waste forms. Also, it is stated that four room-scale tests will be performed; whereas, the Test Plan lists six rooms for these experiments. Which plan is correct? Finally, what is the effect of the short time frame in which to conduct these experiments on the value of the results?

22. Page 3-30, Alternative Action. The discussion on waiting until DOE demonstrates compliance with the EPA Standards does not address a number of facts that should be included:

A. DOE has not objected to the NRC requirement to demonstrate compliance in Nevada before beginning construction of the repository, and DOE has published plans to do so. Why does DOE object at

WIPP?

B. DOE sees no merit in conducting an operational test phase in Nevada prior to meeting standards and has no plans to do so.

C. Unlike the Nevada repository, which has NRC licensing, DOE has been given the authority by Congress to self-determine compliance with the EPA Standards at WIPP. These Standards state in the 1985 preamble that compliance should be completed during the design phase. Why does the SEIS ignore that statement and present an analysis to bring up to 83,000 drums (10% of design volume) to WIPP first? This is particularly relevant since DOE has not published any progress (except a schedule) in compliance with those Standards.

D. The text invokes the mantle of performance assessment (for which DOE only identifies a need of 4,500 drums) in discussions which variously require 83,000 drums, 36,000 drums or 18,400 drums.

E. The text does not acknowledge that representative mixtures of waste may not be available for shipment until March 1990 at the earliest (projected date for EPA authorization for mixed waste). Therefore, meaningful bin experiments at the site may not begin for a year.

F. Additionally, there is no discussion of why gas measurements have not been made at the generator sites since 1985. If the measurements are useful, discuss this as well as the impact of a year's delay in starting to get data.

G. The text also does not address limits in gas pressurization in the alcoves (e.g., 1 psi extrapolated to 2,100 psi, absence of repository conditions of backfill, engineered fixes, leakages of gas from instrumentation connections).

H. Standards issued by NRC and EPA do not require tests. Explain why they must be done and do not imply that such tests are obligatory. The text should describe how the information derived may be useful or helpful in long-term risk assessment analyses.

SECTION 4

1. Page 4-2, Socioeconomic Environment. The nearest community to the WIPP site is Loving, whose population "decreased from an estimated 1,600 in 1980 to 1,450 in 1986..." While the presence of the proposed repository probably did not cause a negative economic impact on the community, it obviously did not result in any positive economic impact. Discuss the absence of this despite the proximity to the site, high unemployment rate, availabiity of local manpower, the railroad track to WIPP passing through the community, and the presumed naturally occurring breach surfacing at Malaga Bend in the Pecos River at Loving. Identify the number of workers from Loving of the 640 employed for WIPP.

2. Page 4-3, First Paragraph. The text should provide the distance and direction of the three ranches and three mining operations located near the site or locate them on a suitable map.

3. Page 4-3, Land Use. The SEIS should provide (either here or in Chapter 2) a summary of the natural resources, estimated to be present, beneath the 16-section WIPP site, and the extent of private mining leases still being held within the site boundaries.

4. The information contained in the last sentence of Section 4.1.4 should explain what is meant by "restricted" mining and drilling within the WIPP site. How does DOE plan to implement these "restrictions" and for how long? If the DOE obtains control in perpetuity of this real estate, currently managed by the Department of Interior, how will mining be prevented? Will DOE delegate those

responsibilities back to the Department of Interior, Bureau of Land Management?

5. Page 4-4, Background Radiation. EEG's preoperational environmental radiation surveillance program should be referenced here (as well as in Chapter 2).

6. Page 4-4. Reference EEG's work in the preoperational environmental radiation surveillance.

7. Page 4-7, Last Sentence. The sentence should be expanded to, "The WIPP horizon is in a 26-foot-thick section bounded by Marker Beds 138 and 139, that consists mostly of halite with a few thin interbeds of anhydrite, clay, and polyhalite. Detailed stratigraphy of this section between the two marker beds and the location of WIPP excavations is shown in Figure _____." (Add a figure.)

8. Page 4-13, Hydrology and Water Quality. Add "Dewey Lake Redbeds" among the geologic units of hydrologic interest of WIPP.

9. Page 4-13, Section 4.3.1.1, Third Paragraph. "Deposits" is not a synonym for brine "reservoirs."

10. Page 4-14, Brine Inflow. The stated in-flow rate of 1.6 L/day/m^2 would completely fill an empty 4 x 10^3 m^3 room with brine in three years! With waste, it would be filled to the ceiling in less than a year! The correct value from the Nowak and McTigue report is 1.6 mL/day/m^2.

11. The development of the concept of Salado salt as a saturated medium should be described and the work of Bredehoeft (1988) should be cited.

12. Page 4-18. Reference the required tests that DOE conducted for the Stipulated Agreement to the lawsuit by the New Mexico Attorney General. Ignoring those required tests ignores the true history.

13. Page 4-22, Table 4.2. The work of Stormont et al, 1987, is cited on Pages 4-22 through 4-25, but not referenced at the end of the chapter.

14. Page 4-20. The discussion of gas permeability should include estimates of the expected amounts of gas and the pressure to be reached. If a modification to the waste form is required to reduce the amount of gas produced, the environmental impacts should be discussed.

15. Page 4-25, Section 4.3.2.4. "Underground experience at the WIPP indicates that these fractures open locally in response to excavation" does not adequately describe the extensive continuous fractures up to four inches thick that have been observed in the SPDV rooms.

16. Section 4.3.2.4. This section should describe extensive fracturing observed in the roofs of the SPDV rooms that will also provide potential pathways for gas or brine migration.

17. Page 4-33, Last Sentence. Arguments counter to the hypothesis advanced by Lambert and Harvey (1987) should also be provided here. See, for example, Chapman, 1986 (EEG-35).

18. Page 4-55, Section 4.3.3.4. This section should also refer to Chapman, 1988 (EEG-39) and Ramey, 1985 (EEG-31) to describe the geochemistry of the Rustler Formation, especially since Siegel et al, 1988, has not yet been published.

19. Page 4-58, Figure 4-20. The "Disturbed Zone" boundaries have become enlarged with each new encounter of a Castile brine reservoir. There is no rational basis for the delineation of these zones and they should be abandoned.

20. Page 4-60, Last Full Paragraph. The request to relocate the repository and the report by Channell should both be attributed to the New Mexico Environmental Evaluation Group.

21. Channell's calculations (in EEG-11, 1982) were made with a lesser waste inventory and likelihood of occurrence of a brine reservoir and did not address compliance with the EPA Standards, which were not promulgated until 1985. Therefore the report cannot be used to conclude that the presence of an underlying brine reservoir would not result in exceeding the EPA Standards.

22. Page 4-60, Paragraph Beginning at Bottom of Page. "The presence of Castile brine beneath the repository is of concern only in the event of human intrusion." (Emphasis added.) Gas pressures exceeding lithostatic in the repository could cause fracturing to ERDA-9 and then to the upper anhydrite layer of the Castile where brine is located.

SECTION 5

1. Page 5-2, Biology. It is stated that the salt levels do not appear to inhibit plant species diversity or abundance. This statement should be clarified to say that "current" accumulations do not have an effect, unless soil salt concentrations are not expected to increase in the future as a result of operations. Also, the phrase "do not appear" suggests that a detailed study has not been performed. Has it?

2. Page 5-3, Last Sentence of Paragraph Two. Delete the words "modifications of."

3. Page 5-6, Land Use. A justification should be provided for the choice of the WIPP site boundaries and various control zones that have changed since the FEIS (See Chapter 2 comments).

4. Page 5-6, Air Quality. The occurrences where state and federal air quality standards have been exceeded are not adequately explained in this paragraph. For example, the text states:

> "The WIPP has not been determined to be responsible for the elevated sulfur dioxide levels."

How was this determined? Similarly, the cause of high ozone levels "has not been identified," but WIPP has been exonerated.

With respect to dust loadings exceeding the air quality standards, it is stated that the cause is attributed to heavy use of a dirt road near the air sampler. Has this cause been verified by moving the sampler to another location, or from analysis of deposits on the filter?

There are possible explanations for the high values. They could be due to sampling or analytical errors, or could cover a wider area than the WIPP site, or could be due to WIPP-related traffic. But no explanations have been justified here. We must conclude from this paragraph that the WIPP site has not been shown to have a negligible effect on air quality standards.

5. Page 5-22, Transportation. EEG has thoroughly evaluated the calculations presented in Appendix D for transportation and our detailed comments are included in that section. Our findings on the evaluation are summarized here.

A. The methodology and assumptions used to calculate population doses to workers and the public from routine transportation were appropriate and conservative.

B. The estimated dose to the maximally exposed members of the public (1.6 mrem during 25 years) is unrealistically low by one to two orders of magnitude.

C. Assumptions used for the Total Respirable Release Fraction from the different Severity Category Accidents are more conservative than those used by EEG in EEG-33 for a doubly-contained, non-vented TRUPACT. Thus, the total radiological impact projected for transportation accidents is conservative.

D. The probabilistic method of presenting accident results completely hides the effect of accidents, especially the more severe ones, from all except the technical reviewer who digs them out of the tables himself. For example, the total number of accidents and the number of accidents leading to a release are not presented anywhere. Neither are any route specific total accident and release values provided. If the SEIS is going to use these numbers, it should summarize them in a way that is understandable.

E. The Bounding Accident is very non-conservative because it uses the average PE-Ci trailer-load from the Rocky Flats Plant. The average PE-Ci value for the entire system is 6.5 times the RFP value and the average SRP trailer is 64 times as great.

F. EEG believes the appropriate Bounding Accident (with SRP wastes) would result in 35,800 person-rem. This would be about ten Latent Cancer Fatalities (LCF).

G. The probability of a bounding accident is not "extremely low" as stated on Page 5-24. From the tables and assumptions in Appendix D, one can calculate a probability of about 0.6% that an accident involving >0.75 LCF will occur during the WIPP operational period.

6. Page 5-24 to 5-28, Human Health Consequences of Transportation Releases. We believe the LCF/rem factors used are appropriate, and, since we judge the total doses received from transportation to be conservative, the total LCF are considered conservative. EEG has the following observations about transportation health effects:

A. Transportation causes the majority of the radiological health effects of the entire project.

B. The expected effects are about 0.96 LCF for 100% truck shipments and 0.31 LCF for maximum rail shipments.

C. Consideration should be given to maximizing rail shipments and other ALARA practices to reduce the total health effects.

7. Page 5-29, Transportation Accidents. Although the statement that the bounding accident assumes that all drums are breached is incorrect, we agree with the assumption that all headspace gas is released in an accident.

8. Page 5-29, Trichloroethylene. We agree with the inclusion of this VOC in the waste inventory because it was commonly used prior to and during the 1970's. This point had been raised to DOE by our consultant, Dr. William Lappenbusch, some months ago, and we are pleased that it has been accepted.

9. Page 5-30, Quantities of Chemicals Released. We agree that 100% of Volatile Organic Compound (VOC) gases present in the headspace should be assumed to be released in a transportation accident. However, we also believe that a fraction of the total VOCs in the waste matrix should be assumed to be released in an accident. The SEIS assumes that .02% (2E-4) of all TRU radionuclides in a TRUPACT are released in the most severe accident. There are experimental data to support releases of this order for TRU radionuclides, which are typically in a non-mobile, non-volatile form. We believe a factor of 2E-4 would be appropriate for the VOC fraction in the waste matrix. This will increase the source term by 29% to 630%. For carbon tetrachloride, which has the most hazardous headspace gas concentration (40 times TWA-TLV), the increase would be 86%. Note also that there would still be the non-conservative assumptions of assuming average values for headspace gas concentration and concentrations in the waste.

10. Page 5-30 to 5-32, Quantities of Lead Released. The release values are unrealistically low. Starting from an

average amount of lead in an average drum of wastes of 60.3 kg, the released amount is only 0.46 mg. So the total release fraction is 7.6E-9! Again, we compare this to the average value of plutonium in these wastes of 2E-4. We don't believe plutonium is 26,000 times as mobile as lead.

The very low value resulted from the DOE assumption that no lead could possibly be released from any waste form other than sludges, which have only 10 mg/kg of lead. EEG rejects this assumption and believes the appropriate source term should be 507 grams per trailer.

11. Page 5-31, Paragraph Three. These two sentences have fires lasting for 2.0 hours and 1.5 hours.

12. Page 5-31, Paragraph Five. Why is the maximally exposed individual at 30m here and at 50m in paragraph seven?

13. Page 5-32, Second Paragraph. What is the origin of the 1300°K temperature in the bounding case accident? Assumed temperatures for the hypothetical test accident are somewhat lower (800°C or 1073°K).

14. Page 5-33, Table 5.10. It is not clear how the values in this table were calculated. Is g/m^3 the correct unit? Why would the concentration (g/m_3) in six TRUPACTs be twice as great as in three TRUPACTs? Using carbon tetrachloride as an example, the average headspace gas concentration in Table 5.26 and the average emission rate in Table 5.28, we can also calculate a concentration. There are 1.9 g/m^3 in the headspace gas. If this were also diluted in the TRUPACT cavity outside the drums (2.45 m^3), the average concentration in the entire TRUPACT void volume would be 0.87 g/m^3. This value is 50 times that reported in Table 5-10 for three TRUPACTs. The emission rate for carbon tetrachloride would

add another 0.12 g in 100 hours. Thus, we believe the amount of carbon tetrachloride in the TRUPACT void space should be assumed to be 2.0 g or 0.82 g/m^3. This value is 27 times the TWA-TLV. The 1,1,1-Trichloroethane and trichloroethylene values are 3.2 and 1.2 times TWA-TLV values.

15. Page 5-34, Table 5.11. For the quantity of lead available for release, the fraction received by the maximum receptor is very high. The intake for an individual amounts to 8.5E-5 of that released. The radiological bounding accident had only 3.1E-8 fractional intake, and EEG-33 had 5.5E-8. Should the concentration be micrograms/m^3?

This very low dilution offsets a good bit of our objection to the very low release fraction. We believe the quantity released from a CH-TRU trailer should be about 5E+5 mg, and the fraction inhaled by the maximum individual about 5E-8 for an intake of 2.5 x 10^{-2} mg. The air concentration (~42 $\mu g/m^3$) would be about 28 times the Clean Air Act Standard for 90 days but for a time weighted average would be well below any of the limits shown on Page G-15.

16. Summary Comment on Section 5.2.2.2. EEG has significant reservations about the quality of the data, some of the assumptions, and calculation inconsistencies in this section. Because of these concerns, we cannot yet conclude that reported concentrations, which are low compared to TLV-based limits, indicate that hazardous chemical releases from transportation accidents are negligible.

17. Section 5.2.2.3, Non-Radiological, Non-Chemical Transportation Requests. Comments on this subject are also included in comments on the Summary Chapter and Appendix D. The only additional observations are that:

A. Expected LCF from vehicle emissions are less than 20% of the LCF from radiation for truck shipments, and less than 30% for rail shipments.

B. Expected deaths from accidents are much greater than from radiation, 8.6 times for truck shipments, and 6.6 times for rail shipments.

C. Since rail transportation is predicted to be safer than truck transportation in all areas (radiation, accidents, vehicle emission), consideration should be given to maximizing rail shipments.

18. Page 5-39, Assumptions and Considerations of Uncertainty. As mentioned previously, the use of a "fullness factor" of 0.80 is incorrect and will influence many of the calculations that follow.

19. Page 5-44, Waste Retrieval. Our general comments on waste retrieval also apply to comments on Pages 5-46 and 5-49, and Table 5.18. It is difficult to believe that routine exposures from retrieval would be the same per shift as emplacement (but twice as much per drum, because of greater handling time) or that surface contamination would be present on only one-half (5%) of the drums that were brought underground contaminated (10%). Table 5.18 assumes that the 5% of drums that are contaminated can be retrieved and repackaged with a dose of only 1.7 mrem per drum. This is unrealistic. If retrieval is believed to be no more hazardous, why are there plans to HEPA filter area exhausts during retrieval, but not during emplacement?

19. Page 5-45, Routine Radiological Releases. Two fundamental errors were made in calculating releases of radionuclides to the environment in Table 5.15. First, the

number of drums was overestimated by the erroneous use of the 0.8 fullness factor. This results in increasing the annual drum equivalents handled. The values should be about 17,000 and 38,000 drums per year in the test phase and disposal phase, respectively. Secondly, the use of the 1E-5/m resuspension factor to calculate amount removed in a year is incorrect, because this factor includes amounts that settle out as well as those carried away. This error also occurred in the December 1988 Draft FSAR. In fact, the amount of alpha curies shown in Table 5.15 to be released in a year is 1.55E-3 Ci/year. The curies of alpha radiation included on all drums brought in during a year (with 10% contamination at 50 pCi/100 cm^2) is only 5E-5 Ci/year! The SEIS claims to carry off 31 times the amount of radioactivity brought in!

Both of the errors give conservative predictions, that is, they predict greater releases to the environment. However, such significant errors cause real doubts about the thoroughness and accuracy of subsequent calculations.

20. Page 5-47, Table 5.15. It is noted that the radionuclide releases in this table are about 35% higher than those in Chapter 6 of the Draft FSAR. The ratio on a per drum basis would be about 58% higher. However, the values in both tables need to be recalculated.

21. Page 5-48, Table 5.16. The values of annual radiation exposure in this table are apparently scaled up (by a factor of about 1.33) from the Draft FSAR. As stated above, we believe the source term (Table 5.15) is incorrect. Our comments on the environmental pathway analysis are substantive and are included under Appendix F.

22. Page 5-48, Table 5.17. These occupational radiation doses are apparently scaled up from the Draft FSAR. EEG

conclusions on the FSAR numbers were that the direct radiation dose was reasonable, but the inhalation dose was not reproducible from assumptions listed and was probably low. The same conclusions apply here.

23. Page 5-49, Section 5.2.3.4, Accidental Radiological Releases and Exposures. The accident scenario assumptions, releases, and doses are identical to those in the Draft FSAR. EEG's principal conclusions are summarized below. A more detailed explanation of these conclusions is included in EEG-40, Pages 50 to 52.

A. The C-8 (hoist drop) accident is not incredible and should be included in dose calculations.

B. The use of a 1,000 PE-Ci upper limit for individual waste containers is unacceptable to EEG.

C. The potential doses to radiation workers from accidents are unreasonably low, because of the assumption that all accidents occur with an average PE-Ci drum.

D. The C-2 (forklift) accident doses are unreasonably low, because the forklift operator is assumed to receive no dose.

24. Page 5-54, Table 5.2.1. The Draft FSAR calculated doses to a member of the public at the maximum location in the WIPP site where public access is allowed. The doses are 60% higher than at Mills Ranch and would be more appropriate to use.

25. Page 5-55, Third Paragraph. There are three errors in this paragraph relative to Table 5.22, and the table is correct in each case. The excess fatal cancers are per year

and not during the entire operation. The fatal cancers per year in the population from facility operations should be 7.6E-6, during the Test Phase, and 2.5E-5, during the Disposal Phase, as shown in Table 5.22. They are incorrectly described in the text on Page 5-55 as 8.4×10^{-6} and 2.7×10^{-5}, respectively.

26. Page 5-57, Table 5.23. The values given for risk of latent cancer fatalities from accidents are correct for the doses presented in this section. However, if the maximum exposed worker (in the C-6 accident) had been handling a 1,000 PE-Ci drum, the dose would have been 713 rem. This would lead to a 0.20 probability of a LCF. EEG has estimated that the dose to the C-2 forklift operator with a 1,000 PE-Ci drum would be about 2,900 rem.

27. Page 5-61, Heavy Metal Releases. The statement that WAC certification assures no radioactive contamination exists on the surface of containers is incorrect. A limited amount of radioactive contamination is allowed (50 pCi/100 cm^2 for alpha emitters and 450 pCi/100 cm^2 for beta-gamma emitters) and some containers are expected to contain measurable contamination between zero and the limit. Also, the "elaborate HEPA filtration system" will not normally be operating to filter underground exhaust, and, thus, cannot be categorized as routinely filtering exhaust air.

28. Page 5-64, Line 4. The statement that use of average concentrations represent a bounding case is misleading. In any scenario where only a few drums are involved (e.g., when unloading a TRUPACT), a conservative assumption would be at least as great as the average concentration for the maximum class of waste. This is especially pertinent because the original TRUPACT certification is not expected to permit mixing of waste types. For example, carbon tetrachloride

Waste Category 2 (cemented and uncemented organic sludges) are 10.5% of all wastes and have a concentration of 50,000 mg/kg, 9.3 times the average.

29. As mentioned in the Chapter 3 comments, EEG is not yet confident that the hazardous chemical inventory is accurate, including RFP.

30. Page 5-64, Last Paragraph. The statement that 10% of the 6.2 million cubic feet of total repository capacity is 110,000 drum-equivalents is incorrect. The 6.2 million cubic feet is based on the total volume within the containers, not the estimated volume of waste within the container. A 55-gallon drum holds about 7.34 cubic feet. There would then be 845,000 drum-equivalents in 6.2 million cubic feet.

31. Page 5-67, Table 5.28. The 1,1,1-trichloroethane emission rate (9.3E-9) is inconsistent with the other values and the assumption that the diffusion coefficient is related to the square root of the molecular weight ratios. A consistent value would be 1.7E-7, which was used in the December 1988 Draft FSAR, and is 19 times greater. Also, the value in Table 5.31 uses the higher emission value.

32. Page 5-68, Assumptions of Operational Exposure. We believe the assumptions listed on this page are all reasonable and slightly conservative.

33. Page 5-70, Air Dispersion Modeling. The EPA Industrial Source Complex (ISC) dispersion is used to predict off-site concentrations of VOC's. Is it being assumed in these analyses that hazardous wastes are not adsorbed onto particulates in the exhaust? If true, then documentation for this assumption is required in the SEIS for proper justification; otherwise, it should be considered in the

assessment.

34. Page 5-71, Exposures from Above Ground Operations. The statement is made that releases from waste containers into the TRUPACT-II may occur during transport. We believe they will surely occur. Your assumptions of average emission rates in Table 5.28 would lead to significant gas concentrations in a TRUPACT-II while it was sealed during shipment. In 100 hours, the predicted concentration would be 1.6 times the TWA-TLV for carbon tetrachloride in an average load. In a maximum load, the concentration would be 15 times the TWA-TLV for carbon tetrachloride and 1.8 times for 1,1,1-trichloroethane. It is apparent that sampling must be done before opening the TRUPACT-II units at WIPP, and that precautions may have to be taken to insure safety of those most involved in waste handling with the TRUPACT.

35. Page 5-71, Exposures from Underground Operations. The assumption of an air velocity of 3m/s is non-conservative by a factor of at least two. This assumption requires a flow rate of 120 m^3/s in either one storage room or in the panel exit drift. The total flow rate for a panel is about 58 m^3/s and for an individual room would be only a fraction of this. This discrepancy was pointed out in our Draft FSAR comments and acknowledged by Westinghouse. The values in Tables 5.31 and 5.32 check for the assumptions used.

36. Table 5.31 and 5.32, Exposures from Underground Operations. From the assumptions stated on Page 5-68, the above ground worker should be exposed to the emissions from an average of 66,000 drums during the first five years, and 6,000 drums thereafter. The estimated daily intakes in Table 5.32 reflect this 11 to 1 ratio. Also, the concentration for an above ground worker in the 20-year period is consistent. But the above ground worker concentrations for five years are

too low by a factor of about three. The effective X/Q value for the 20-years concentration is about 1.5 x 10^{-6}. It is about a factor of ten low compared to Table H-49 of the FEIS, but without knowing stack height assumptions we can't comment on its validity.

37. Page 5-78, Table 5.34. Units of micrograms/m^3 are missing.

38. Page 5-82, Table 5.36. Footnote "a" is missing.

39. Page 5-100, Non-radiological Risks. The LCF for CH-TRU shipping by rail would be 0.088 (See Table D.4.9).

40. Page 5-109, Third Bullet. Although the assumption used in the FEIS that TRU waste in the repository dissolves at the same rate as salt is called unrealistic, it led, because of other assumptions, to a concentration that was less than 4E-6 Molar.

41. Page 5-110, Last Sentence. Since concentrations of VOC's in some waste forms average as high as 150,000 mg/kg (see Table B.3.2), it is imprudent to call this limited or minor.

42. Page 5-111, Fourth Paragraph. The statement implies there is a definite plan and commitment to using a backfill containing bentonite. We are unaware of any such commitment, and the text should not take credit for it.

43. Page 5-113, Fourth Paragraph. EEG has been assured in the past that there was not enough brine in the Salado to fill a room before closure. We believe the current hypothesis is more reasonable.

44. Page 5-114, Third Paragraph. Although a human intrusion drill hole may be considered unlikely by the SEIS writers, its evaluation is required by 40 CFR 191.

45. Page 5-114, Last Paragraph. EEG has been told that blowout preventers do not activate unless pressures are quite high and might not be activiated by a brine reservoir. Also, since the WIPP-12 brine reservoir unavoidably permitted 27,000 barrels of brine to flow to the surface before it could be shut in for pressure testing (see Page H-9 of TME 3153), how can the claim be made that little or no brine would reach the surface?

46. Page 5-115, First Paragraph. What assurance is there that standard borehole plugs would be installed? Who inspects these?

47. Page 5-117, Cases IIC and IID. We agree with plutonium and americium solubility values of 1E-6M for average and 1E-4M for degraded conditions. An order of magnitude increase in the solubility for uranium might be more appropriate.

48. Page 5-119, Third Paragraph. Again, credit is taken for bentonite in the backfill.

49. Page 5-125, Last Paragraph. It is not obvious that gas generation by radiolysis is negligible. Waste inventories have become more concentrated and more work has been done on gas generation since 1980. The average concentration in an equivalent drum in the repository will be about 6.16 alpha curies. The Safety Analysis Report for Packaging (SARP) for TRUPACT-II uses G factors (net gas) that range from 0.6 - 8.4 atoms of gas per 100 electric volts of absorbed alpha energy for five of the six waste forms considered. A G factor of 1.0 would generate 0.64 moles/year/drum. Even though G

factors are usually assumed to decrease, in a poorly defined manner, with time it does not seem conservative to ignore radiolysis. Besides, the only reason to use real waste for experiments is the contributor by radiolysis. Neither bacterial decay nor chemical reactions require waste.

50. Page 5-129, Last Paragraph. The flow would be around as well as through the seal in MB139.

51. Page 5-135, Table 5.52. The large retardation factors, for 100% of the wastes, assumed in the Culebra should guarantee that you will have no problems, regardless of other assumptions. Since there are so many complexities to this waste and large quantities of material that are potential chelating materials, we believe that a small percentage (perhaps in the 1 - 10% range) of waste should be assumed to move with no retardation.

52. Page 5-137, Fifth Paragraph. It is stated that 12 liters of brine with a radionuclide solubility of 1E-4 molar would carry 1% of a drum's radionuclides. Our calulations show that this volume of brine at 1E-4 molar would contain about 0.288 grams each of plutonium and americium and about 0.281 grams of uranium. These quantities would be 3.2%, 100%, and 24% of the average grams in a drum (See Table B.2.14.).

53. Page 5-138, Table 5.54. We agree with the calculated dose for the assumptions used. For the average LANL wastes, which has an Am-241 concentration 7.3 times the WIPP average, the dose would be 0.6 mrem. This is still a low value.

It should be recognized that taking a cuttings sample from RH-TRU wastes could conceivably result in somewhat higher doses. For example, if an RH-TRU cylinder contained an average of 10 Ci/L of Cs-137 at time of emplacement (this would meet the requirements of the State of New Mexico for a total concentration of less than 23 Ci/L), this would still be 1.0 Ci at 100 years. A 526 cm^3 cutting would have a dose rate at 1 meter of 175 mrem/hour, even if no compaction of the waste were assumed.

54. Section 5.4.2.6, Analysis of Scenarios: Cases IIA, IIB, IIC, and IID. EEG has not had the time to check all of the calculations in this section, so we are unable to provide a comprehensive assessment of the analysis. Most of the checking we have done is discussed in Appendix I. There was one significant finding.

The calculations of human exposure from the stock-well-beef pathway are calculated incorrectly and understate the doses that should have been calculated from the assumptions by over two orders of magnitude. The problem was caused by calculating the intake of radionuclides by the steer for <u>only one day</u>. Two hundred days of intake is typically considered to be a reasonable assumption. The 200-day feeding assumption would increase the concentration in the nuclides of interest by factors of 100 to 200, depending on the effective half-life of the specific nuclide. When calculated correctly, the 129 mrem dose in Case IIC becomes 15.7 rem Committed Effective Dose Equivalent per year of beef consumption.

This dose (using the SEIS assumptions) is significant, about two orders of magnitude above natural background doses. A great deal of explanation is needed to explain why this type of dose is acceptable, even for an event with a probability somewhat less than 1.0.

The fact that Uranium-233 turns out to be the dominant radionuclide in a well scenario is not suprising to EEG. We came to the same conclusion in EEG-9, published in September 1981.

EEG has long maintained that a well scenario with humans drinking treated water directly is reasonable to consider. The technology to reduce high solids water is available today (with reverse osmosis being perhaps the most practical method), and is used some in water-short areas that do not have access to better quality water. The well water in Case IIC, if treated to remove 90% of the solids, and, incidentally, remove 90% of the radionuclides, would result in a dose of about 33 rem/year (CEDE). Even if 99% of the radionuclides were released, the CEDE would still be 3.5 rem/year.

SECTION 6

1. Page 6-2, Introduction. The text states, "If, for example, it were determined through the Test Phase experimentation that gas-generation is a long-term repository problem, then gas-getter materials could be selected as a mitigative measure."

Current DOE estimates clearly show that gas generation is a long-term repository problem. For gas not to be a problem, measurements would have to show a 25-fold reduction in the amounts expected of 2.4 moles/y-drum to 0.1 moles/y-drum, a most unlikely situation.

The text states that the solution is to use gas-getters. If this is the case, why do the experiments? The text further states, "Other experimental results could identify the need for other treatments." What are the kinds of results that could prompt other treatments?

2. Page 6-2. The text states, "The requirements of the Occupational Safety and Health Administration (OSHA) and Mining Safety and Health Administration (MSHA) have been closely followed." Include a discussion of violations and citations identified by those federal agencies since the FEIS was issued and how these have been corrected.

3. Page 6-2, Existing Facilities. The reader is led to believe that HEPA filters are continuously filtering underground exhaust air during normal operations. This is not the case, and the wording should be changed to indicate that air is normally discharged without passing through the HEPA filters.

4. Page 6-2. It is inferred that the remainder of the

repository has not been excavated because of premature closure due to salt creep. It should be added that those rooms which have been excavated require rock bolting and wire-mesh surfacing to insure worker safety due to fracturing in the ceiling of the drifts and rooms along with salt creep during the short term.

5. Page 6-2, Socioeconomics. The release of land in Control Zone IV for unconditional use for economic reasons, as opposed to the FEIS which did not allow this option, impacts on both health and safety, and on ecological preservation. Presumably, these were the original reasons for control of this zone. What has changed since the FEIS to account for this release? How does this release impact on slant drilling under the site for mineral exploration and extraction which is not currently permitted?

6. Page 6-5, Emplacement of Backfill. It is stated that the FEIS considered only crushed salt as a backfill for waste containers, and that various types of backfill developed since that time may speed the entombment process and the attainment of final porosities within the waste areas. A 70:30 crushed salt-bentonite mixture with yet unidentified gas getter(s) is the only option discussed in the SEIS as bulk backfill. Is the only option a selection of getters? What other backfill materials, including getters, are being considered?

7. Page 6-5. "The reason for backfilling WIPP disposal rooms and access tunnel systems...would be to shorten the estimated 'time for closure' of the disposal room." That is not the sole reason. Getters, such as bentonite, are used to retard radionuclide movement after a hydrologic breach. Additionally, EPA requires engineered barriers. Since the WIPP waste is soluble, respirable, and housed in a carbon

steel oil drum, backfill at the present time is the only engineered barrier at the WIPP.

The text states that compaction of backfill in situ would be costly and require manual labor. Thus, a loosely placed backfill is seemingly being proposed, and faster emtombment using backfill compaction is not being considered. Because brine sorption and minimized gas production through the use of getters are now being completed since the FEIS was written, what is the mechanism for more rapid entombment of waste exclusive of these two processes? It appears from this analysis that the SEIS authors favor getters rather than bulk backfill material.

8. Page 6-8, Figure 6.1, Tentative Location of Panel Seals. The impact on workers' safety after the first panel is sealed, becomes pressurized with hydrogen and other gases, and potentially blows out the bulkhead prior to closing the mine 25 years later, is not discussed in the SEIS. Estimates of the potential pressures should be included.

9. Page 6-10-19, Mitigation by Waste Treatment. The discussion of waste treatment in the SEIS appears to favor postponing any decision on waste processing on the basis that knowledge acquired during or after the Test Phase may modify the approach to take, yet all evidence points to a need for immediate consideration with respect to potential gas generation problems, brine influx, and hazardous waste components. Neither immobilization treatment nor incineration are included in the experiments. The investigation of incinerated wastes and/or immobilization may be more important because of their potential in reducing the problems and hazards associated with gas-generation and hazardous wastes, in addition to ameliorating the consequences of transportation accidents, and enhancing WAC

Certification. Why aren't these treatments being considered in the Test Phase? The lack of experience with incinerators is not the problem, as about 80 incinerators have been operated for this purpose internationally (Page 6-16), and immobilization has been employed at nine commercial reactors (Page 6-13). This experience may be compared to compactor utilization at 74 commercial power reactors (Page 6-17).

10. Page 6-17, Effects of Waste Treatment. It is stated that it is not currently possible to qualitatively estimate any long term benefit from waste treatment. How about the indirect benefits of diffusing objections, meeting Performance Assessment requirements (if otherwise not met), and, in short, allowing disposal to proceed?

SECTION 7

1. Page 7-1, Section 7.1.1. Why is DOE proposing to increase the fenced area at WIPP from 250 acres to 1,454 acres? No explanation is provided.

2. The 1980 FEIS stated, "The waste that is emplaced underground is not expected to release any radioactivity; it will, therefore, produce no long-term radiological impact." The 1989 SEIS repeated this statement that the wastes "would not be expected to release any radioactivity..." Statements like these without documentation of probabilities are inconsistent with the stated DOE position that it will be October 1993 before the DOE can complete the demonstration that the facility can meet the Standards for safe disposal issued by EPA.

3. Page 7-2, Cost Reduction Program. A discussion of the decision under the Cost Reduction Program in 1982 to eliminate the fourth shaft should be included, since subsequent events led the DOE to eventually build the fourth shaft. A number of issues were raised on the Cost Reduction Program by EEG in November 1982 (see EEG-19), and the economic and environmental impacts should be discussed.

4. Page 7-4. DOE concludes that delaying the receipt of TRU waste until compliance with the Standards (Alternative Action) would not result in any difference in unavoidable adverse impacts when compared to the alternative of bringing waste now. In that case, why not commit to full compliance first?

5. Page 7-4. The conclusion that the emplacement of 65,000 drums in WIPP before meeting the Standards would not have any

differences in potential impacts with the option of completing compliance first has not been thought through. If wastes had to be retrieved, the costs of retrieval, transportation risks, and operational risks would be substantially different for both cases. A detailed benefit/risk analysis should be included.

SECTION 8

1. The text discusses slant drilling to permit the extraction of hydrocarbon resources under the WIPP site. This is counter to previous DOE commitments to prevent the extraction of those resources.

2. In addition to the bin tests, discuss alcove tests at sites other than WIPP, since EPA indicated that the earliest date for shipment of RCRA wastes, which are representative of the various waste streams, may be March 1990.

SECTION 9

1. The discussion of conducting bin-scale tests at WIPP versus generating sites should address the potential of a one-year delay for authorization to ship RCRA type waste, which would substantially delay the availability of experimental results.

2. Page 9-4. Add the appropriate references to the list. Only one is shown.

3. The discussion on bin tests should be extended to include alcove tests and room tests.

Was there a commitment by DOE not to allow drilling in Zone IV?

SECTION 10

1. Page 10-6, "Complete waste characterization data for waste expected to be shipped to WIPP is not yet available." Reference whatever data is available.

2. The status of the variance request for a no migration petition should be updated, including an estimate on the earliest date mixed waste could be shipped to WIPP.

3. Add a commitment to the list of regulations for safe transportation to those issued by the U.S. Department of Transportation, 49 CFR, Parts 171 through 178.

4. Add a commitment in Table 10.1 to have the CH-TRU and RH-TRU shipping container certified by NRC.

5. Page 10-13. The text cites the Second Modification of Agreement 4, 1987, to the New Mexico Department of Energy C&C Agreement as the earliest date to meet NRC transportation regulations. Actually, DOE agreed to do this in the October 1980 FEIS, Page 6-1, which states, "The transportation of radioactive waste to the WIPP will comply with the regulations of the U.S. Department of Transportation (DOT) and the corresponding regulations of the U.S. Nuclear Regulatory Commission (NRC)." Unfortunately, DOE would not honor their 1980 FEIS commitment until 1987. This is discussed in EEG-33, "Adequacy of TRUPACT-I Design for Transporting Contact-Handled Transuranic Wastes to WIPP, June 1986," and should be discussed here.

6. Page 10-13. Although there are 8000 shipments of RH-TRU waste identified in the SEIS, the document is silent on the status of that shipping container. Include a drawing of the

shipping cask, the expected date of construction, schedule for testing and planned submittal of documentation to NRC and the expected date of certification.

Include an explanation on the absence of progress in this area since shipments of RH-TRU waste were planned ten years ago.

APPENDIX A

1. Page A-4, Table A.1.1. Table A.1.1 does not show a limit on the amount of RH-TRU waste that can have a maximum surface dose rate of 1,000 rem/hour. It should be 5% of the expected 93,000 cubic feet of RH-TRU or 4,650 cubic feet as agreed in the C&C Agreement as modified. The remainder has a maximum surface dose rate of 100 rem/hour.

2. Page A-5. Change the text to require all CH-TRU waste containers to have a venting feature.

APPENDIX B

1. Page B-2, Inventory. Some explanation should be provided for the enormous changes in waste concentrations and amounts shown in the SEIS in comparison to the FEIS.

2. Page B-3, Table B.2.1. The term "Newly-generated" is used to describe waste that has yet to be produced. A better term might be "to be produced."

3. Page B-4, Table B.2.2. Table B.2.2 lacks units and contains seven-place accuracy for two-thirds of waste yet to be produced.

4. Page B-5, Table B.2.3. Table B.2.3 lack units.

5. Page B-6, Table B.2.4. What is a "volume scale-up?"

6. Page B-7. EEG does not agree with the 1,000 PE-Ci limit per package established by DOE.

7. Page B-7. Additional information on the radioactive waste inventory has been drafted in a report, DOE/WIPP-88-049 (WIPP, 1989), and "constitutes the fundamental basis for analysis reported in the SEIS and in the WIPP FSAR." Since DOE has not provided the report to EEG, no conclusions can be drawn as to its value.

8. Page B-8. Table B.2.5 lacks units.

9. Page B-8, Table B.2.5. Table B.2.5 lacks units. Fill in the blanks in the table which shows major changes from the FEIS.

10. Page B-11, Paragraph Three. The equation includes the 0.80 "fullness" factor. This generates more drums than WIPP can hold and results in 23% more shipments than expected.

11. Page B-12, Table B.2.8. The table indicates 6.26×10^4 m^3 of newly-generated CH waste for Rocky Flats, and 1.29×10^5 containers. This implies a container volume of 0.485 m^3 that does not match either a drum (.208 m^3) or a SWB (1.798 m^3). The value for newly-generated waste in the table (6.24×10^4 m^3) is <u>greater</u> <u>than</u> the value of 5.66×10^4 m^3 (2.0×10^6 ft^3) given in Table B.2.4 (Page B-6) for <u>both</u> stored <u>and</u> new waste at Rocky Flats.

12. The equation in Table B.2.8 includes a factor of 3 m^3/TRUPACT. It is actually 2.9 m^3/TRUPACT for drums, and 3.6 m^3/TRUPACT for SWBs.

13. Page B-13, Table B.2.9. Total RH volume 1.98×10^4 probably should be 1.98×10^1, which would then be consistent with 2.20×10^1 containers. The 19.8 m^3 stored + 5.4 m^3 newly-generated waste (Page B-12) totals 25.2 m^3, somewhat less than the $1.2 \times 10^3 \times .02832 = 34.0$ m^3 indicated by Table B.2.4 (Page B-6).

14. Page B-15, Paragraph One. What is the citation for "updated by WIPP, 1989?" Is it DOE/WIPP 88-005? The citation should be given.

15. Page B-15, Paragraph Two and Table B.2.14 on Page B-20. The process used to obtain the modified inventory for long-term performance analysis, although not cited, was found in SAND 89-0462, pages 4-23 to 4-26. The "modified inventory" shown in Table B.2.14 shows a 22% increase of Am-241 adjusted for decay and ingrowth from Pu-241, whereas, all of the latter is not present in the inventory. Also, there is no

change in the Pu-238 inventory over the time period, nor does Np-237 appear to reflect its production from Am-241. Is the decay time allowed 100 years? What is the justification for this inventory?

16. Page B-15, Section B.2.2.2, Operational Analysis. The draft FSAR is referenced for operational impacts of waste handling and storage at WIPP. It should be noted in the SEIS that reference is being made to a draft, and that changes may have to be reflected in the SEIS. Only a brief mention of "updating" the SEIS for this purpose is mentioned in a footnote.

17. Section B.2.2.3, Long Term Performance Assessment. It is stated that emplacement procedures at WIPP of RH-waste will minimize degradation. In light of brine seepage, how is corrosion of canisters minimized? Also, how does the uncertainty of RH-inventory justify excluding this type of waste in performance assessment? These terms need clarification.

18. Pages B-22 and 23, CH-TRU Mixed Waste. It is not clear how RFP wastes represent a conservative upper bound for potential risks rather than just a representative sample for risk assessment involving hazardous wastes. Are all identified hazardous waste quantities in RFP waste in higher concentrations than that generated at other locations? Is there any quantitative reasoning behind this assumption?

19. Page B-15, High Curie Waste. It is gratifying to note the correction in the SEIS in identifying the heat source Pu-238 contribution is 17% of the inventory, in comparison to the 1.2% used in the FEIS. However, it is not reassuring to realize that the FEIS calculations were predicted on the more dilute weapons grade waste streams and ignored the heat

source Pu-238 wastes.

20. Page B-16, Table B.2.10. An explanation should be provided for the increases in the activities represented in the SEIS from the FSAR.

	Factor Of
Pu-238 increased	260
Pu-239 increased	2
Pu-240 increased	1.7
Pu-241 increased	2.4
Am-241 increased	300
TOTAL	6.2

21. Page B-17, Table B.2.11. Table B.2.11 describes waste in a Standard Waste Box. Hence, mass and activity should not be shown as "grams per drum" and "Ci per drum." They should be "g/box" and "Ci/box."

22. Page B-18, Table B.2.12. While the table is technically correct in telling the reader that daughter products are not included in reporting 260 Ci/container of RH-TRU waste, it is deliberately misleading to delete the contribution of Y-90 of 250 Ci and report only half of the actual radioactivity present in the container, which is 510 Ci. Besides, the Y-90 was included in the FEIS Volume II, Page E-4, which shows 5.1×10^2 Ci/canister. The deletion masks the 12-fold reduction of radioactivity in each container. Please explain the difference.

23. Page B-19, Table B.2.13. The table lists the initial CH-TRU inventory. A similar table should be provided with the initial inventory for RH-TRU, which would include fission products and activation products.

APPENDIX C

EEG has had a number of critical comments on the adequacy of the emergency response program and has transmitted these concerns to DOE in a June 21, 1989, letter from the Director of EEG to the WIPP Project Manager. Hence, those concerns will not be duplicated here with the expectation that they will be addressed in the Final SEIS.

1. Page C-7, Emergency Response Scenario. There are a number of unrealistic conditions portrayed in the emergency response scenario. It is unlikely that any state's police officer would have the expertise to verify that radiation levels were at normal background levels even if he did have the correct instrumentation. Radiochemical analyses of soil samples would be required if the goal was to return the accident area to background levels as is inferred.

APPENDIX D

1. Page D-10 and 11. The text indicates that all applicable U.S. DOT regulations, with respect to "preferred routes," have been implemented. They have not.

The definition of preferred route in the context of U.S. Department of Transportation regulations is incorrect and fails to acknowledge the May 8, 1988, revision of the U.S. Department of Transportation regulations, 49 CFR 177.825, requiring a state to formally notify DOT when it has completed the procedures. Such notification has not occurred and the text should make this clear.

The first 42 pages of this appendix cover routes to WIPP in considerable detail. This is useful information, and only a few minor discrepancies were noted.

Incident Free Transportation

1. Page D-47, Table D.3.2. Footnote B shows that the 0.80 factor, erroneously used throughout the SEIS, is used in calculating the number of shipments. See our comments in the Summary Chapter. However, we believe it would be appropriate to use a factor to allow for the likelihood that TRUPACT shipments from some generators will be weight-limited. For example, they will not be able to carry 14 drums and stay within permitted trailer weight limits. This is because the average payload of the three TRUPACTS on a trailer is now down to about 5,300 pounds per TRUPACT (380 pounds per drum), and there have been predictions that RFP wastes will average about 600 pounds/drum after the supercompactor is operational in 1990.

2. Page D-48, Table D.3.3. This table is very useful

because it gives the average radionuclide distribution and concentration for each generator. It also points out that any use of RFP wastes as a typical or average waste is incorrect and misleading. The SEIS uses an average RFP trailer-load for the "bounding" transportation accident. The average trailer-load is 183 PE-Ci, 6.5 times the RFP average. The SRP wastes, which comprise 11.9% of all shipments, average 1,787 PE-Ci, 63.8 times the RFP average. It is noted that the values in this table should be calculable from Tables 13.2.1, D.3.1, and D.3.2, but they are not consistent even with the 0.8 factor.

3. Page D-53, Table D.3.7. The stop time (hr/km) for trucks seems unreasonably high. For example, on the LANL to WIPP route, the vehicle would have 7.02 hours of driving time and 6.07 hours of stops.

4. Pages D-50 to D-57, Tables D.3.5 to D.3.10. We have spot-checked the dose values presented in Tables D.3.8 - D.3.10 by non-RADTRAN methodology and believe they are reasonable. See additional comments on Chapter 5 in the significance of these doses. However, in Table D.3.10, we note that the differences between the proposed action and alternative action apparently do not assume RFP waste will be transported to INEL with the alternative action scenario. If they were, the approximately 1,270 (or 1,590 with 0.8 factor) shipments during five years would result in about 100 - 130 additional person-rem, compared to direct shipment.

5. Page D-57 and Table D.3.14. The claim that the "...hypothetical maximum exposure to an individual from incident-free transportation during Test Phase and Disposal Phase is only 1.6 millirems over 25 years..." is unreasonably low. This value would be approximately correct for a resident at a 100-foot distance from a roadway where trucks

were stopped for 30 seconds each. However, there are locations along the route where residences are within 50 feet of the roadway, and this would lead to doses of about 6 mrem.

But the above assumptions are not reasonable for the maximum exposed individual. For example:

A. A person in the adjoining traffic lane for <u>one</u> 30-minute period during the entire lifetime of WIPP would receive a dose of 2.6 mrem from an average ORNL CH-TRU load and 3.1 mrem from a Hanford RH-TRU shipment.

B. An employee at a restaurant who is exposed to 10% of all trucks stopped for 45 minutes each from a distance of 100 feet would receive about 14 mrem. If this person were exposed to 5% of trucks at a distance of 50 feet, the 25-year dose would be about 26 mrem.

C. A service station attendant who refuels 10% of all trucks and spends two minutes each time at a distance of 10 feet from the center of the truck would receive almost 110 mrem over the 25 years.

D. A guard at the entry to the WIPP site (who is not a "member of the public") who observed one-half of all shipments being checked for contamination (the present procedure takes over 15 minutes) at a distance of 25 feet would receive about 450 mrem.

None of the above assumptions are incredible or bounding. They are likely to happen. The SEIS should not try to trivialize the maximum individual doses by presenting non-conservative dose estimates.

Transportation Accidents

1. Page D-57, Severity Categories. The claim that 99.5% of truck and 99.6% of rail accidents are less severe than regulatory criteria is not consistent with other statements and the calculations presented in this section. For example, the statement is made on Page D-68 that Severity Category III slightly exceeds the regulatory limits and Tables D.3.15 and D.3.16 (which are used in the calculations) show that 9% of truck and 20% of rail accidents are Category III or higher.

2. Page D-73, Table D.3.19. EEG believes the Total Respirable Release Fraction (TRRF) values given for the various Severity Categories are conservative. In fact, they are more conservative than the values used in EEG-33 for a doubly contained, non-vented TRUPACT, except for the Category VIII accident.

3. Page D-79, Resuspension. We do not agree with the assumption that governmental authorities will impound foodstuffs and clean up contaminated land to the level necessary to result in zero dose from ingestion. The RADTRAN III model can calculate ingestion doses, and it should be used here.

4. Pages D-79 to D-86, Accidental Risk Results. We have checked portions of the risk results and believe that the total values are reasonable and conservative. Also, we agree that the probabilistic method of calculating the "expected" radiation doses from accidents is appropriate. However, presenting the results only in a probabilistic manner hides much of the impact from a non-technical or casual technical reader.

For example, the total number of accidents expected was not found in either Volume 1 or 2. One can calculate a value of 78 accidents with wastes and an equal number without wastes. Also, one can calculate a prediction of 7.0 accidents where radioactive material is released, and 4.8 of these would be in urban or suburban areas.

Route specific totals could also be calculated. For example, LANL shipments would lead to 1.64 accidents, 0.19 deaths, and 1.19 injuries. The expected number of release accidents would be 0.15, and about 40% of these would be in suburban areas. If 40% of the suburban accidents occurred in Santa Fe, there would be about a 2.3% probability of a release occurring.

Accident results should be presented in a form where laymen can get a feel for the number and severity of release accidents that may occur along routes where they live. Another statistic that would be informative to laymen is that in the section of the route between Vaughn and Carlsbad (which carries about 91% of all WIPP vehicles) on Highway 285, there would be about a 3.4% probability of an accident occurring along each mile of roadway. There would be about 0.3% probability of a release accident per mile.

Bounding Transportation Accident

EEG does not believe the "bounding case" transportation accident is bounding. Our reason is principally due to the choice of a typical RFP waste trailer load. The average RFP trailer would carry only 28 Plutonium Equivalent Curies (PE-Ci). The averages, concentrations, and percentages of shipments from major generating sites are:

SITE	AVERAGE TRAILER (PE-Ci)	PERCENTAGE OF CH-TRU SHIPMENTS
RFP	28.	32.8

SRP	1787.	11.9
LANL	583.	10.3
LLNL	231.	4.2
Hanford	67.	13.0
INEL	61.	23.5
ORNL	338.	1.1
CH-TRU Average	183.	100

We believe that a "bounding case" should include the average SRP waste, which comprises about 12% of the total CH-TRU shipments.

Otherwise, the values assumed for parameters are conservative. The 2E-4 fractional release rate is twice that used by EEG for a Severity Category VII accident.

Consequently, the "EEG Bounding Accident" would be a release fraction of 0.5 times the SEIS release value, and a PE-Ci load of 63.8 times. This would result in a population dose of 35,800 person-rem. The estimated latent cancer fatalities (LCF) would be 10.0.

The probability of the "EEG Bounding Accident" can be calculated from data in Appendix D. The probability is about 0.1% (1E-3), certainly not incredible.

There are other probabilities that can be determined from those data and assumptions. The total probability of having an accident that leads to greater than 1.0 LCF (>3,570 person-rem) is 2.5×10^{-3} from the SRP, LANL, LLNL, and ORNL routes. The total probability of having an accident that leads to 0.75 - 1.0 LCF is 3.7×10^{-3} from the Hanford, INEL, and ORNL (suburban) routes.

The SEIS should clearly present some of these doses and probabilities so that the reviewer understands you are predicting a fairly high possibility of accidents leading to latent cancer fatalities.

Nonradiological and Nonchemical Consequences

There is only one basic comment on this section (and related portions of Volume 1). The differences in projected deaths from shipments by truck (8.3) vis a vis rail (3.0) is significant. Likewise, the expected injuries are 106 by truck and 34 by rail. These are the most significant health and safety impacts predicted anywhere in the SEIS. Yet, there is no discussion of why the truck mode is being chosen and why this difference of 5.3 deaths and 72 injuries is considered negligible. Also, if all RFP wastes for the first five years were shipped to INEL for storage (and then to WIPP later), this would be expected to add about 0.3 - 0.4 accidental deaths by truck (compared to the proposed plan). Yet, Table D.4.8 shows 0.11 less deaths for the alternative plan (RFP + INEL shipments) than the compared plan values in Table D.4.6. Why?

APPENDIX E

1. Page E-5. Appendix D should read "E".

2. Page E-18, Hole NG252. It is stated that hole NG252 appears to be an anomaly because of its substantially higher rate of brine flow than other comparable holes distant and nearby. How can a real observation and measurement be considered an anomaly?

3. Page E-49 to 54, WIPP Brine Flow Model. References are made to a significant number of citations ...36, 37, 25, 40, Figure 1, Appendix A, Sec 4.3.4 which are either not identified in the SEIS, or are not referred to in the discussion. This information should be included in the SEIS.

4. Page E-55 and 59, WIPP Moisture Release Data. References are made to citations, 30, 25, 26, 29, Table 1, Table 2, Figure 2, which are also not identified in the SEIS as they should be. It appears that the brine flow and moisture release information in the SEIS were taken from another publication(s) where the citations appeared. The references for these documents should also be included in the SEIS if they were not referenced in the missing citations.

5. Page E-57, Equation(8). Shouldn't the parameter listed as 10E14 be listed as 10E-14?

APPENDIX F

1. Page F-2, Stack Effluent Modeling. It should be explained how a stack which exhausts gases and particulates at an acute angle to the horizontal and shrouded to force exit in one direction can be made to fit Rupp's Equation for estimating effective stack height. The resulting effective stack height from the use of this equation is probably not valid. Since it probably affects the shape of the exhaust plume as well, the use of the equation without modification should be verified in the SEIS.

2. Page F-2, Dispersion Modeling. The use of a constant scavenging coefficient is probably not conservative. Precipitation scavenging is about 10 times more efficient than dry deposition mechanisms in removing particulates from the atmosphere and varies with the amount of precipitation. Scavenging should be coupled to precipitation pattern at the site with other parameters such as wind direction and velocity. Precipitation varies both temporally and in amount throughout the year at WIPP with most of the precipitation occurring during the growing season. Where precipitation is more evenly distributed and in larger amounts than occur at WIPP, the assumption may have more validity. If this assumption is to be used for performance assessment, then it should be verified with models which take the stochastic and temporal characteristics of precipitation events at the site into consideration. It does not appear to be a valid assumption at WIPP.

In the case of accidental releases, the occurrence of an accident during an intense precipitation event (or scavenging) should not be discounted as indicated in the SEIS. In fact the probablity of a serious accident is increased by bad weather conditions which limit visibility and affect road conditions. A scenario of this type should be included in the SEIS as a credible event.

3. Page F-2, Terrestrial Modeling. What is the scientific basis for using 12.5 years (one-half the repository life) as the period of long-term buildup of radioactivity on the soil surface. How does the life of the facility enter into the determination of this process. Why isn't the build-up process modeled?

4. Page F-3, Dose Modeling. The terms "exponential transfer" and "decaying exponential functions" are not used properly when modeling ingestion. The transfer is governed by exponential functions, not exponential transport. Retention of nuclides in organs is represented by exponential functions with negative exponents, not decaying exponential functions.

5. Page F-4, Table F.1, Meteorological Data. It is not clear from the footnote "Categories A-D are not utilized in AIRDOS-EPA Code" how the frequencies for the individual stability classes are adjusted for in the model, unless one stability class is being used in the simulation. The adjustment of frequencies other than A-D should be explained in the SEIS.

6. Page F-8, Table F.5, Stack Information. Are the reported values actual stack heights? If so, then "effective stack heights" should also be included in the Table as estimated from the use of the Rupp equation. How is the correction made for the angular and directional release of the exhaust stack from the repository? Is it valid to apply Rupp's equation to stack(s) in question? If so, please document how this adjustment is made.

7. Page F-9, Table F.6, Terrestrial Modeling Assumptions. How was the build-up time of 4,562.5 days for surface deposition obtained? What is the scientific basis for this determination? Why is the resuspension rate of particulate matter from both soils and plants not taken into account in the model? Also, why have potential contamination pathways involving erosion events (saltation-creep, rainsplash) been ignored in the model since they are important processes in arid sites? Why is it that physical removal of particulates (weathering) from plant surfaces was considered without including these other important processes?

Were the reported biomass densities of forage crops fresh weight or dry weight? In either case, the reported value appears high by a factor of 2-3 above the forage biomass values existing at the site. These larger biomass densities would tend to decrease radionuclide intakes because of tissue dilution of surficial contamination and lower resuspension rates with increasing biomass density and crown cover.

Why is a value of 15.6 kg/day utilized as a consumption rate in lieu of the NRC-reported value of 12.5 kg/day for cattle? A lag period from slaughter of beef to consumption of meat by humans (20 days) is used in the model although it is not that important for transuranics. However, it is not clear whether a similar and more important lag between grazing and slaughter has been incorporated in the model. The build-up of radionuclides in beef tissue during this period is significant, and it is not clear whether this period of radionuclide ingrowth in these tissues has been taken into consideration in making dose calculations. If not, then the total amount of radioactivity ingested by humans from this pathway would be underestimated and incorrect. More documentation of this process is required in the SEIS.

8. Page F-19, C2: Drum Drop From a Forklift. The use of the average radionuclide content of a drum (12.9 PE-Ci) is not conservative, even though other parameters may have been conservatively assumed. The maximum allowed content (1000 PE-Ci) would have been the most conservative approach, while a value at the 99% c.l. of the activity distribution would have been more realistic in bounding the release. Also, reference is made to the draft FSAR for more specific information concerning this scenario, yet the description is identical to the SEIS; hence no new needed information for evaluation of this scenario is available. Also, the time of exposure of the worker that is 20 feet away is not included in the SEIS (or FSAR) which does not allow straightforward verification of dose calculations in this case. It is not clear what type of exposure would be received by the forklift operator if he became immersed in the cloud. Furthermore, if the operator removed the forklift from the punctured drum before he left the scene, then the activity from the punctured drum would probably reach him before he could shut down the forklift and take flight. This scenario is not conceptually well established as it now stands and needs more study. Finally, what is the scientific basis for the contamination dispersal rate used in these calculations?

9. Page F-22, Hoist Cage Drop. The annual probability of a catastrophic accident is given as 1.7×10^{-8} and concludes that such an accident is not credible. Over a 30-year operational life of WIPP, that becomes 0.51×10^{-6}. EEG has never agreed with the assumptions and calculations used by DOE and still believes such an accident is sufficiently credible to warrant the calculation of the consequences which would require a higher QA classification system than the one used in the hoist system.

The assumption by DOE that faulty maintenance would be negligible as a contributing factor to a potential accident was found to be incorrect when workmen installed a valve backwards in the waste hoist system. Similarly, excluding human error as a contributing factor to a potential accident was found incorrect when the wrong valve was purchased and installed. The assumption that a poor design could not contribute may now be considered unreasonable based on the recent defects found in one of the three main bearings on the hoist shaft. Our position has been expressed in letters to the WIPP Project Manager dated May 15, 1985, October 8, 1985 and April 8, 1986.

EEG is aware that our request in 1980 to address the consequences of a fire in the mine was rejected by DOE on the basis that it was an incredible event. Earlier this month, there was a fire in an instrumentation panel in the mine.

10. Page F-23, Fire Within A Drum Underground. What criteria were used in estimating that 80% of the heated aerosol was deposited on the walls of the repository before leaving in the exhaust stream?

11. Page F-24, R5: Hoist Drop With a Canister of RH Waste. The premise for not including this scenario as a credible accident is the same as C8, and is submitted without proof or evidence in support of the assumption. This information should be provided in the SEIS.

APPENDIX G

1. Page G-4, Summary. The formula for methylene chloride is CH_2Cl_2, not Ch_2Cl_2.

2. Page G-4, 5, Fate and Transport. Reference is made to biodegradation of CH_2Cl_2 occurring both aerobically and anaerobically. A reference or documentation to this effect should be included in the SEIS.

3. Page G-8, Health Effects. Reference is made to an LC50 for rats of 14,000 mg/kg. It appears that LC50 has been confused with an oral LD50; otherwise what do the units refer to in terms of concentration?

4. Page G-24, Long Term Risk Estimation for Non-Carcinogens, Routine Operations. The basis for excluding non-carcinogens if they are present in amounts less than 1% by weight is not clear. Since the reference cited is not readily available (Rockwell, 1985), a summary or explanation of its contents should be included in the SEIS. Also, in equation G-4, the term "Ri" and RLi" appear to reference the same variable. What is the correct usage? If Li is a variable, then it should be defined in the SEIS.

5. Page G-24, 25, Risks Associated With Accident Scenarios. What does the phrase "...to the only occupational population" mean? Also, what is the meaning of "residential exposure," and how does the assumption of filtration validate that the latter are assumed to be excluded from exposure? Does the filtration system also "filter" out VOC's? How does dilution exclude persons from exposure?

APPENDIX H

1. Page H-6. In the section on EEG, add the sentence "EEG has published 40 major reports on their investigation and analyses." That is far more significant than the number of quarterly meetings between DOE and EEG, which appears to trivialize the 11 years of work.

APPENDIX I

In general the SEIS provides information in the form of Tables and Figures which are quite useful for verification purposes. However, in many cases involving dose calculations, some of the assumed parameters are either not present in the SEIS, or must be searched for in an unspecified location in the two volumes. Furthermore, there usually isn't any citation as to where these parameters may be located. This makes it difficult, if not impossible, to verify some of the SEIS dose estimates for a reader that is not familiar with secondary sources which provide this information. This has lead to the use of more than one value in the SEIS for a given parameter and to units for these parameters which give incorrect dimensional analysis in the document itself. Therefore, it is imperative that the assumed values for parameters be presented in the SEIS at each location where doses are being estimated. In addition, many of the parameter estimates are "assumed values" and are presented without any validation of their worth to the reader. All assumed values should be more fully justified in the SEIS to give them more credibility.

Several other problems arise with respect to pathway analyses notwithstanding those already discussed. A major problem is the reliance on established source codes to the extent that flexibility or site-specific alternative pathways or processes of importance to the WIPP site may be excluded. The rationale given in some instances is that many of these processes are not significant and, therefore, are not worthy of analysis. However, the analysis upon which these conclusions are based may be flawed, and have not been validated or proved. Investigators who utilize established codes are not exempt from using realistic input parameters and from incorporating site-specific information if necessary. An example is the use of the Rupp equation for determining effective stack heights of the two underground exhaust stacks at WIPP: the existing configuration is probably not amenable to this type of analysis, yet it is still utilized in the SEIS for this purpose. Another example concerns the climatology of the WIPP environment: erosion events which may significantly contribute to the atmospheric transport of contaminants to man are ignored because they are not readily incorporated into the codes being used in the analyses. The SEIS is silent on these issues.

There also appears to be a generalized carelessness with respect to the assemblage of transport pathways of contaminants, particularly those involving the food chain. Some of the large discrepancies in dose estimates have been caused by the failure of the SEIS to properly estimate steady-state concentrations of contaminants in soils as a result of air deposition events, and by not accounting for ingrowth of contaminant concentrations in beef tissue beyond one day. These oversights should be addressed in the SEIS.

SPECIFIC COMMENTS

1. Page I-5, top. Arrival times at points of interest for cases 1A and 1B "were determined by the times at which the discharge rates rose to 10^{-18} Ci/day." This extremely low activity represents material discharged per day having an activity of only about <u>one</u> disintegration per <u>year</u>! This represents the extreme leading edge of a distributed nuclide and <u>effective</u> arrival times are <u>longer</u> than stated.

2. Page I-7, The Swift II Groundwater Transport Code, Influence Functions. Figure 1.1.2.1 referred to in the text

is missing, it should be Figure 1.1.1.

3. Page I-13, Table 1.1.3.1, Maximum Dose Received by a Member of the Drilling Crew. Plutonium-239 is cited twice in the Table. Does the first citation refer to Pu-238?

4. Page I-14, Table 1.1.3.2, Radionuclide Concentrations in Dried Mud Pit. Not enough information was presented in the SEIS to reproduce the values in this Table. They were reproduced by using the assumptions presented in SAND 89-0462 (p. 5-9) which was not cited for this purpose. The use of "drum equivalents" for TRU activities is nowhere mentioned in this section (we could not find it in the entire SEIS), yet it is not possible to estimate the values without it. Also, other assumptions: percent solid in mud(50%), density of dried mud (1.4 g/cc) were also found in SAND 89-0462. Curiously, the density of the mud for plume dispersion is given as 2.0 g/cc which is inconsistent. The SEIS should settle on one value for both calculations and "stick" to it.

5. Page I-15, Table 1.1.3.3, Air Concentrations And Deposition Fluxes. The values of Ci/M3 in this Table appear to be about 20+% too low based on eq.(I-37) unless drum equivalent activities are being used. Our calculation is summarized below.

Assumptions:

Mud Density = 2.0 g/cc (p)
Wind Velocity = 3.7 m/s (U)
Resuspension Rate = 5.065E-12 (1/s)
Distance Downwind = 500 M (d)
Plume Vertical Standard Deviation = 40.92 m (Tz)
Plume Lateral Standard Deviation = 57.68 m (Ty)
Depth of Resuspension Layer = 1 cm (do)
Area of Mud Surface = 46.45 m2 (A)
  (taken from Pb plume, Page I-29)
Mud Activity = 1.54E-8 Ci/g (CS) for Pu-239
Source Strength = 1e04*p*do*A*K*CS, Ci/s (Q)
Air Concentration = 2*Q/2.51*3*Ty*Tz*U

= (2*2*1*46.45*5.065E-12*1.54E8*1e04)/
(2.51*3*57.68*40.92*3.7)
= 2.2E-18 Ci/m3 (X)
(reported value = 1.68E-18 Ci/m3)

Assuming a density of 1.4 g/cc yields X = 1.54 E-18 Ci/m3 for this parameter, however, recalculation of Ty and Tz:

Ty = 0.11*d/(1+1E-4*d)1/2 = 53.67 m,
Tz = 0.08*d/(1+2E-4*d)1/2 = 36.36 m, which yields a value of:
X = 1.86E-18 Ci/m3.

The FEIS reports a pit area of 66.9 m2 for resuspension of radionuclides and 46.45 m2 is reported for resuspension of Pb from the same mud pit in the SEIS, a factor of 1.4 difference for these estimates. Why do the areas vary? Which one was used in obtaining the reported values? If the higher value was used, then greater disagreement in estimates arises.

6. Page I-16, Table 1.1.3.4, Steady State Soil Concentrations. The steady state soil concentrations as reported in Table I.1.3.4 appear to be very low estimates based on steady state approximation. Our calculation used the following assumptions from SAND89-0462, Page 7-9:

Plow Layer Thickness = 0.2 m (plt)
Soil Density = 1.4e03 Kg/m3 (p)
Sink Loss Rate = 1.1E-4 /d (lr)
Deposition Rate = 1.68E-20 Ci/m2-s
= 1.452E-15 Ci/m2-day (I)
Soil Radionuclide Buildup as a Function of Time, Days, QA(t), Ci/m2 = (I/lr)*(1-exp(-lr*t), for t=100 years and negligible radioactive decay.
= (1.45E-15/1.1E-4)*(1-exp(-1.1E-4*100*365))
= (1.32E-11)•(1-.018)
= 1.3E-11 Ci/m2
Mass of Soil = plt*1*p
= 0.2*1*1.4e03
= 280kg/m2
Pu-239 Concentration, Ci/kg Soil = 1.3E-11/280
= 4.64E-14 Ci/kg

The reported value = 5.17E-18 Ci/kg, is a factor of 8,975 too low. The details of how this estimate was derived is not included in the SEIS, therefore, it is not possible to compare analytical strategies. Since the relationship between soil concentrations and rem doses is linear, then those contributed from beef, milk, vegetables, and root crops are also underestimated by almost four orders of magnitude. However, other factors also contribute further in underestimating these pathways.

7. Page I-18, Exposure From Stock Well Water. A reference to Table 5.7 should be to Table 5.59. The former refers to annual cumulative exposures from RH-TRU waste, whereas, the latter refers to stock well water concentrations at 1,000 years.

8. Page I-19 to 21, Soil-Plant-Beef Pathway Analysis Using Pu-239 as an Example. The following assumptions were used:

Soil Specific Activity = 5.18E-18 Ci/kg (CPu)
Soil-Plant Transfer Factor = 1.4E-2 Kg-p/Kg-s (SPF)
Forage-Meat Transfer Factor = 1.0E-6 d/Kg-meat (FMF)
Forage Consumption Rate = 15 Kg-p/d (FCR)
Feeding Period to Slaughter = 200 days (FP)
Biological Half-Life = 64000 days (TB)

The concentration in beef after 1 day of feeding ,uCi/Kg-meat, (CBD) is estimated as:

CBD = CPu*SPF*FMF*FCR*1e06 uCi/Ci
= 1.0857E-18 uci/Kg-meat

The concentration in beef after 200 days, uCi/Kg-meat, (CB200D) is estimated as:

CB200D = (CBD/(.693/TB)*(1 - exp(-(.693/TB)*FP))

= (1.0E-13)*(.0022)
= 2.2E-16 uCi/Kg at

If one uses the concentration in beef after one day of feeding, then the committed dose after one-year consumption is estimated as 1.95E-15 mrem/50 year integration. The reported value (1.98E-15) agrees with this estimate quite well, however, it is a factor of 199 too low if the beef concentration at slaughter time (200 days) is used in the estimate, providing all other assumptions are correct. Previously it was determined that soil concentrations were a factor of 8,975 too low, hence an underestimate of as much as 1.82E6 are reported, and the rem dose would be 3.7E-09 mrem/50 year integration. Similarly, the dose contribution from milk, vegetables, and root crops would be a factor of 8,975 too low because of the higher soil radioactivity. The corresponding corrected values for milk, vegetables, and root crops would be 2.8E-13, 3.4E-8, and 1.4E-7 mrems/50 year integration period, respectively. These pathways would yield a total of 1.8E-7 mrems/50 years, whereas the reported dose total equals 1.96E-11 for this radionuclide or a factor of 9,183 too low. Assuming that this underestimate applies to all radionuclides, then the reported dose for these pathways (4.87E-10 mrem/50yr) would be increased to about 4.5E-07 mrem/50 years. Throughout this analysis it has been assumed that a 20cm plow layer has been used for beef cattle grazing such as on winter wheat. If cattle are grazing on open range, then the thickness of the radionuclides deposit is closer to 2cm or the Pu-239 concentration is a factor of ten higher than the corrected value or 4.64E-13 Ci/Kg. Assuming that cattle at the WIPP site consume one pound of soil/day from foraging in an arid environment, then the daily intake would be 2.1E-13 Ci/day from this source. The dose from this pathway alone would be 1.68E-8 mrem/50 year integration period or about 1.3E-8 mrem/50 year when adjusted for that present on vegetation surfaces.

Inclusion of this pathway in the total analysis would increase the dose to 4.6E-07 mrem/50 yr. These values are admittedly small when compared to doses resulting from inhalation, but are not as small as that reported. As commented earlier, the method of estimating deposition using a constant value may yield lower soil activity values than one which employs stochastic methods involving precipitation pattern and precipitation amounts. Also, the contribution of beef cow radionuclide uptake from inhalation and translocation to internal organs and tissues has been ignored in these calculations.

9. Page I-19 to 21, Inhalation Pathway for Humans. The reported dose from this pathway (5.4E-2 mrem/50 yr) compares well with our estimate (5.44E-2 mrem/50 yr).

10. Page I-20, 21, Stock Well Pathway Using Pu-239 as an Example and Case IIB. The values reported for Np-237, Pb-210, Pu-239, and Pu-240 are 1.0E06 too low (column 5); all other values for the rest of this column and for other columns are correct according to the assumptions used. The confusion comes from the use of the relationship presented in the footnote; Column H = FxGx365(days) where F is given in Ci/d, and G is given in rem/uCi, that is H must be multiplied by 1.0E06 to make the conversion to uCi/d before the terms can be multiplied. The conversions were made for all calculations except those noted.

Assumptions for Beef Cows:

Water Consumption Rate = 49 Kg/d (WCR)
Pu-239 Activity in Water = 6.66E-8 Ci/Kg (CWpu)
Water-Meat Conversion Factor = 5.0E-7 d/Kg (WMF)
Feeding Period to Slaughter = 200 days (FP)
Biological Half-Life = 64000 days (TB)

The concentration in beef after one day of drinking water, Ci/Kg-meat, (CBD) is estimated as:

CBD = CWPu*WCR*WMF*1.0e06 uCi/Ci
= 1.66E-6 uCi/Kg

The concentration in beef after 200 days, uCi/Kg-meat, (CB200D) is estimated as :

CB200D = (CBD/(.693/TB))*(1-exp(-(.693/TB)*FP))
= (1.53E-1)*(.0022)
= 3.4E-4 uCi/Kg-meat

The dose obtained when using the Pu-239 concentration in beef after one day of drinking water uptake agrees quite well with that reported (.224 mrem/50yr vs .225 mrem/50yr), however, the concentration after 200 days water consumption is 199 times greater. Therefore, the 50-year committed dose would be 46 mrem/50 yrs on this basis which alone exceeds the EPA Standard. Assuming that this analysis applies to all radionuclides in the water, then the following doses would be projected:

Case IA:	reported = 2.09E-4	corrected = .0425 mrem/50y
Case IIB:	= 72	= 14630
Case IIC:	= 129	= 26213
Case IID:	= .915	= 186

With the exception of Case IA, all cases exceed the standard on this basis.

11. Page I-22, Calculation For Chemical Exposure Pathways. It is not entirely clear why lead is selected as a representative toxic metal in lieu of others, such as cadmium, which may be more toxic, other than it is present in the

highest concentration. Some further explanation of other wastes, including organics, should be included in the SEIS to document or justify this "lead bounding" assumption further.

12. Page I-23, Modeling Assumptions For Calculating Lead Solubility in Culebra Groundwater. Why hasn't the possibility of chelation of metallic ions by organic compounds been considered in these calculations? Some of the compounds used for decontamination purposes are of this type.

13. Page I-27, Health Effects Associated With Stable Lead From Wind Dispersion. Because cattle consume significant quantities of soil, which is present on plant surfaces as a result of erosion processes (lbs/day), it may not be advisable to ignore lead consumption by animals through this pathway. Do any of the models employed incorporate this pathway? Also, why wasn't inhalation of lead contaminants taken into consideration from both ambient and resuspension pathways for these animals?

14. Page I-28, Calculation of Inhalation of Pb Containing Particulates. The variable (RV) is given in units mg/m3/day and m3/day. Dimensional analysis indicates that the latter set of units is applicable. Also, the conversion factor should probably be in mg/g rather than ug/mg for the same reason (although they are equivalent). Finally, the equation incorporating these variables should be:

$$Ir = (Cai) \bullet (RV) * (Tai) \bullet (A) / Wa$$

To obtain the correct units for Ir:

$$(g/m3)(m3/day)(mg/g)(1/kg) = mg/kg/day$$

The reported equation has the variable (A) incorrectly in the denominator. Were the calculations in the SEIS made with the reported equation?

15. Page I-29, Table 1.1.4.5, Calculation of the Ambient Lead Concentration at Receptor Site. The equation used for these calculations shows 2*pi rather than the square root of 2*pi as required (see equation I-37, Page I-14). However, the actual estimate does use the square root value in arriving at the average concentration estimate. This equation should be corrected.

16. Page I-32, Intake by Beef Cattle. The parameter "49.21" is assumed to be the variable (Qw) referenced in Table 1.1.4.5, however, the value reported is 49.0 l/day. Is there any significance to this inconsistency?

17. Page I-35, Waste Porosity. The void ratio, e = Vv/Vrs, is not clear. Is the term "Vrs" actually "Vs" defined as the solid volume? If not, then what is "rs"? Should not the equation be e = Vv/Vs?

18. Page I-25 to 33, Lead Pathway Analysis. The reported value for the concentration of Pb in the drilling mud (3.6E-5 g-Pb/g-mud) agrees with our estimate (3.602E-5 g/g) assuming a mud density (2g/cc), 22,000 gal (1.665E8 g), and 6 Kg of Pb in the mud overall. Two values of air concentration at the designated distance downwind (500 m) are obtained depending on the values of Ty and Tz. Using the reported values (Ty = 57.68 m, Tz = 40.92 m), a value of 5.15E-15 g/m3 is obtained which compares with the reported value (5.16E-15 g/m3) quite well. The value obtained when using the recalculated values of these parameters under the conditions specified (Ty = 53.67 m, Tz = 36.36 m) yields a slightly higher estimate (6.23E-15 g/g). The SEIS text is inaccurate because it confuses g/m3 with ug/m3 in several locations (Page I-27). Also, when radionuclides were being considered, a steady-state concentration of radionuclide

soil concentrations was used as a result of deposition at the receptor site (100 years). Why was only one year of Pb deposition utilized in these analyses assuming parallel exposure scenarios? The reported air deposition at the site after one year (1.63E-9 g/m2) compared with our estimate (1.62E-9 g/m2). However, assuming steady-state accumulation and a Pb loss rate from the plow layer equal to 1.1E-4, then a concentration of 1.45E-5 g/m2 results over a 100-year period as described earlier for radionuclides. Estimation of Pb concentration uptakes in mg/kg/day for beef cattle via this pathway is based on the following assumptions:

Soil Pb Concentration = 1.45E-5(g-Pb/m2)/280(Kg-s/m2)
= 5.2E-8 g/Kg (CPb)
Soil-Plant Transfer Factor = 0.1 Kg-p/Kg-s (SPF)
Forage-Meat Transfer Factor = 3.0E-4 d/Kg-meat (FMF)
Forage Consumption Rate = 15 Kg-p/d (FCR)
Feeding Period to Slaughter = 200 d (FP)
Biological Half-Time = 1460 d (TB)

The concentration in beef after one day of feeding, g/Kg-meat, CBD is estimated as:

CBD = CPb*SFP*FMF*FCR

CBD = CPb*SPF*FMF*FCR
= 2.3E-11 g/Kg-meat

The concentration in beef after 200 days, g/Kg-meat (CB200D) is estimated as:

CB200D = (CBD/(.693/TB)*(1 - exp(-(.693/TB)*FP))
= (4.85E-8)*(.091)
= 4.4E-09 g/Kg-meat

This analysis agrees with the statement in the SEIS that this pathway contributes an insignificant Pb burden to humans.

Pathway analysis on plant food consumption yields comparably low values as well, even after steady-state soil concentrations are reached.

The calculation involving the inhalation of Pb by humans is flawed in the following ways:

A. The relationship used is in error. The relationship requires the conversion factor 1000 mg/g to be in the numerator:

Ir = Ca(g/m3)*RV(m3/d)*Ta1*A(mg/g)/Wa(Kg)
= mg/Kg/day

B. The concentration employed is 5.16E-9 g/m3 which is 5.16E-9 ug/m3; thus, the value 5.16E-15 g/m3 is correct.

The calculation yields, (5.16E-15)(20)(.35)(1000)/70 = 5.16E-13, which yields the reported value by coincidence. In addition, there are two sets of units for RV.

19. Page I-30, Transport of Pb From Stock Water to Beef Cows. The reported concentration of Pb in stock well water (2.31 mg/l) was obtained from a 10 mg/l prediction of SWIFT-II allowing for lateral dispersion of 4.2 which gives an estimate of 2.38 mg/l from the ratio 10/4.2. The correction for dispersion was not mentioned in connection with radionuclide concentrations, and the SEIS should document that SWIFT-II does not make this correction in its operation. The following assumptions were used to predict the transport of Pb from well water to beef cattle:

Concentration of Pb in Well Water = 2.31 mg/l (CPbW)
Water Consumption Rate = 49 Kg/d (WCR)
Water-Meat Conversion Factor = 3.0E-4 d/Kg (WMF)
Feeding Period to Slaughter = 200 d (FP)

Biological Half-Life = 1460d (TB)

The concentration of Pb in beef after 1 day of drinking water, mg/Kg-meat (CBD) is estimated as:

CBD = CPbW*WCR*WMF
= 0.034 mg/Kg-meat

The concentration in beef after 200 days, mg/Kg-meat (CB200D) is estimated as:

CB200D = (CBD/(.693/TB))*(1 - exp(-(.693/TB)*FP))
= (71.6)*(0.091)
= 6.48 mg/Kg-meat

The reported concentration is equal to that estimated using one day of drinking water. However, the concentration after 200 days of drinking is 191 times higher than that reported. Therefore, the daily intake of Pb by humans is 2.79E-3 mg/Kg/day instead of the reported value (1.46E-5 mg/Kg/day). The corrected hazard index (HI) is equal to 6.4 which indicates that the EPA Standard is exceeded in this scenario by this amount.

ATTACHMENT 1

Informal Analysis of WIPP Capacity for CH and RH Wastes
S. E. Logan, May 1989

Reference volumes used in calculations are as follows:

	m^3	ft^3	Drum Equivalents
55 Gallon Drum	0.208	7.35	1
Standard Waste Box	1.798	63.51	8.64
RH Canister	0.850	30.02	

WIPP "Capacity":

CH TRU		6.2E6
RH TRU		2.5E5

CH Waste

The capacity of a room is generally stated to be 6,000 drums. A review of the CH Criticality Safety Analysis report, shows that 6,750 drums can ideally be accommodated in a room if the slip sheet alignment tabs are oriented lengthwise in the room with alternate seven-packs staggered for close packing. This is essentially 15 drums wide, 150 drums long, and three tiers high. Allowing for some over packed drums and emplacement anomalies, the 6,000 value appears to be a reasonable average.

An array of Standard Waste Boxes (SWB) six boxes wide, average of 55 boxes long, and three tiers high, representing a total of 990 boxes, can be accomplished if half of the boxes are placed lengthwise and half are placed crosswise across the room width. However, if seven boxes are placed with the small dimension across the room by 50 boxes long, 1,050 boxes can be placed in a room using three tiers (700 boxes with two tiers). But, the CH Criticality Analysis is ambiguous about whether two tiers or three tiers will be used.

The capacity of a room becomes:

	Drums	Boxes	Drum Equivalents
Drums, maximal	6,750		
nominal	6,000		6,000
SWB, 3 tiers		1,050	9,072
2 tiers		700	6,048

The CH waste storage areas are calculated to be as follows:

	m^2
One room	920
One panel	11,664
Total, 8 panels	93,308
Central zone	20,382
Total	113,690

These areas include the effect of area loss to isolation plugs, except no isolation plugs are included for division of the central zone into two halves (division is indicated in the SEIS).

The multiplier for total capacity as compared to the capacity of one room is:

$$113,690/920 = 123.6$$

This assumes that the areal efficiency is the same throughout the CH storage area, although it has not been shown that drifts as narrow as 14 feet can accommodate seven-packs and SWB's with the same packing efficiency as in the 33 foot-wide rooms. Using the above multiplier, the WIPP capacity becomes:

	Number	Drum Equivalents	ft^3
All as drums	741,600	741,600	5.45E6
All as SWB, 2 tiers	86,520	747,533	5.49E6
3 tiers	129,780	1,121,299	8.24E6

The draft source term document (DOE, 1988) indicates that the projected division by volume between drums and the SWB is 65% in drums and 35% in the SWB (number of containers 94.2% and 5.8%, respectively).

Some calculations are needed at this point.

Let D = number of drums

D_T = total number if all drums (741,600)

B = number of boxes

B_T = total number if all boxes (129,780 in 3 tiers, 86,520 in 2 tiers)

V_d = volume of drum, ft^3 (7.35)

V_b = volume of box, ft_3 (63.51)

C = total waste volume capacity of WIPP, ft^3

Then, for 65% by volume in drums, and 35% by volume in boxes:

$$DV_d = 0.65\ C \qquad (1)$$

$$BV_b = 0.35\ C \qquad (2)$$

$$DV_d + BV_d = C \qquad (3)$$

$$D/D_T + B/B_T = 1 \qquad (4)$$

Solving equations 1 through 4 for D, B, and C, the following results are obtained for numbers of drums and boxes, and WIPP waste volume capacity:

	Number	Drum Equivalents	ft^3
Drums	546,951	546,951	4.020E6
3 Tiers of Boxes	34,076	294,417	2.164E6
Total	581,027	841,368	6.184E6
Drums	483,741	483,741	3.555E6
2 Tiers of Boxes	30,115	260,194	1.912E6
Total	513,856	743,935	5.468E6

Note that here waste volume is taken to be container volume. On this basis, the WIPP has a capacity approximately equal to the generally stated 6.2E6 ft^3, providing at least 5.8% of the containers (35% of the volume) is emplaced in SWB's, and that all SWB's are placed three tiers high. If only two tiers of SWB's are used, the WIPP capacity is less than 5.5E6 ft^3 regardless of the drum/SWB mix. Adding isolation plugs in the central zone reduces storage area by approximately 600 m^2 or 0.5% of the total. This eliminates about 3,900 drum equivalents of storage space. This decreases the drum/3-tiers-of-SWB total from 841,368 drum equivalents by 3,900 to 837,468 drum equivalents (6.155×10^6 ft^3).

If we adjust the total waste volume slightly from 6.155×10^6 ft^3 to the "design" 6.2×10^6 ft^3 (a factor of 1.0073), it corresponds to adjusting the calculation basis of 6,000 drums/room up to 6,044 drums/room. The net WIPP capacity then becomes as follows:

	Number	Drum Equivalents	ft^3
Drums	548,361	548,361	4.03E6
3 Tiers of Boxes	34,164	295,176	2.17E6
Total	582,525	843,537	6.20E6

Recently, major DOE documents have emerged, notably the SEIS, that erroneously interpret the 6.2E6 ft^3 "waste capacity" of WIPP to be the volume of settled contents of containers instead of the volume of the containers themselves. Using an average "fullness" of 80%, this leads the SEIS to increase the number of drums by a factor of 1/0.80 = 1.25, which would increase the actual capacity of 843,537 drum equivalents (with 3-tier SWB component) to a fictitious 1.05 million drums (the SEIS uses 1.10 million). There simply is no space for the "extra" 256,463 drums!

RH Waste

The WIPP capacities for RH waste are generally stated as 250,000 ft^3 or 6,000 canisters. At 30 ft^3 per canister, the two values are not consistent. 250,000 ft^3 represents 8,300 canisters, and 6,000 canisters represents 180,000 ft^3. The planned nominal spacing is eight feet along CH storage walls. The total CH storage perimeter has been calculated to be 26,000 m, including the central zone between the two sets of panels. This would indicate a maximum number of horizontal RH storage holes, on 8-foot centers, of 10,663. Subtracting 672 to avoid interference at 336 corners and 100 for possible isolation plugs added in the central zone leaves a capacity, with full wall utilization, of 9,890, though some reports indicate the total requirement is for about 4,800. Looking at this another way, utilizing 8,300/9,890 = 84% of the available wall for RH would provide for 250,000 ft^3, 61% of the wall would provide for 6,000 canisters, and 49% of the wall would provide for an expected 4,800 canisters. If the central zone is not available for RH emplacement (can the hole boring and emplacement equipment operate in a 14-foot-wide drift?), the wall perimeter is reduced 29% to 18,439 m and the corresponding number of emplacement holes is limited to 7,562 - 416 = 7,146. This would accommodate 2.15E5 ft^3 of RH waste (will not accommodate 2.5E5 ft^3). Some of this potential RH storage wall perimeter may not be accessible after experimental emplacement of CH waste. If longer holes are bored to accept two or more RH canisters, additional wall perimeter becomes unavailable to avoid interference, but a net increase in emplacement can be obtained.

<u>References</u>

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IMPLICATIONS OF OIL AND GAS LEASES AT THE WIPP ON COMPLIANCE WITH EPA TRU WASTE DISPOSAL STANDARDS

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James K. Channell

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New Mexico

June 1992

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FOREWORD

The purpose of the Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure the protection of the public health, safety, and environment. The WIPP Project, located in southeastern New Mexico, is being constructed as a repository for permanent disposal of transuranic (TRU) radioactive wastes generated by the national defense programs. The EEG was established in 1978 with funds provided by the U.S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and continued the funding from DOE under contract DE-AC04-79AL10752 as DE-AC04-89AL58309.

EEG performs independent technical analyses of the suitability of the proposed site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria and the generator sites' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP. Another important function of EEG is independent environmental monitoring of background radioactivity in air, water, and soil, both on-site and in surrounding communities.

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EXECUTIVE SUMMARY

A decision by the U.S. Department of Energy (DOE) to proceed with the disposal of transuranic waste at the Waste Isolation Pilot Plant will require the DOE to determine compliance with Standards (40 CFR 191) issued by the Environmental Protection Agency (U.S. EPA, 1985).[1] The Standards recognize that future exploration for natural resources sometime during the next 10,000 years could disrupt the integrity of the repository and release radionuclides to the biosphere and require consideration of inadvertent human intrusion. The Standards appear to allow the assumption that active institutional control will completely deter human intrusion for 100 years. At the WIPP, the DOE has assumed active control will prevent any human intrusion during this period. After 100 years, the Standards allow credit for passive institutional controls such as public records and markers to reduce the risk of human intrusion.

The U.S. Department of Energy (DOE) documentation overlooked two active oil and gas leases and a gas well within the WIPP Site Boundary in spite of lease, drilling, and production records filed by the oil company with the federal government; a condemnation suit filed in civil court by the federal government in 1977; a Consultation and Cooperation Agreement between the State of New Mexico and the federal government; a Memorandum of Understanding between agencies of the federal government recognizing the existence of these leases; technical reports funded by the federal government on area oil and gas resources; and the visible existence of a producible gas well from the south access highway to the WIPP facility.

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[1] The DOE has sole regulatory authority to make a determination of compliance of the WIPP facility with Environmental Protection Agency (EPA) Standards and proceed with the WIPP as a repository. Legislation pending before Congress would transfer that authority to another agency.

Several important DOE documents are either incorrect, silent, or inconsistent on the existence of these leases. For example, the Final Environmental Impact Statement (FEIS, U.S. DOE, 1980, pp. 8-8—8-10) identifies the oil and gas leases held by ten companies in March 1979, yet the 1952 Conoco and 1957 Bass leases in the southwest corner of the WIPP Site on Section 31 are not mentioned. The WIPP Final Safety Analysis Report (WIPP FSAR, U.S. DOE, 1990a, Section 2.1.1.1), incorrectly states that there are no active oil and gas leases within the WIPP Site Boundary and fails to chart the intruding well on its map of producible oil and gas wells. The DOE No-Migration Variance Petition to the EPA incorrectly states that the DOE has purchased all oil and gas leases in the area of the WIPP site to prevent any exploration now and in the future (U.S. DOE, 1990b). The Secretary of Energy's Decision Plan monitored the status of an active potash lease until it was purchased by the DOE but remained silent on the active oil and gas lease issue even after an article in the Albuquerque Journal raised the issue (McCutcheon, 1990). The recently published DOE Implementation of the Resource Disincentive document, (U.S. DOE, 1991) is inconsistent on the number of active oil and gas leases within the WIPP Site Boundary and on the production status of the forgotten gas well.

The actual experience of forgotten oil and gas leases at the WIPP strongly suggests that the U.S. Environmental Protection Agency and the U.S. Department of Energy need to reexamine the assumption that active institutional control will be completely effective for 100 years after disposal and how much credit should be taken for passive institutional control between 100 and 10,000 years. The EPA Standards should require the implementing agency to publish specific plans on how the agency intends to maintain active institutional control. Even in the absence of such a requirement, the DOE should publish plans now that specify in detail how the Department intends to maintain control at the site for 100 years after decommissioning and describe how that control will completely deter human intrusion. Finally the DOE needs to describe in detail their passive institutional control system and show how it will provide a deterrence to inadvertent human intrusion after 100 years.

1.0 STATEMENT OF PROBLEM

Most analyses of the safety of a nuclear repository identify scenarios of inadvertent human intrusion for natural resource exploration as the most likely mechanism to return unwanted radioactive residuals to the biosphere. The question arises as to how long our institutions would maintain knowledge of the repository as a deterrent to an unplanned release. The U.S. Environmental Protection Agency (EPA) has issued Standards (U.S. EPA, 1985) which allow the implementing agency to take credit for active institutional control, for up to 100 years after decommissioning. Beyond 100 years, the EPA Standards allow credit only for passive institutional controls such as markers, public records and archives, government ownership and regulations regarding resource use and other methods of preserving knowledge.

On November 3, 1990, the Albuquerque Journal reported the rediscovery of a natural gas well that had been completed beneath the WIPP Site Boundary.

> [Department of Energy] Officials had previously believed that they had acquired all existing mineral leases at the site as part of their push to open WIPP for testing.... officials had known of the well years ago but rediscovered its existence only recently.... Department records indicate the well was drilled in about 1981 or 1982 after its owners obtained permission from the federal Bureau of Land Management, the current owner of WIPP's land.... After the well was first drilled, its owners decided to slant it underground, still keeping it off the site, officials said. When WIPP's geographic configurations were later remapped, the bottom of the well wound up appearing inside the underground boundary of WIPP lands.... (McCutcheon, 1990).

This report focuses on the history of two oil and gas leases and one well completed within the WIPP Site Boundary that were overlooked by the DOE for several years. The incident is important because it indicates that active institutional control and passive institutional control, such as markers and records, do not always deter unwanted drilling activity or effectively convey necessary information to decision makers. The report addresses the question of whether the EPA and the DOE are assuming more credit for the deterrent value of institutional controls than is warranted.

The decision by the DOE to use the WIPP as a repository for defense transuranic waste will depend in part on results of performance assessment analyses required by the EPA Standards (40 CFR 191). The performance assessment analyses calculate the probability and quantities of radionuclides released into the accessible environment for different breach scenarios within the first 10,000 years after disposal. The Standards for disposal of radioactive waste were issued by EPA in November 1985. Subpart B was vacated by the First Circuit Court of Boston in June 1987. EPA is not expected to promulgate the revised Standards before mid-1993 (SNL, 1991). Until the revised Standards are available, the State of New Mexico and the U.S Department of Energy have agreed to use the 1985 Standards as a basis for performance assessment planning (U.S. DOE, 1981). At the present time, the Department of Energy has the sole authority to use the analyses to determine if the DOE WIPP facility complies with the Standards yet to be repromulgated by the EPA. The remanded Standards required the consequences of inadvertent human intrusion to be calculated because such an event could significantly disrupt the integrity of a repository.

Guidance to the Environmental Protection Agency's *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes, 40 CFR 191* (U.S. EPA, 1985) allows credit to be taken for active institutional control when making assumptions about the frequency and severity of human intrusion into the repository. Specifically, the Guidance states "... the implementing agency will assume that none of the active institutional controls prevent or reduce radionuclide release for more than 100 years after disposal" (U.S. EPA, 1985, p. 38088). The statement in the latest working draft of the Guidance remains unchanged (U.S. EPA, 1992, p. 30). This Guidance appears to allow the repository operator to assume that active institutional control will deter all inadvertent human intrusion. In the WIPP performance assessment calculations, Sandia National Laboratories (SNL) has assumed active institutional control will be maintained for 100 years and this control will be 100 percent effective in deterring human intrusion (Sandia National Laboratories, 1991, p. 2-5) even though the DOE has made no commitment to maintain active control at the WIPP for any specific length of time.

This report does not address the issue of whether the "forgotten" gas well, which is completed within the WIPP Site Boundary, is a hazard to the long-term safety of the repository. Only the implication of the effectiveness of institutional controls is being addressed.

2.0 INTRODUCTION

The Waste Isolation Pilot Plant (WIPP) is ultimately intended to serve as a repository for the safe disposal of transuranic waste generated by the defense activities of the United States Government. The anticipated inventory includes a maximum of 176 000 cubic meters (6.2 million cubic feet or 850,000 drum equivalents) of contact-handled transuranic (CH-TRU) waste and about 7100 cubic meters (250,000 cubic feet or 8,000 canisters) of remote-handled transuranic (RH-TRU) waste. The CH-TRU waste is estimated to contain 9 million curies of activity. The activity of the RH-TRU waste is limited to 5.1 million curies.

The repository is located in the Los Medaños area in southeastern New Mexico, 17 miles (28 kilometers) east-northeast of the city of Loving and 25 miles (40 kilometers) east of the city of Carlsbad and the repository is sited at a depth of 2,150 feet (655 meters) in the lower part of a 1,970-foot (600 meters) thick salt formation.

The area of land that lies within the WIPP Site Boundary is a square four miles (6.44 kilometers) on a side. It contains 10,240 acres (4144 hectares) including Sections 15, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, and 34 in T22S, R31E, NMPM in Southeastern New Mexico (U.S. DOE, 1990a, Section 2.1.1.1)

Figure 1 illustrates the WIPP boundary and the areas of Zone I and Zone II. Zone I contains the WIPP facility surface structures, is surrounded by a chain link fence, and covers about 35 acres (14 hectares) in Sections 20 and 21. Zone II defines the maximum extent of the area for underground development. The WIPP Site Boundary provides a minimum one mile (1.6 kilometers) buffer area of intact salt around Zone II (U.S. DOE, 1990a, Section 2.1.1.1).

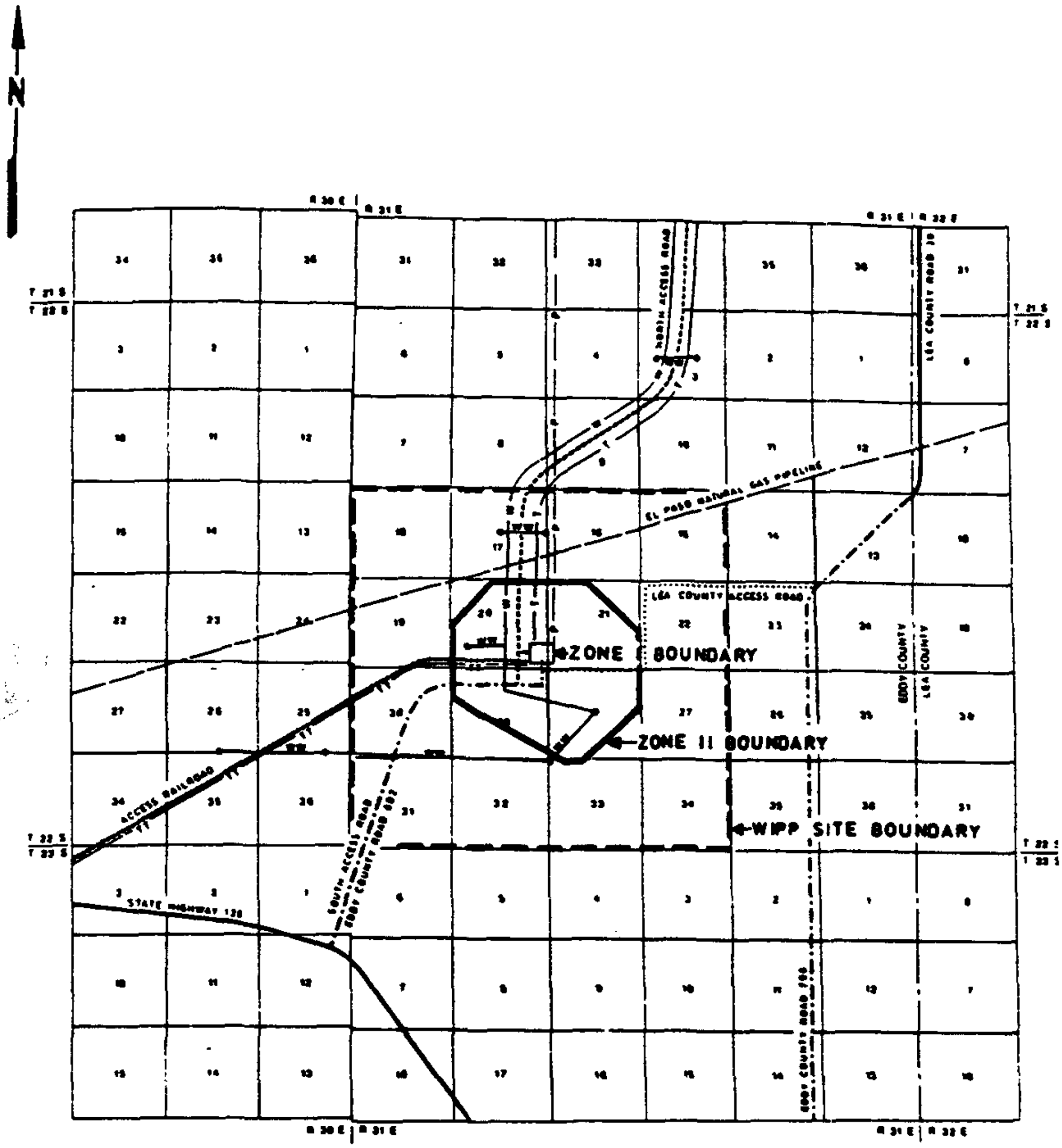

Figure 1. 1990 Zone I, Zone II, and WIPP Site Boundaries. From Figure 2.1-3, WIPP FSAR. (U.S. DOE, 1990a, reproduced with permission).

Although the designations of Zone III and Zone IV are no longer used, they merit a brief description because much of the initial WIPP documentation refers to these zones. The location of Zones III and IV are shown in Figure 2.

Zone III essentially provided a one-mile (1.6 kilometer) buffer around Zone II. In Zone III, all mining, other than for the repository, and deep drill holes penetrating through the evaporites were prohibited (U.S. DOE, 1980, p. 8-4).

Zone IV provided a one-mile (1.6 kilometer) buffer around Zone III. Within Zone IV, conventional potash mining would be permitted but solution mining was prohibited. Deep drill holes were also allowed but water flooding and massive hydrofracture for hydrocarbon recovery would not be permitted. The Final Environmental Impact Statement also noted existing oil and gas wells producing in this zone will be permitted to continue through their useful lives. To protect the repository, they will be sealed as prescribed by the DOE when abandoned. New wells for oil and gas production may be drilled in conformance with DOE standards to facilitate eventual plugging (U.S. DOE, 1980, p. 8-4).

When Zone IV was relinquished by DOE as being unnecessary, the Zone III boundary was "squared off" and the new site boundary extended into the former Zone IV at the four corners (Weart, 1990). Hence, the current four mile (6.44 kilometers) by four mile WIPP Site Boundary[2] also provides the one-mile buffer originally established as Zone III.

[2]Throughout this report, the term "WIPP Site Boundary" refers to the four mile by four mile area described above and the term "WIPP Site Area" refers to the approximately thirty-two square mile area that includes all of Zone IV.

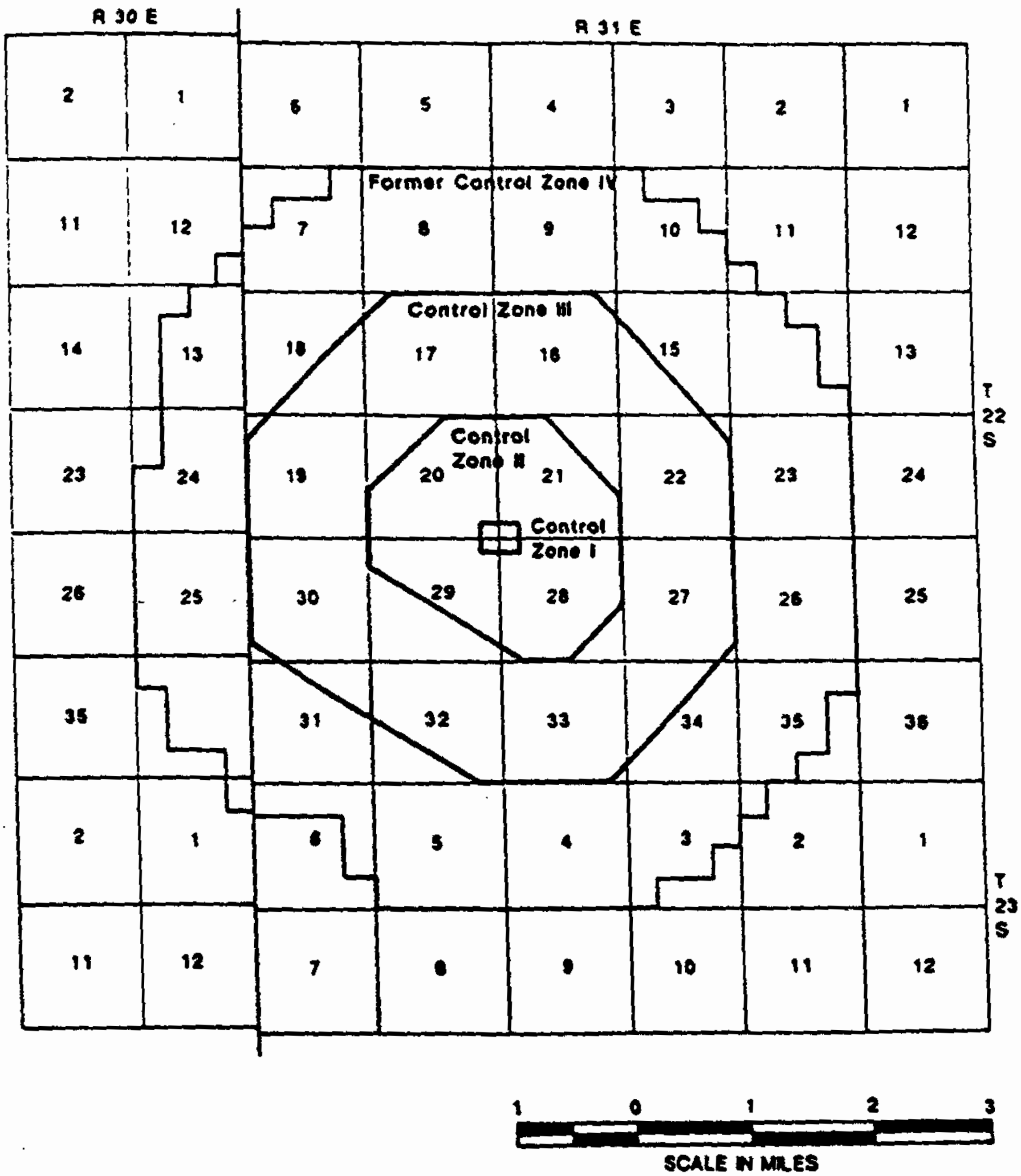

Figure 2. 1980 Control Zones at the WIPP Site. (FSEIS, U.S. DOE, 1990d, reproduced with permission).

3.0 REPORTS ON PETROLEUM RESOURCES AND LEASES

EPA's requirements for establishing a repository in a resource rich area were clearly stated in 40 CFR 191.14(e):

> Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites. Resources to be considered shall include minerals, petroleum or natural gas.... Such place shall not be used for disposal of the wastes covered by this part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future (U.S EPA, 1985).

From 1976 through 1980, SNL published several reports on the mineral resources in the Los Medaños area. Each discussed oil and gas resources.

A report by the petroleum consulting firm of Sipes, Williamson, and Aycock, Inc. (Keesey, 1976) focused on estimating the remaining economically recoverable oil and gas reserves underlying the proposed disposal site. The evaluation was intended to serve as a guideline to SNL in determining the acceptability of the "site area" and the potential value to the owners of the hydrocarbon rights.

Griswold's (1977) subsequent evaluation of site selection and mineral resources incorporated the information provided by Keesey (1976).

Powers, et al. (1978) prepared the geological characterization report for the WIPP citing the work of Keesey (1976) and Griswold (1977) as well as earlier work by Foster (1974).

Keesey (1977) provided a more detailed analysis of the hydrocarbon resources including those in Section 31, T22S, R31E, the section containing the active gas leases in the southwest corner of the current WIPP Site Boundary. The study was limited to surface and subsurface rights to 6,000 feet (1829 meters), which were eventually condemned and purchased by the federal government in 1979. The evaluation did not include the deeper resources.

Keesey (1979a) evaluated the feasibility of directionally drilling for oil and gas reserves under the WIPP Site Area, which, by previous definition, included Zone IV. It was technologically feasible to drill into gas and condensate reserves underlying the WIPP Site Area from outside the WIPP Site Area.

Keesey (1979b) updated the estimated potential hydrocarbon reserves and associated costs and incomes for oil and gas underlying the WIPP. The estimates were intended for use in the Environmental Impact Statement for the WIPP being prepared by Westinghouse Electric Corporation. The estimates were not intended to represent future net revenue values normally used by the petroleum industry to determine the fair market value of oil and gas producing properties. The undiscounted value of the gas and condensate reserves underlying the WIPP Site Area (including Zone IV) was determined to be $287,502,346 (Keesey, 1979b, p. 6; U.S. DOE, 1980, p. 7-72).

4.0 HISTORY OF NATURAL GAS EXPLORATION AND PRODUCTION

The WIPP site is situated in the northern portion of the Delaware Basin. While there were no oil or gas wells within the 32 square miles (8288 hectares) of Zone IV in 1976, oil and gas were being produced from 60 wells in a 368 square-mile (95 312 hectares) area surrounding the site. Although the area was considered to be potentially rich in hydrocarbon reserves, extensive deep drilling had not been ventured in the New Mexico portion of the Delaware Basin. Only 10 to 15 percent of the available acreage had been investigated. The lack of more complete drilling and development was attributed to several factors including historically restrained gas prices, a higher exploration risk due to the varying depositional environment, a lack of readily available pipelines during earlier periods, and moratoriums on drilling in the potash areas to prevent methane gas from entering potash mines (Keesey, 1976; Powers et al., 1978).

As noted by Griswold (1977), the energy crisis of the mid-1970's had driven up the price of natural gas at least fourfold in just two years, prompting a renewed interest in previously unattractive areas. In 1977, deep exploratory drilling for natural gas was underway throughout the Delaware Basin. Just prior to the publication of Griswold's report, three different companies applied for drilling permits in the Los Medaños site area.

Known petroleum production in the area extended from the Delaware Formation (mean depth 4,200 feet; 1280 meters) down to the Morrow Formation (mean depth 13,400 feet; 4084 meters). The deeper Morrow sandstones and the overlying Atoka sandstones of the Pennsylvanian series held the best promise for commercial natural gas production (Griswold, 1977).

In addition to several single well fields, there were two major producing fields in the Los Medaños area. Five wells were producing gas from the Morrow Formation in the Cabin Lake field just northwest of the WIPP site. A five-well field, the Los Medaños Field, was producing gas from both the Morrow and the Atoka Formations just southwest of the WIPP site.

4.1 Shell James Ranch Unit No. 1 - A Prolific Gas Well

A very productive gas well is located two thousand feet (610 meters) west of the WIPP site in the southwest corner of Section 36, T22S, R30E. The location is shown in Figure 3. Known as the Shell James Ranch Unit No. 1, the well was drilled, in 1957, to a total depth of 17,555 feet. The well was completed in the 12,920 to 12,929 foot (3938 to 3940 meters) interval for production of gas and oil condensate from the Los Medaños-Atoka Formation and has been producing since 1958.

The well has been prolific throughout its production history. Initial twenty-four hour production was 9,000 MCF gas and 104 BBLs condensate.[3] As of mid-1976 cumulative production exceeded 17,000,000 MCF (481 000 000 cubic meters) of gas and 200,000 barrels (32 000 cubic meters) of condensate. The gas production rate from that single well in 1976, was over 100,000 MCF (2 800 000 cubic meters) per month. Keesey (1976) calculated the James Ranch Unit No. 1 would ultimately recover 35,900,000 MCF (1 billion cubic meters) of gas and 425,000 barrels (68 000 cubic meters) of condensate.[4] The history of gas and condensate production since 1970 is shown in Figure 4.

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[3]An MCF is equal to one thousand standard cubic feet (28.32 cubic meters) of gas. A BBL is equal to one barrel (0.159 cubic meters) of oil or condensate.

[4]As of August 1, 1991, production records filed with the U.S. BLM for the James Ranch Unit No. 1 show that cumulative gas production has exceeded 25,000,000 MCF and condensate oil production has exceeded 270,000 BBLs.

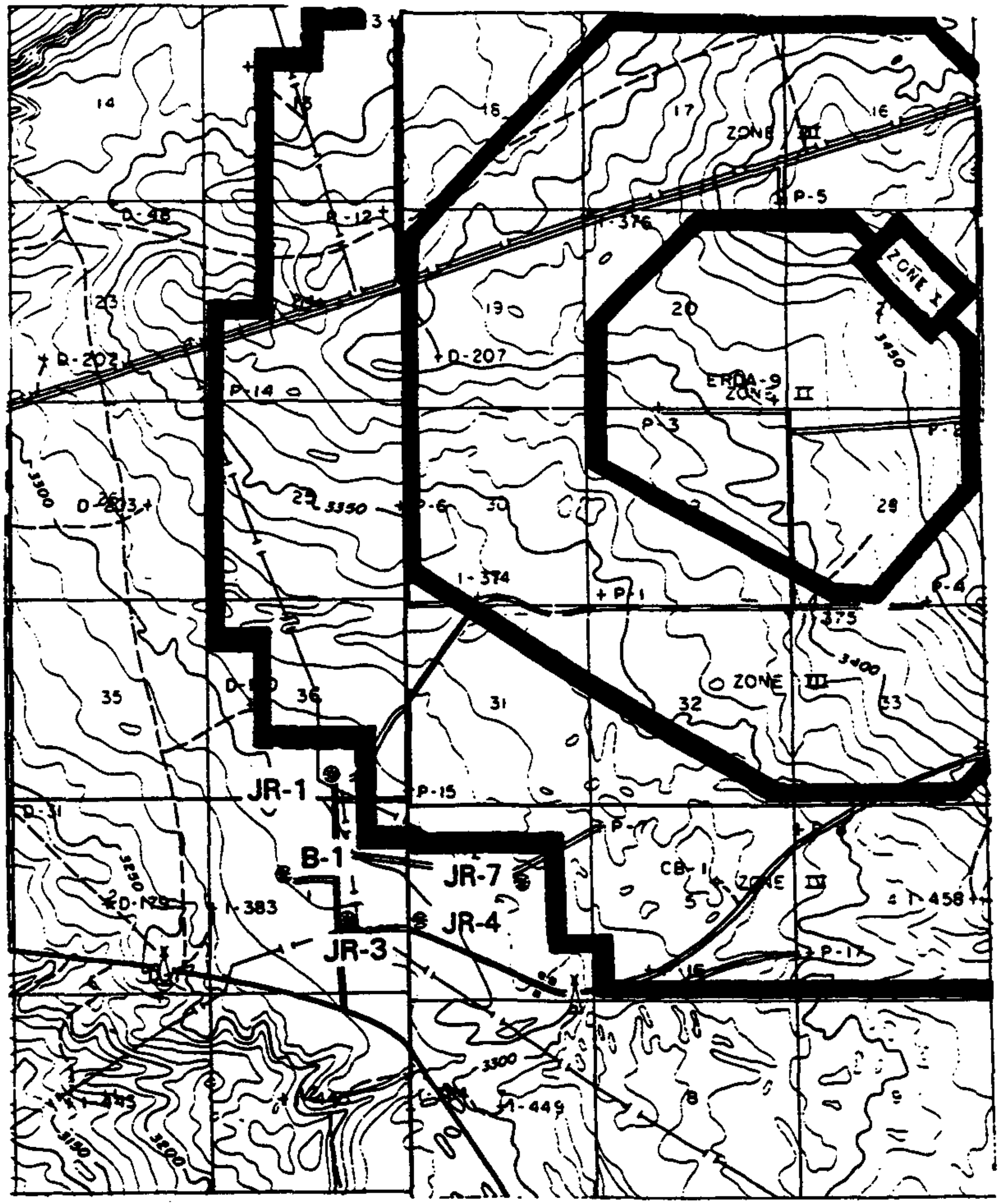
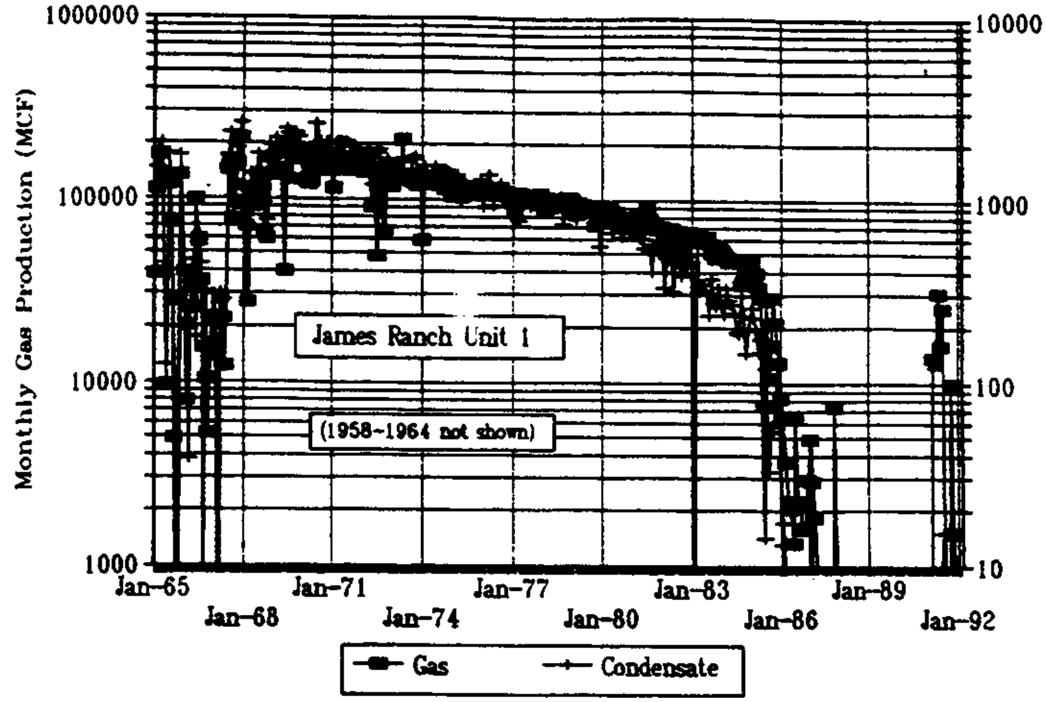


Figure 3. Five Gas Wells Outside Southwest Corner of WIPP Site in 1977. James Ranch Unit No's 1, 3, 4, 7 and Hudson Federal No. 1 (B-1). (after Griswold, 1977, Figure 4, highlighted and reproduced with permission.)



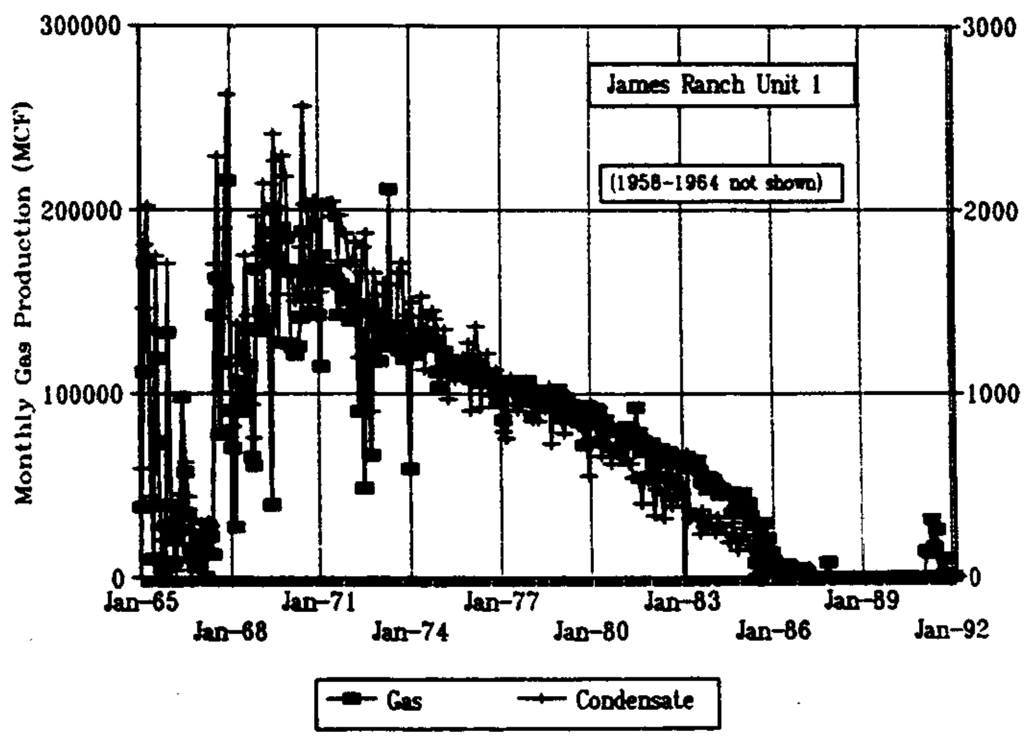


Figure 4. Gas and Oil Production from 1965 - 1991; James Ranch Unit No. 1. Data provided by Roswell District Office, U.S. BLM, 1992.

By 1977, the Shell James Ranch Unit No. 1 was flanked by an arc of four other wells on the south and west that essentially failed to tap the Atoka reservoir. The four wells were initially completed in the deeper Morrow Formation (Griswold, 1977). Figure 3 shows these wells included the Hudson Federal No. 1, Belco's James Ranch Unit No. 3, Belco's James Ranch Unit No. 4, and Conoco's James Ranch Unit No. 7.

4.2 Natural Gas Beneath the WIPP Site

A faulted anticline controls the Morrow reservoir in the Los Medaños field, southwest of the WIPP site. This same structure probably persists up into the Atoka and both reservoirs probably extend toward the northeast (Griswold, 1977).

Analysis of production decline curves through 1976 for the James Ranch No. 1 well indicated the well was probably draining at least five square miles (1300 hectares). That observation, coupled with the favorable geologic structure and the failure of wells drilled to the west and south, further suggested that wells drilled to the north-east would have a high chance of success (Keesey, 1976; Griswold, 1977; U.S. DOE, 1980).

As part of the hydrocarbon resource evaluation, potential drilling sites were selected based on the structure contours of the Morrow Formation. Depending on the geologic structure and distance from producing wells, the potential drilling sites were ranked as either 1) proved undeveloped, 2) probable, or 3) possible. Proved undeveloped reserves identified commercially recoverable hydrocarbons to be recovered from new wells on undrilled acreage or from existing wells requiring a major expenditure for recompletion or new facilities for fluid injection. (Keesey, 1976; Griswold, 1977, U.S. DOE, 1980).

The two locations ranked as "proven undeveloped" were north and east of the Shell James Ranch No. 1, as shown in Figure 5. The production data and geologic information available in 1976 indicated that much of the natural gas being produced from the Atoka Formation came from beneath the defined WIPP Site Boundary and the best place to drill a well would be in Section 31, T22S, R31E, which is precisely where the two active gas leases beneath the WIPP site are located.

Keesey (1976) noted that the drilling and completion of additional wells northeast of the Shell James Ranch No. 1 would only enhance the rate of recovery of the Atoka reservoir now being drained by the one well. Ultimate recovery would remain about the same.

4.3 Early History of Leases

In May 1952, Continental Oil Inc. (Conoco) obtained an oil and gas lease (NMPM Lease # NM 02953) that included all 640 acres (259 hectares) of Section 31, T22S, R31E. In June 1953, the area was approved by the U.S. Geological Survey (U.S.G.S.) as the James Ranch Unit. Sid Richardson and Perry R. Bass were designated Unit Operators.[5]

As discussed above, Shell Oil Company drilled the James Ranch Unit No. 1 in 1957, on Section 36 just west of the Conoco lease. Shell began prolific production of gas and condensate from the newly discovered resources in the Atoka Formation in March 1958.

[5]Information about drilling applications, completion records, pipeline connections, production records, and official memoranda concerning these leases was obtained from U.S. Bureau of Land Management Offices in Roswell, New Mexico and Santa Fe, New Mexico.

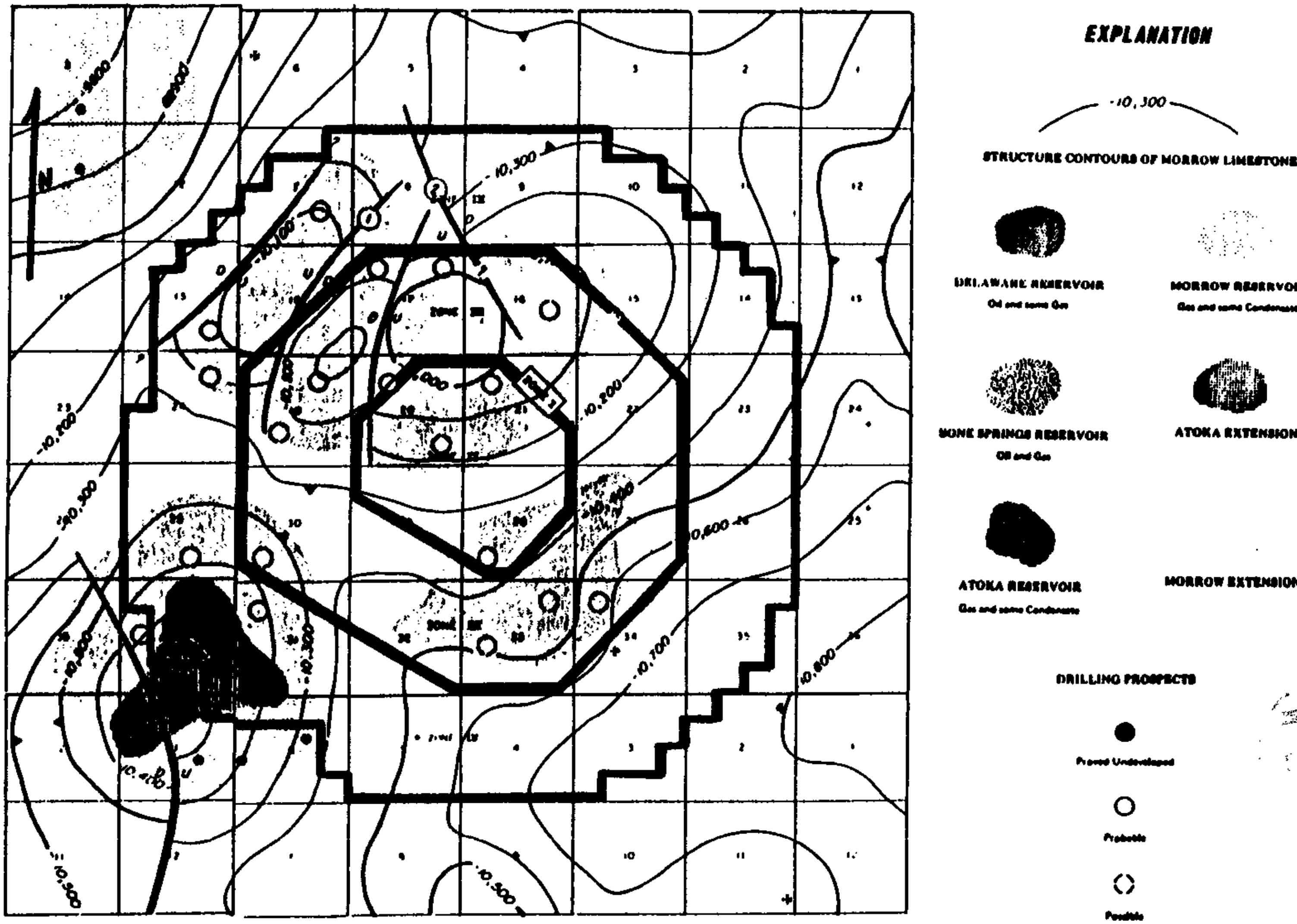


Figure 5. Hydrocarbon Resources and Possible Extensions (Griswold, 1977, Figure 32, reproduced with permission).

In February 1959 the Conoco lease on Section 31 was divided. The north half of the section remained with Conoco and the south half was assigned to Richardson and Bass under lease NM 02953-C. Perry R. Bass was designated the Unit Operator, in March 1961.

Keesey (1976) completed the analysis of hydrocarbon reserves for SNL, effective September 1, 1976, in which he concluded:

> that the Los Medaños (Atoka) reservoir extends north and northeast underneath the 'site area' in section 31-22S-31E [Conoco's and Bass's undeveloped leases] and 36-22S-30E [Shell's producing lease] (Keesey, 1976, p. 16).

4.4 <u>1976 Application to Drill For Natural Gas Beneath the WIPP Site</u>

On November 7, 1976, Bass formally filed for a permit with the U.S. Geological Survey to drill a well on Section 31. Three days later, November 10, 1976, Conoco was designated as the operator and local agent for Bass "with full authority to act in his behalf in complying with the terms of the lease and regulations...." (Bass, 1976).

On November 11, 1976, the District Engineer for the U.S.G.S., routinely notified the New Mexico Division of Lands and Minerals Program and Land Office in Santa Fe, New Mexico, of the intent of Bass Enterprises Production company to commence drilling operations.

On December 10, 1976, a withdrawal notice appeared in the *Federal Register*. The Energy Research and Development Administration (ERDA, precursor of the DOE) applied for withdrawal of 17,000 acres (6880 hectares) of public lands in New Mexico for a nuclear waste disposal site including the land containing the Bass lease.

On January 20, 1977, the U.S.G.S Area Oil and Gas Supervisor, James W. Sutherland, approved the Bass application to drill for oil and gas .

4.5 Court Condemnation of Oil and Gas Leases at the WIPP Site

On February 9, 1977, the U.S. Government, at the request of the Acting Administrator for the ERDA, filed a complaint in civil court (Case # CIV 77-071 B) against Bass Enterprises et al. condemning their oil and gas lease from the surface to a depth of 6,000 feet (1829 meters) for the southern half of section 31.

On April 4, 1977, the U.S. BLM Assistant Solicitor of Lands, John J. McHale, informed the Director of the U.S. BLM that an attorney for the U.S. ERDA in New Mexico had inquired by telephone about the impact of the Federal Land Policy and Management Act (FLPMA) on the land status because the issue had been raised in litigation. The lessee (Bass) was contending in court that the condemnation of oil and gas leases by the Government was illegal, arguing that the Government can only terminate the lease through the lease provisions. The Assistant Solicitor had advised the ERDA attorney, that in BLM's judgment, the land should never have been taken (McHale, 1977).

On December 7, 1977, an additional complaint was filed in civil court (Case # CIV 77-776 B) by the U.S. Government against Conoco Inc. condemning their oil and gas lease from the surface to a depth of 6,000 feet (1829 meters) for the northern half of Section 31.

On February 12, 1979, both cases were settled jointly. The court condemned the oil and gas lease from the surface to 6,000 feet (1829 meters) and assigned $1,350,000 to Conoco, Bass Enterprises, and other defendants as just compensation for these leases.

4.6 1981 Application to Drill Natural Gas Well Beneath the WIPP Site

On December 11, 1981, Bass Enterprises filed a formal application to drill a wildcat well, James Ranch Unit No. 13, on Section 6, T-23-S, R-31-E (#NM 02887-D) with the intent to deviate north into Section 31, T-22-S, R-31-E. This section, would fall entirely within the defined WIPP Site Boundary fourteen months later.

On December 14, 1981, James Pettengill, geologist with the U.S.G.S. Office in Roswell, filed a review of the drilling application with the U.S.G.S. District Engineer in Artesia. The review noted that the "completion location is within the boundaries of the Department of Energy's proposed Waste Isolation Pilot Project (WIPP)" (Pettengill, 1981).

On December 16, 1981, the U.S.G.S. District Supervisor in Roswell, James Gillham, issued a memo to the U.S.G.S. Deputy Conservation Manager of Oil and Gas transmitting the request to drill and commenting that the "drillsite is not considered to be in a politically sensitive area" (Gillham, 1981).

On December 18, 1981, the U.S.G.S Area Manager for the Carlsbad Resource Area notified the DOE WIPP Project Manager of Bass's application to drill and requested advice on any special stipulations or concerns by December 28, 1981 (Koski, 1981).

The DOE December 30, 1981, response noted that the Department had obtained exclusive use of the surface and uppermost 6,000 feet (1829 meters) of subsurface for the specific purpose of preventing any drilling activity in Section 6, N½,NW¼, T23S, R31E and Section 31, T22S, R31E. The letter cautioned the BLM that "the approval to drill must include the stipulation that Perry R. Bass is not permitted to drill into the areas described above" (McGough, 1981) .

Following the January 11, 1982, approval by the U.S.G.S. (Reitz, 1982) to drill, drilling started on February 6, 1982. On September 13, 1982, the well was tested and produced 141 MCF of gas for an eight hour period. On September 21, 1982, drilling was completed. On February 14, 1983, the Natural Gas Pipeline Company of America connected to the well, James Ranch Unit No. 13, for the purpose of purchasing gas. The wellhead is shown in Figure 6 with the WIPP Waste Handling Building in the background.

4.7 Zone Designation and Resource Recovery Control

On February 17, 1983, the DOE WIPP Project Manager notified the Director of the Environmental Evaluation Group (EEG) that:

> the configuration of WIPP surface control zones has changed as a result of the cost reduction program, the DOE resource management policy and Bureau of Land Management land withdrawal action.... Descriptions of the new control zones are also enclosed (McGough, 1983a).

On February 24, 1983, the DOE WIPP Project Manager further informed the EEG Director that:

> the DOE does not plan to exercise any control over resource recovery activities outside the Site boundary and will rely, primarily, on other Federal and State regulatory agencies to assure that the WIPP boundaries are not violated (McGough, 1983b).

On October 28, 1983, the EEG requested a clarification on the DOE's conflicting descriptions of the Zone III boundaries and a clarification on the interim controls on resource recovery. The EEG was puzzled by the DOE's reference to the new WIPP site boundary as Zone III. The EEG was also concerned the restriction against drilling into the first 6,000 feet (1829 meters) was not included in the BLM/DOE

Figure 6. James Ranch Unit No. 13 with WIPP Waste Handling Building in Background.

Memorandum of Understanding or in the Resource Management Plan. Hence, EEG suggested that there was no apparent reason for the BLM to enforce the restriction (Neill, 1983a).

On December 7, 1983, the DOE WIPP Project Manager acknowledged that:

> 1. Our February 24, 1983 letter incorrectly identified the WIPP Site boundary as being the Zone III when in fact the Zone III boundary has not changed from that shown in the FEIS. The zone being controlled as regards mineral extraction, is the 16 full sections of land as shown in the sketch enclosed in our February 17, 1983 letter. These 16 sections comprise the area identified in the June 29, 1983 administrative land withdrawal.
>
> 2. All lease rights which have been purchased by the DOE within the site boundary have been purchased in their entirety or alternatively we acquired only the upper 6,000 feet of the leases to reduce the acquisition cost to the DOE and to allow access to potential hydrocarbon resources below the WIPP Site. It was not considered necessary to detail this information in the DOE/BLM Memorandum of Understanding (MOU) or Resource Management Plan because the BLM is required to enforce mineral leasing laws which prohibit violation of adjacent (in this case, DOE's) lease boundaries (McGough, 1983c).

In evaluating the suitability of the WIPP Site, the EEG (Neill et al., 1983, p. iii) recommended that

> no potash mining will be allowed in Zones I, II, and III of the WIPP site. Deviated drilling for oil and gas from outside the WIPP site to reach under the WIPP site at depths greater than 6,000 feet may be allowed. The federal government shall exercise active institutional control at the site for this purpose for at least 100 years after repository decommissioning.

The recommendation was reiterated on December 6, 1983, in a letter from the EEG Director (Neill, 1983b) to the WIPP Project Manager on the suggested wording for the First Modification to the Consultation and Cooperation (C&C) Agreement between the U.S. Department of Energy and the State of New Mexico. On November 14, 1984, the State of New Mexico and the U.S. Department of Energy agreed that:

> During facility construction and operation the DOE will not allow subsurface mining, drilling or resource exploration from within the WIPP site. The 'WIPP site' as used here means the 4 x 4 mile (10,240 acres) area consisting of sections 15, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, and 34 of Township 22 South, Range 31 East, NMPM, in Southeastern New Mexico.
>
> Deviated drilling for oil and gas from outside the WIPP may be allowed so long as the subsurface of the WIPP site is not penetrated above a depth of 6,000 feet from the surface.

EEG's recommendation to include a statement that the federal government shall exercise active institutional control at the site for at least 100 years after repository decommissioning was not included in the modification. Rather, the First Modification to the C&C agreement stated that:

> the consultation process concerning the length and extent of the post-closure institutional control, shall be negotiated and resolved by the parties in the future, and at least one year prior to the start of the decontamination and decommissioning of WIPP.

5.0 THE FORGOTTEN GAS LEASES AND WELL BENEATH THE WIPP SITE

The 1984 agreement between the U.S. Department of Energy and the State of New Mexico to allow slant drilling under the WIPP Site changed on August 4, 1987, in the second modification to the C&C agreement (U.S. DOE and NM, 1987), which states:

> The DOE will not permit subsurface mining, drilling, or resource exploration unrelated to the WIPP Project on the WIPP site during facility construction, operation, or after decommissioning. This prohibition also **precludes slant drilling**[6] under the site from within or from outside the site.

Several important DOE documents are either incorrect, silent, or inconsistent on the existence of the two oil and gas leases and the gas well. For example, the Final Environmental Impact Statement (FEIS, U.S. DOE, 1980, pp. 8-8—8-10) identifies the oil and gas leases held by ten companies in March 1979, yet the 1952 Conoco and 1957 Bass leases in the southwest corner of the WIPP Site on Section 31 are not mentioned. The WIPP Final Safety Analysis Report (WIPP FSAR, U.S. DOE, 1990a, Section 2.1.1.1), incorrectly states that there are no active oil and gas leases within the WIPP Site Boundary. Moreover, the WIPP FSAR (U.S. DOE, 1990a, Figure 2.2-1) fails to chart the intruding well on its map of producible oil and gas wells. The DOE No-Migration Variance Petition to EPA incorrectly states that the DOE has purchased all oil and gas leases in the area of the WIPP site to prevent any exploration now and in the future (U.S. DOE, 1990b). Revisions 1 through 5 of the Secretary of Energy's Decision Plan were monitoring the status of an active potash lease until it was purchased by the DOE. Yet Revisions 6 through 10 remained silent on the active oil and gas lease issue even after the article in the Albuquerque Journal raised the issue (McCutcheon, 1990). The recently published DOE Implementation

[6]Emphasis added.

of the Resource Disincentive document, (U.S. DOE, 1991) is inconsistent on the number of active oil and gas leases within the WIPP Site Boundary and on the production status of the forgotten gas well.

5.1 1980 WIPP Final Environmental Impact Statement

The WIPP Final Environmental Impact Statement (U.S. DOE, 1980) identifies the gas and oil leases held by ten companies in March 1979 at the WIPP Site. Figure 7 (reproduced from the 1980 WIPP FEIS) does not show the Bass and Conoco leases on Section 31. While those two leases were condemned in February 1979 from the surface to 6,000 feet (1829 meters), the oil and gas leases below 6,000 feet (1829 meters) did remain valid.

5.2 1990 WIPP Final Safety Analysis Report

The DOE's stated commitment to prohibit slant drilling and the loss of knowledge is also documented in the WIPP Final Safety Analysis Report (U.S. DOE, 1990a) which the DOE describes as the top level document in the hierarchy of the WIPP safety documents. The WIPP FSAR states:

> The area of land that lies within the WIPP Site Boundary and committed to the WIPP facility is a square four miles on a side. It contains 10,240 acres (16 mi^2) including Sections 15-22 and 27-34 in township T22S, R31E....
>
> The DOE will not permit subsurface mining, drilling, or resource exploration unrelated to the WIPP Project within the WIPP Site Boundary during facility operation or after decommissioning. This prohibition **precludes slant drilling**[7] under the WIPP facility from within or outside the WIPP facility. (U.S. DOE, 1990a, Section 2.1.1.1).

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[7]Emphasis added.

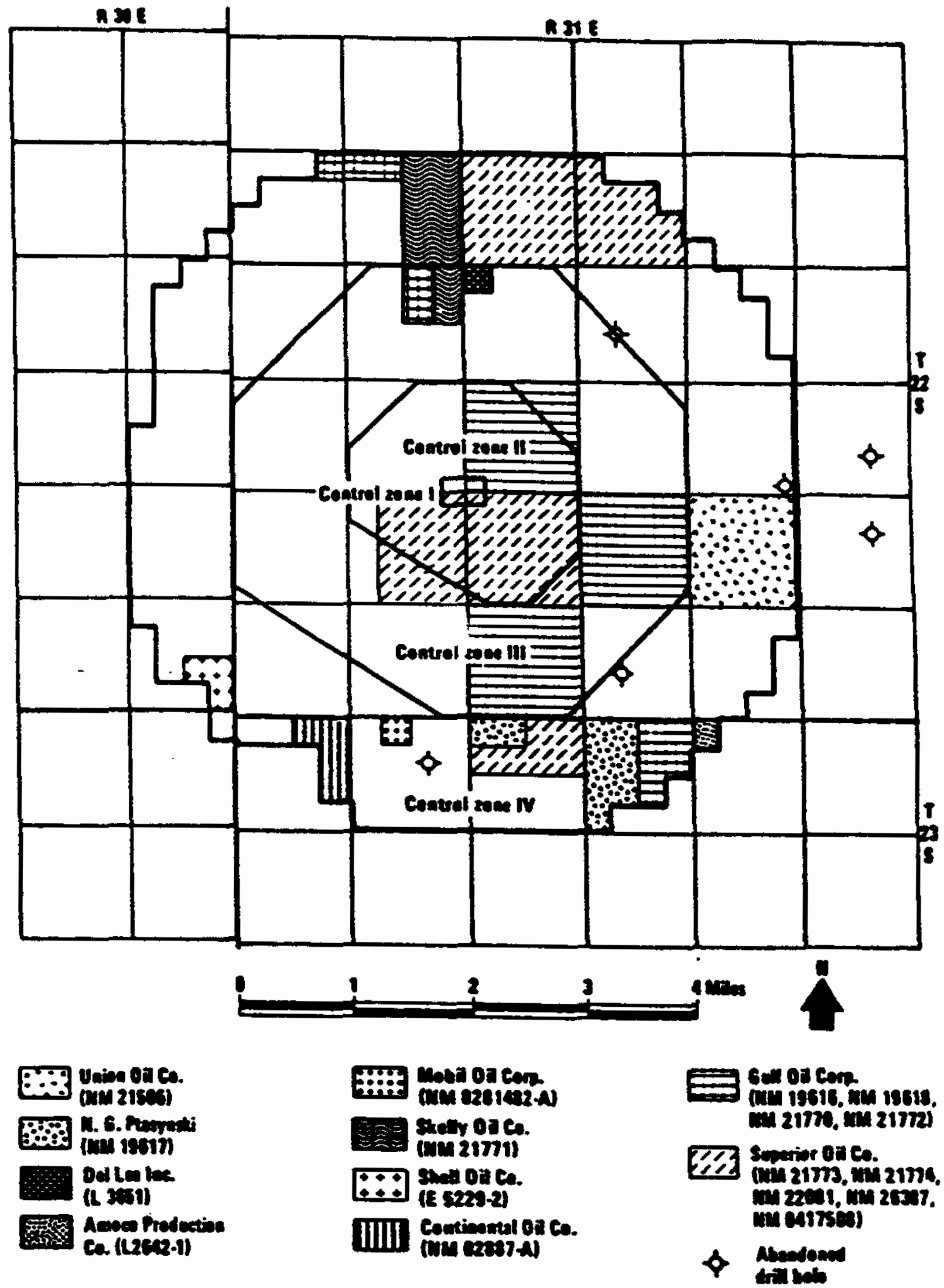

Figure 7. Oil and Gas Leases Within the WIPP Site according to the DOE FEIS, (U.S. DOE, 1980, Figure 8-6, reproduced with permission).

The WIPP Final Safety Analysis Report also incorrectly states:

> ... all oil and gas leases within the WIPP Site Boundary have expired (U.S. DOE, 1990a, Section 2.1.2.1.3).

Furthermore, Figure 2.2-1 (Figure 8 in this report) of the WIPP FSAR fails to show all of the 1986 operable natural gas and oil wells within a ten mile (16.1 kilometers) radius. This figure shows seven wells just outside the southwest corner of the site - James Ranch Unit Nos. 1, 3, 4, 7, 10, 11 and Hudson Federal No. 1. James Ranch Unit No. 3 appears to be plotted in the wrong location. At least two wells, James Ranch Unit Nos. 13 and 14 shown in Figure 9, both slant drilled wells, are not shown in the WIPP FSAR. James Ranch Unit No. 13 and James Ranch Unit No. 14 were not only operable, but each was producing through the entire year of 1986, as shown in Figures 10 and 11.

Table 1 (prepared from data provided by the Roswell District Office of the U.S. BLM) lists the gas and condensate production from the James Ranch Unit No. 13. Production was stopped for one month in July 1985 and again for three extended periods of several months beginning in April 1987. Nonetheless, gas and condensate were produced for several months in 1987, 1988, and again in 1991. To date this well has produced over 3,000,000 MCF gas. The latest available production records in the Roswell District Office of the U.S. BLM show production of 27,618 MCF gas and 164 BBLs condensate for February 1992 (U.S. BLM, 1992).

James Ranch Unit No. 14 was slant drilled in 1983. The top of the well is located in Section 6, T23S, R31E and completed in the Los Medaños-Morrow Formation in Section 7, T23S, R31E. Since production began in December 1983 records through February 1992 show this well has produced gas every month except for a two month period in 1987.

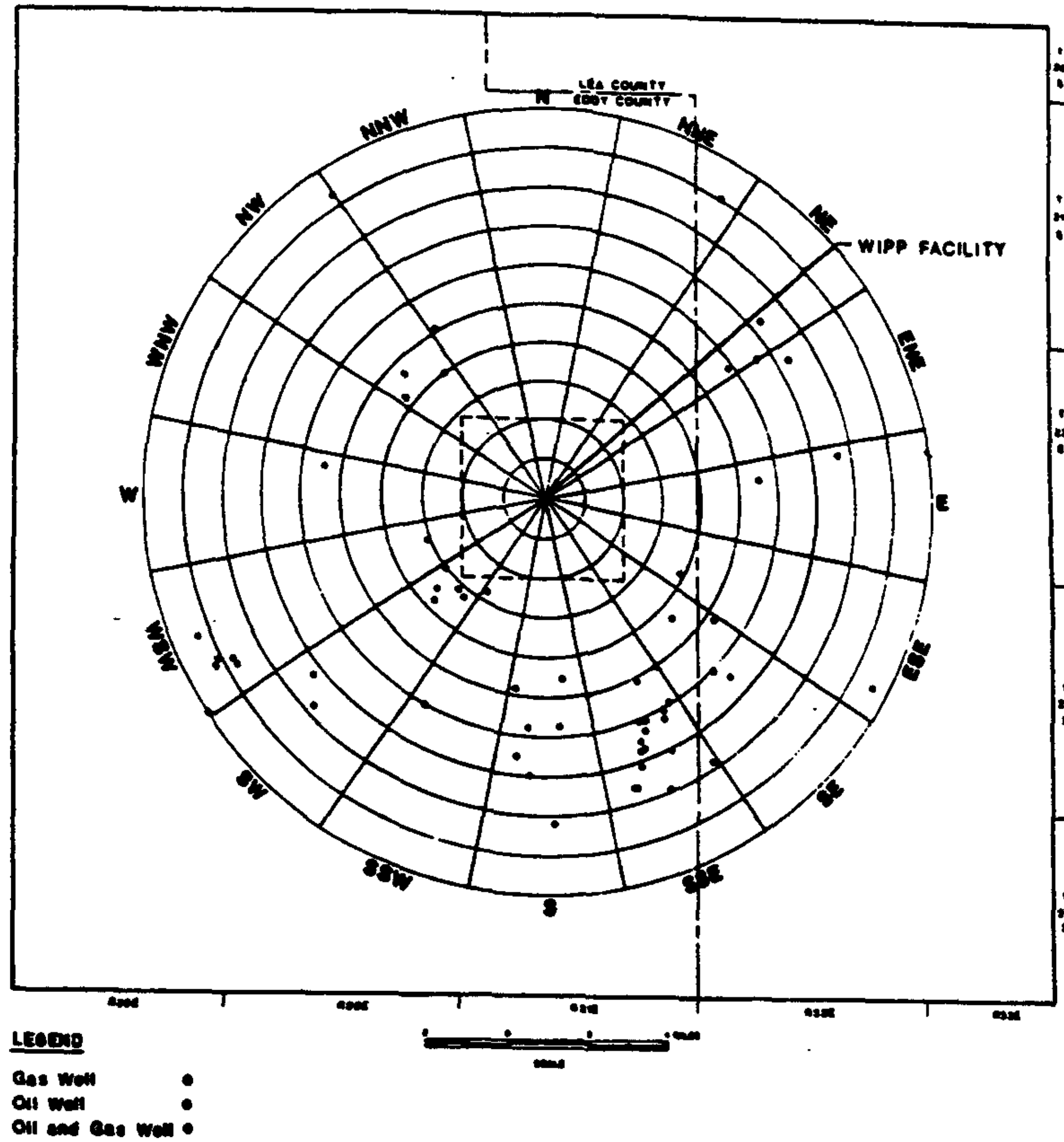

Figure 8. 1986 Operable Natural Gas and Oil Wells, within 10 Mile Radius (WIPP FSAR, U.S. DOE, 1990a, Figure 2.2-1, reproduced with permission).

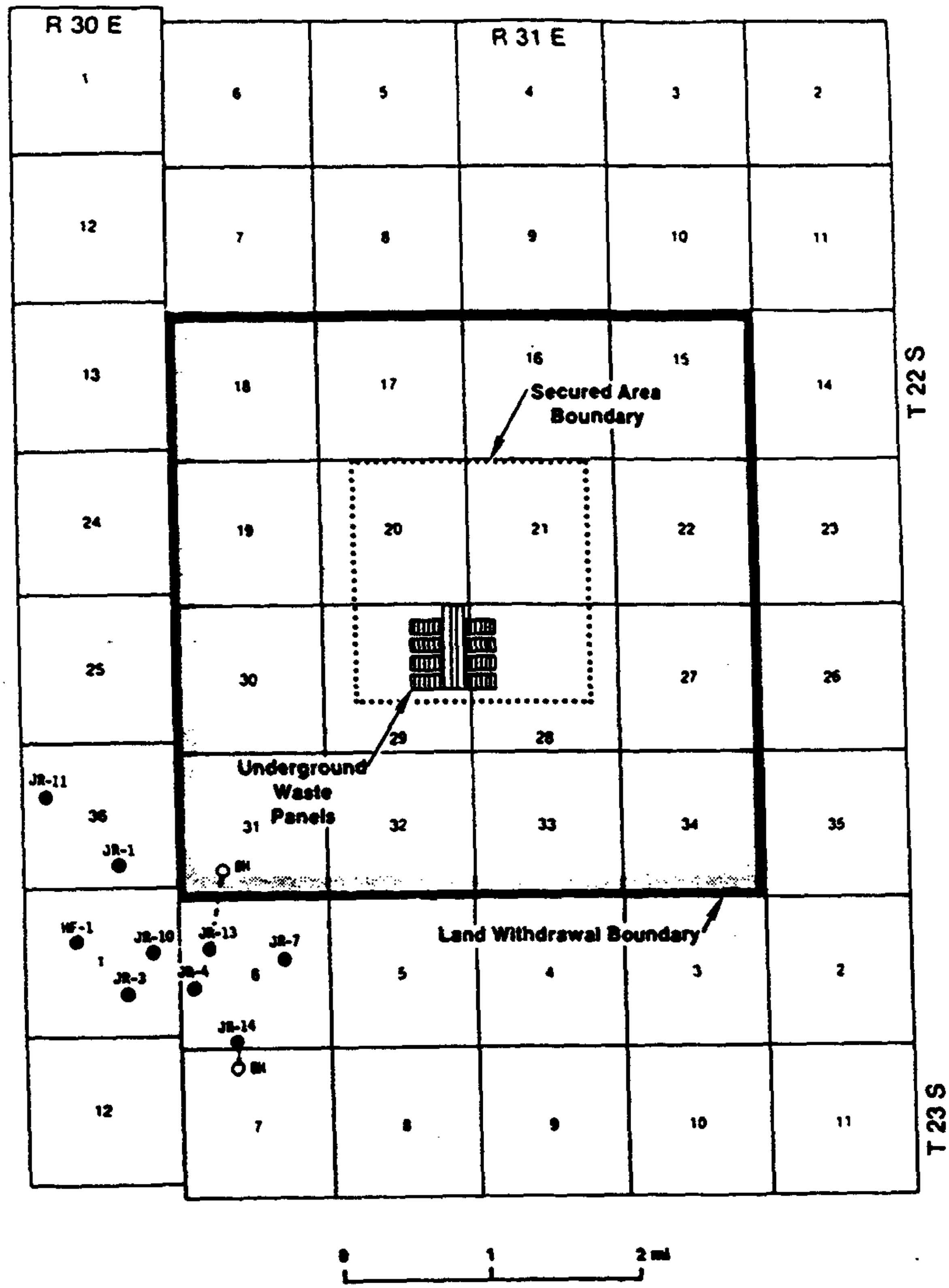

Figure 9. Gas and Condensate Wells at Southwest Corner of WIPP Site. Well locations plotted from U.S. BLM records.

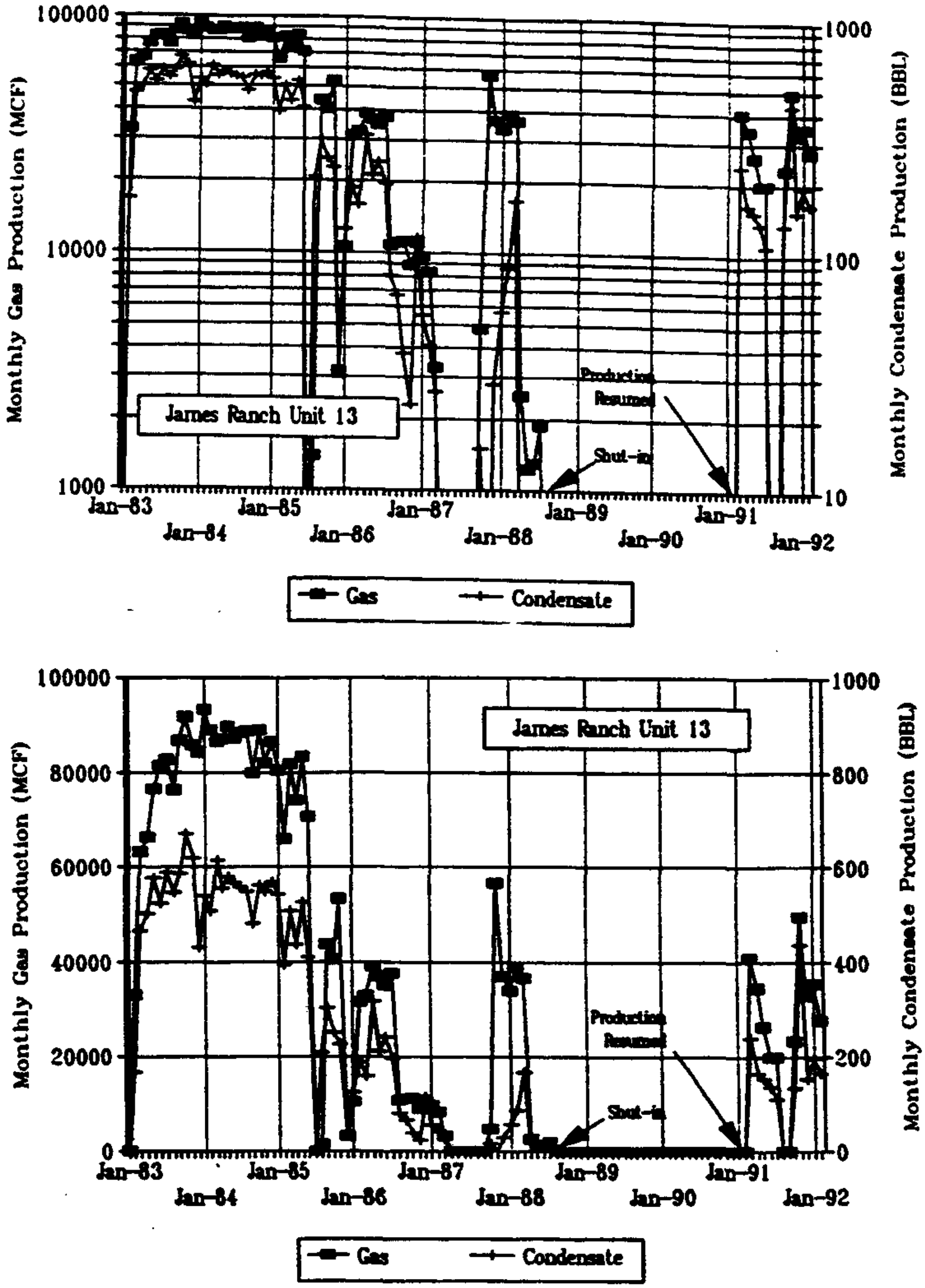

Figure 10. Production History of James Ranch Unit No. 13. Data provided by Roswell District Office, U.S. BLM, 1992.

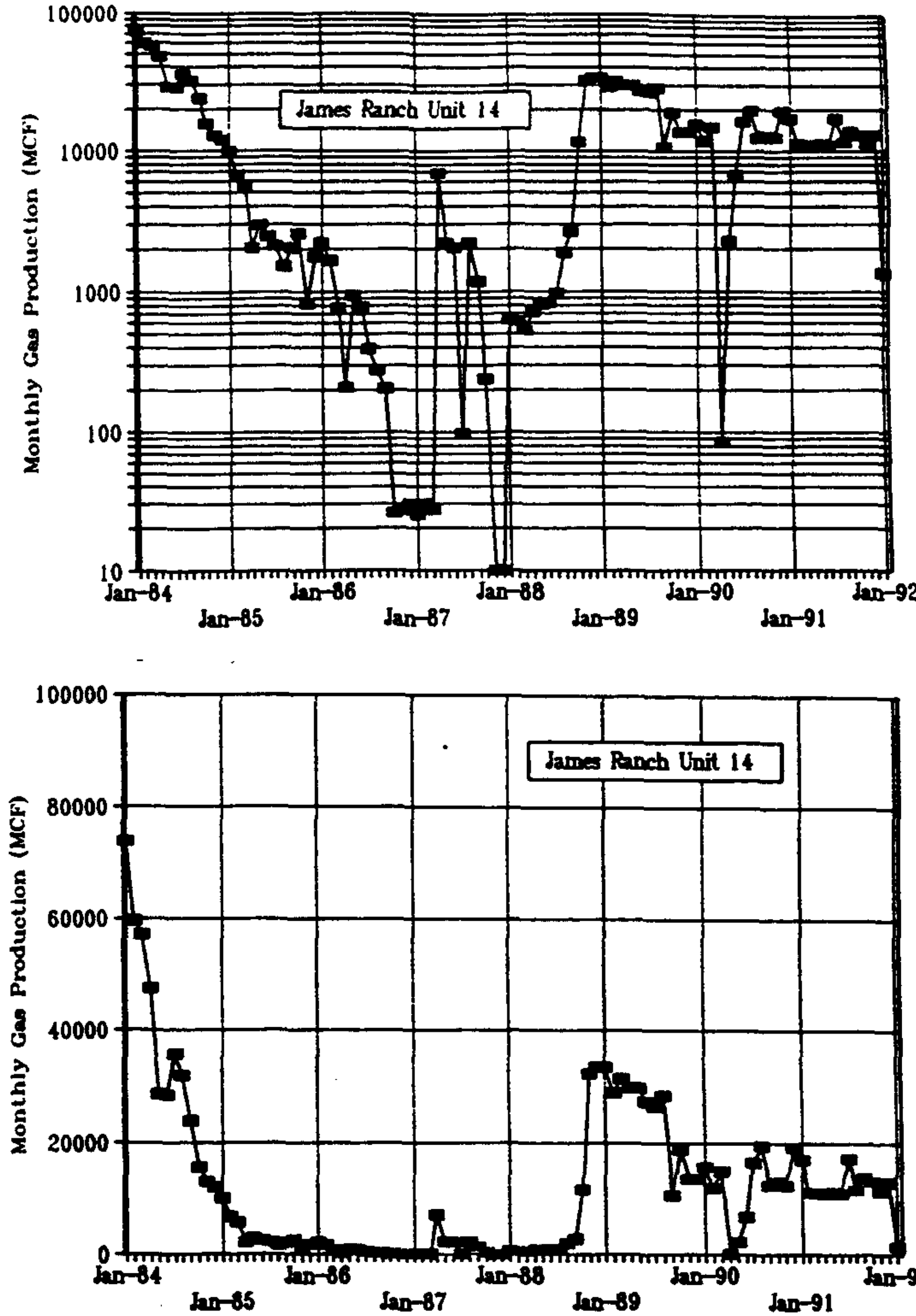

Figure 11. Production History of James Ranch Unit No. 14. Data provided by Roswell District Office, U.S. BLM, 1992.

TABLE 1: PRODUCTION HISTORY OF JAMES RANCH UNIT NO. 13

DATE	OIL (BBL)	GAS (MCF)	WATER (BBL)
01/31/83	0	0	0
02/28/83	167	32970	17
03/31/83	467	63373	31
04/30/83	501	66425	27
05/31/83	579	76613	30
06/30/83	524	81409	30
07/31/83	589	82734	31
08/31/83	546	76421	31
09/30/83	588	86647	30
10/31/83	672	91799	31
11/30/83	619	85720	30
12/31/83	431	84334	29
01/31/84	539	93266	31
02/29/84	508	88828	29
03/31/84	615	86519	30
04/30/84	555	86971	30
05/31/84	580	89612	31
06/30/84	567	87216	30
07/31/84	557	88357	31
08/31/84	548	88778	31
09/30/84	481	80027	29
10/31/84	562	89005	31
11/30/84	549	82072	30
12/31/84	569	86411	31
01/31/85	543	80505	30
02/28/85	393	65972	26
03/31/85	507	81783	31
04/30/85	437	74131	58
05/31/85	526	83292	31
06/30/85	410	70727	28
07/31/85	0	0	0
08/31/85	207	1391	16
09/30/85	302	43919	17
10/31/85	250	40550	17
11/30/85	227	53275	21
12/31/85	33	3112	14
01/31/86	126	10583	4
02/28/86	189	31505	10
03/31/86	160	32865	13
04/30/86	316	38991	17
05/31/86	212	36926	30
06/30/86	241	35085	16

TABLE 1 (continued)

07/31/86	196	37753	16
08/31/86	81	10837	5
09/30/86	67	11113	5
10/31/86	38	11235	5
11/30/86	23	8979	5
12/31/86	117	10951	6
01/31/87	55	9701	7
02/28/87	41	8374	24
03/31/87	26	3305	3
04/30/87	0	0	0
05/31/87	0	0	0
06/30/87	0	0	0
07/31/87	0	0	0
08/31/87	0	0	0
09/30/87	0	0	0
10/31/87	15	4824	4
11/30/87	0	56786	22
12/31/87	28	36952	36
01/31/88	57	33926	30
02/29/88	87	38970	32
03/31/88	167	36552	28
04/30/88		2518	4
05/31/88		1219	2
06/30/88		1297	4
07/31/88		1872	
08/31/88	0	0	0
09/30/88	0	0	0
10/31/88	0	0	0
11/30/88	0	0	0
12/31/88	0	0	0
01/31/91	0	0	0
02/28/91	0	0	0
03/31/91	240	40888	0
04/30/91	164	34513	30
05/31/91	153	26441	0
06/30/91	136	20034	26
07/31/91	110	20043	31
08/31/91	0	0	
09/30/91	0	0	
10/31/91	135	23393	
11/30/91	436	49658	29
12/31/91	153	32782	31
01/31/92	196	35364	
02/29/92	164	27618	

5.3 No-Migration Variance Petition to EPA

The DOE No-Migration Variance Petition (U.S. DOE, 1990b) to the EPA states in the section on human intrusion:

> Oil and gas exploration has been and continues to occur around the WIPP site. The target horizons for this type of exploration are below the Castile. Oil and gas exploratory drilling requires permits from the state, and it is unlikely that prospective future well drillers would not be informed about the existence of WIPP. As an additional protective measure, **the DOE has purchased all oil and gas leases in the area of the WIPP site**[a] to prevent any exploration now and in the future (U.S. DOE, 1990b, Section 6.3.2).

With respect to petroleum exploration and the human intrusion issue, the last sentence in this paragraph provided incorrect information to the EPA. The EPA subsequently granted a variance to the DOE in November 1990 (U.S. EPA, 1990).

5.4 New Mexico Energy and Minerals Department Report

The 1984 report published by the New Mexico Energy and Minerals Department (NMEMD) Task Force on Natural Resources (NMEMD, 1984) stated that the DOE had acquired several oil and gas leases at a cost of over $19.6 million dollars. The report stated that "As a result of these lease acquisitions, only one hydrocarbon lease remains within the WIPP Site Boundary... an 80-acre tract held by Skelly Oil Company...." (NMEMD, 1984, p. 27). The report did not identify the active gas and oil leases in Section 31, deeper than 6,000 feet (1829 meters).

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[a]Emphasis added.

5.5 1990 Memorandum of Understanding between BLM and DOE

The U.S. Department of Energy and the U.S. Department of Interior's BLM signed the Memorandum of Understanding on October 26, 1990, recognizing that:

> **BLM will prohibit directional drilling underneath the WIPP site boundary, except as may be required for the development of the two leases located under Section 31;**[9] drilling may be allowed below 6,000 feet of the surface.

Hence, it appears the DOE entered into an agreement in 1990 to honor these leases despite commitments to preclude slant drilling in the 1987 C&C Agreement with New Mexico and the 1990 WIPP FSAR.[10] Apparently, the DOE accepted the *fait accompli* without considering the commitments in the C&C Agreement and the WIPP FSAR.

5.6 Department of Energy Position

On November 3, 1990, the Albuquerque Journal reported the discovery of the forgotten natural gas well completed within the WIPP Site Boundary. (McCutcheon, 1990).

On November 15, 1990, the Assistant Manager for Energy and Special Programs of the Albuquerque Operations Office of the Department of Energy sent a letter to the

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[9]Emphasis added.

[10]On January 22, 1991, the Assistant Secretary of the Interior signed 43 CFR Public Lands Order 6826 (Administrative Land Withdrawal). That Administrative Land Withdrawal Order cites the October 26, 1990 Memorandum of Understanding between the U.S. Department of Energy and the U.S. Department of the Interior BLM as the guiding document regarding resource management.

Chairman of the New Mexico Radioactive Waste Consultation Task Force. The letter maintained:

> ...at the time this deviated well was drilled, the section 31 bottom hole was within what was formerly termed "zone IV" of the WIPP site. A 1980 report prepared by Sandia National Laboratories (SNL) concluded that extraction from within zone IV would have no technical impact on repository performance. The 1980 Environmental Impact Statement for the WIPP stated that the DOE would permit drilling for natural gas in zone IV. Accordingly, in 1981 when Bass Enterprises filed an application to drill the well, the DOE stated it had no objection, so long as the operator did not encroach upon the surface or the first 6,000 feet condemned by the United States. Recent review by SNL confirms that the existence of this bottom hole more than 14,000 feet below section 31 does not affect the performance of the repository.
>
> We do not believe that the existence of this 1982 well contravenes the August 4, 1987 Second Modification to our Agreement for Consultation and Cooperation in which we previously agreed to prospectively preclude "subsurface mining, drilling, or resource exploration unrelated to the WIPP Project on the WIPP site" [including "slant drilling under the site from within or from outside the site"].... (Bickel, 1990a).

The DOE response requires further explanation because it cited a "1980 report" from Sandia National Laboratories and a "recent review by SNL." The "1980 report" was a **draft** of a position paper on Zone IV. The 1980 memo of transmittal accompanying those draft pages also recommended that:

> well selected, realistic scenarios addressing the consequences of mining and drilling in Zone IV should be a part of the Zone IV position paper (Weart, 1980).

The cited "recent review by SNL" described in the November 15, 1990, DOE letter was a November 5, 1990, memo (Weart, 1990) prepared at the DOE's request. The one and one-half page memo reexamined the reasoning from the 1980 draft in light of the new dilemma and current regulatory requirements. The memo correctly stated:

> the portion of the hole that penetrates the salt is outside the site boundary and thus beyond the boundary at which compliance with the standards will be evaluated (Weart, 1990).

and concluded that:

> even though the Bass drill hole is bottomed within the site boundary, it is much more than a mile from the waste zone and therefore exceeds the technical safety requirements (Weart, 1990).[11]

The DOE Albuquerque Operations Office November 16, 1990, letter to the Coordinator of the New Mexico Radioactive Waste Task Force stated:

> there is one producing well allowed in each 320-acre production unit. The south half of Section 31 has its one well, James Ranch Unit No. 13 (Bickel, 1990b).

However, the letter failed to note current drilling practices in New Mexico would allow additional deep gas wells to be drilled into Section 31 including the south half

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[11]Initially, the selection of a site required that the repository be located at least two miles from a borehole penetrating the Salado formation. The two mile requirement was believed to be conservative but was also arbitrary (Schueler, 1980). The two mile requirement was reduced to one mile after the site at the ERDA 6 borehole was found to be unacceptable (Neill et al., 1979, Appendix III, p. 6). The Geologic Characterization Report (Powers et al., 1979, p.2-12) stated that justification for a one mile criteria was based on reports by Snow and Chang (1975), Walters (1975), Fader (1973), and Griswold (1977). However, EEG questioned the pertinence of these studies and, hence, questioned the justification for the reduction to a one mile criteria (Neill et al., 1979, Appendix III, pp. 6,7).

of that section. The lessee can request permission to drill on tighter spacing by demonstrating to the New Mexico Oil Conservation Division that the tighter spacing is required to efficiently produce the gas from the formation. For example, if a reservoir exhibits retrograde condensate behavior, the buildup of liquid around the well bore can reduce, sometimes seriously, the flow rate as the pressure declines below the dew point (Craft and Hawkins, 1959, p. 73). Hence, efficient production may require more wells on a tighter spacing.

Also, the existing well in Section 31 could be deepened. That activity would constitute exploratory drilling.

Furthermore, the lessee is still entitled to slant drill an exploratory hole into the north half of Section 31, which has yet to be developed. In summary, as long as the lessee maintains the leases, the U.S. BLM can not deny them access to their oil and gas in Section 31, the southwestern section of the WIPP Site.

5.7 SNL WIPP Performance Assessment Division

The SNL WIPP Performance Assessment Division issues an annual report on the status of the demonstration of the extent of compliance with 40 CFR Part 191. The December 1990 annual report stated:

> About 56 oil and gas wells are within a radius of 16 km (10 mi); the wells generally tap Pennsylvanian strata, about 4,200 m (14,000 ft) deep. The nearest well is about 3 km (2 mi) to the south-southwest of the waste panels (Bertram-Howery, 1990, p. I-20).

There was no discussion on the status of that well. For 1991, the SNL WIPP Performance Assessment Division added:

> The surface location of the well, which is capable of producing gas, is outside the proposed land-withdrawal boundary, but the borehole is slanted to withdraw gas from rocks within the boundary. Except for this well, resource extraction is not allowed within the proposed land-withdrawal boundary (Sandia National Laboratory, 1991, p. 1-15).

The 1991 document also stated in the discussion on natural resources:

> In order to gain control over the development of hydrocarbons at the WIPP, the DOE acquired the oil and gas leases within all the WIPP control zones. The only leases that are still intact are in Section 31. These leases only allow resource production by entry of the proposed land withdrawal area below 6000 feet. **One of these leases is currently in production.**[12] The upper 6000 feet of the leases was taken by the DOE in 1979. Current policy does not allow any further resource development inside the proposed land withdrawal boundary (Sandia National Laboratory, 1991, p. 8-7).

5.8 The Secretary of Energy's Decision Plan

While the Secretary of Energy's Decision Plan for the WIPP had carefully tracked an active potash lease until it was purchased, successive Revisions 6 through 10 did not document the existence of the active oil and gas leases even after the issue had been raised. The potash lease purchase was noted in Revision 5 (U.S. DOE, August 15, 1990). The failure of subsequent revisions to mention the rediscovered gas leases incorrectly suggests that there were no outstanding leases in the WIPP Site Boundary other than the one potash lease.

[12]Emphasis added.

5.9 DOE Implementation of the Resource Disincentive Plan

The *DOE Implementation of the Resource Disincentive Plan in 40 CFR 191.14(e) at the Waste Isolation Pilot Plant* (U.S. DOE, 1991) is inconsistent in reporting the number of oil and gas leases within the WIPP Site Boundary and the production status of those leases. First it incorrectly states that:

> Only one lease currently exists within the WIPP site boundary (U.S. DOE, 1991, p.32).

However, there are two active gas and oil leases within the WIPP site boundary — the Conoco lease on the north half of Section 31 and the Bass lease on the south half of Section 31.

The Resource Disincentive Plan then states:

> This lease, **currently shut in for production of oil and gas,**[13] is being exploited by a well that was initiated outside the WIPP site boundary and was deviated to under the site only after the depth was below 6000 feet (U.S. DOE, 1991, p.32).

The document then reverses its position on the number of leases and their production status:

> In order to gain control over the development of hydrocarbons within the WIPP site area, the DOE acquired the oil and gas leases within all the WIPP control zones. These acquisitions were necessary to keep the salt beds intact. The only leases that are still intact are in section 31. These leases only allow

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[13]Emphasis added.

the production of resources by entry below 6000 feet. **One of these leases is currently in production**[14] (U.S. DOE, 1991, p.50).

The U.S. Bureau of Land Management (U.S. BLM, 1992) records show the well produced 141,919 MCF of natural gas from March 1991 through July 1991 as shown in Table 1, and was shut-in effective August 1991 - coincidently, the issue date of the Disincentive Plan. The latest available records from the Roswell District Office of the U.S. BLM indicate production resumed in October 1991.

5.10 Comments on Credit for Active and Passive Institutional Control

In terms of active institutional control, the leases were forgotten by the DOE in spite of the lease, drilling, and production records filed with the federal government, a condemnation suit filed in civil court by the federal government, agreements between the State of New Mexico and the federal government, technical reports to the federal government on area oil and gas resources, and the existence of a producible gas well visible from the south access highway into the WIPP facility.

The loss of knowledge in just a short few years is cause for concern. There were no major changes in society, government, language, culture, or technology. Yet the WIPP project lost knowledge of this gas well and the active oil and gas leases. The current wording in the EPA Standards permits the assumption that active institutional control can completely deter inadvertent human intrusion for up to 100 years.

We believe that present assumptions about the effectiveness of active institutional control needs to be reconsidered because of this experience of the forgotten oil and gas leases and a forgotten gas well. First, the EPA should reexamine whether full credit for 100 years active institutional control is reasonable given the actual experience of inaccurate record keeping. Second, the DOE should examine the basis

[14]Emphasis added.

for assuming full credit for 100 years control and consider using a lesser value to reflect the actual experience of the WIPP project. Third, the EPA Standards should require the implementing agency to publish specific plans on how the agency intends to maintain active institutional control. Fourth, even in the absence of such a requirement, the DOE should publish plans now that specify in detail how the Department intends to maintain full control of activities in the area of the repository for 100 years after decontamination and decommissioning and how that control will completely deter human intrusion.

At this time the DOE commitment is effectively limited to a statement in the First Modification to the C&C Agreement which states:

> the post-closure institutional control, shall be negotiated and resolved by the parties in the future, and at least one year prior to the start of the decontamination and decommissioning of WIPP (U.S. DOE, 1981).

In the Second Modification to the C&C Agreement, the DOE agreed to provide a plan by February 1, 1988, which would:

> contain an estimated schedule and a description of the process DOE will use to: identify needed active institutional controls, gather data for the implementation of such controls, develop and implement a monitoring plan for passive institutional controls, determine the barriers to be used, assess the selection of the WIPP site in view of the resources at the site, and review the recoverability of the waste for a reasonable period after disposal.

However, the DOE Plan:

> merely describes the steps that the DOE will undertake to implement compliance to one portion of the Standard [40 CFR 191 Subpart B]. For most of the Assurance Requirements, the information needed to specify detailed plans and activities for implementation is not yet available.... Other

information will not be available until close to the time that the Project has completed its mission and the WIPP is closed (U.S. DOE, 1987, p.1).

Furthermore, the remanded EPA Standards allow credit for the use of passive institutional controls to deter inadvertent human intrusion (U.S. EPA, 1985, p. 38080). However, excessive credit for passive controls, such as markers and public records, could reduce the estimated probability of inadvertent human intrusion in the performance assessment calculations and underestimate the actual risk. As discussed above, there is inaccurate information in key DOE documents which can be considered public records. There was the presence of a gas wellhead, visible from the south access highway and availability of lease and production records in the Roswell District Office of the U.S. BLM. Yet that marker and these public records were not effective in notifying the preparers of the DOE documentation of the gas and condensate production activity beneath the WIPP site and the existince of active leases with the WIPP Site Boundary.

6.0 PROPOSED CONGRESSIONAL LEGISLATION

The issue of allowing the existing oil and gas leases and a well to produce hydrocarbons from beneath the WIPP Site has been addressed by the U.S. Congress in the various bills for the WIPP land withdrawal.

The bill passed by the Senate (S. 1671) would:

- ♦ prohibit slant drilling from within or without the site
- ♦ require the Department of the Interior, in consultation with the Department of Energy, to determine the effects of the oil and gas leases on the activities at the WIPP and to recommend as to the advisability of trading or cancelling the leases.
- ♦ authorize funds to be appropriated to the Department of Energy for the cancellation of the leases.

The House Armed Services Committee Bill (H.R. 2637) is identical to S. 1671 except that it does not authorize funds to cancel the lease.

The bills passed by the House Committee on Interior and Insular Affairs (H.R. 2637) and the House Committee on Energy and Commerce (H.R. 2637) would both:

- ♦ prohibit slant drilling from outside the WIPP boundary,
- ♦ provide funds for the DOE to acquire the leases.

7.0 CONCLUSIONS

Several U.S. Department of Energy documents failed to record the existence of two active oil and gas leases and a producible gas well within the WIPP Site Boundary. In its performance assessment calculations, the WIPP project has assumed that active institutional control would deter human intrusion for 100 years after decommissioning. The EPA should reexamine whether full credit for 100 years active institutional control is reasonable given the actual experience of inaccurate record keeping. The DOE should also examine the basis for assuming full credit for 100 years control and consider using a lesser amount to reflect the actual experience of the WIPP Project. The EPA Standards should require the implementing agency to publish specific plans on how the agency intends to maintain active institutional control. Even in the absence of such a requirement, the DOE should publish plans now that specify in detail how the Department intends to maintain full control of activities in the area of the repository for 100 years after decontamination and decommissioning and describe how that control will completely deter human intrusion. Finally the DOE needs to describe in detail their passive institutional control system and describe how it will provide a deterrence to inadvertent human intrusion after 100 years.

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9.0 LIST OF ACRONYMS

BBL	Barrels
BLM	Bureau of Land Management
C&C	Consultation and Cooperation
CFR	Code of Federal Regulations
CH-TRU	Contact-Handled TRU (waste)
DOE	U.S. Department of Energy
EEG	Environmental Evaluation Group
EPA	U.S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
FEIS	Final Environmental Impact Statement
FSAR	Final Safety Analysis Report
MCF	Thousand standard cubic feet
MOU	Memorandum of Understanding
NMEMD	New Mexico Energy and Minerals Department
RH-TRU	Remote-Handled TRU (waste)
SNL	Sandia National Laboratories
TRU	Transuranic
U.S.G.S	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant

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EEG-57

AN APPRAISAL OF THE 1992 PRELIMINARY PERFORMANCE ASSESSMENT FOR THE WASTE ISOLATION PILOT PLANT

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FOREWORD

This is the Environmental Evaluation Group's (EEG) appraisal of the 1992 performance assessment for the Waste Isolation Pilot Plant. Performance assessments have been performed by Sandia National Laboratories for the U. S. Department of Energy to predict the long-term safety of the Waste Isolation Pilot Plant. The 1992 Performance Assessment, entitled *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992,* is in five volumes:

vol. 1: Third Comparison with 40 CFR 191, Part B;

vol. 2: Technical Basis;

vol. 3: Model Parameters;

vol. 4: Uncertainty and Sensitivity Analysis for 40 CFR 191, Part B;

vol. 5: Uncertainty and Sensitivity Analysis for Gas and Brine Migration for Undisturbed Performance.

This current appraisal incorporates EEG's preliminary comments on volumes 1, 2, and 3 transmitted to the U. S. Department of Energy on September 13, 1993, and volumes 4 and 5 received October 27, 1993.

The purpose of the New Mexico Environmental Evaluation Group is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure the protection of the public health and safety and the environment. The WIPP Project, located in southeastern New Mexico, is being constructed as a repository for the disposal of transuranic (TRU) radioactive wastes generated by the national defense programs. The EEG was established in 1978 with funds provided by the U.S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and continued the original contract DE-AC04-79AL10752 through DOE contract DE-ACO4-89AL58309. The National Defense Authorization Act for Fiscal Year 1994, Public Law 103-160, continues the authorization.

EEG performs independent technical analyses of the suitability of the proposed site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria and the generator sites' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP. Another important function of EEG is the independent environmental monitoring of background radioactivity in air, water, and soil, both on-site and off-site.

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The Environmental Evaluation Group (EEG) has reviewed the WIPP *1992 Performance Assessment*. The Sandia team should be commended for both the substance of this work, and a sound theoretical foundation. Progress has been made towards assessing WIPP's compliance with the U.S. Environmental Protection Agency's Standards for high-level and transuranic waste. Our comments on the *1992 Performance Assessment* are organized into Major Issues, and Detailed Comments. Specific recommendations on major issues follow.

1. Claimed Improvements in the *1992 Performance Assessment.*
   - R-1.1 Apply available fully coupled codes to make explicit the relationship between the complex processes of gas generation, brine flow and room closure.
   - R-1.2 Abandon further statistical manipulation of transmissivity fields in the Culebra in favor of additional field and laboratory work to better define multi-well flow and transport characteristics, including flow and tracer tests (sorbing and non-sorbing) at additional locations.
   - R-1.3 Abandon claiming credit for matrix diffusion and corrensite sorption until experimental data can substantiate the claim.
2. Displaying Uncertainty in Final Results
   - R-2 Show the full uncertainty band of CCDFs when comparison with the containment requirement (40 CFR 191) is made.
3. Use of Judgment in Performance Assessment
   - R-3.1 As experimental solubility values become available (e.g. Nitsche *et al.,* 1992; 1993), use them in performance assessment.
   - R-3.2 Use only demonstrable retardation coefficients in performance assessment.
   - R-3.3 Discard the subjective probabilities for human intrusion used in the *1992 Performance Assessment* and adopt the specific suggestion in Section 3.4.
4. Computer Code Documentation
   - R-4 Establish a workable system to provide EEG with relevant documentation, so that EEG has reasonable access to perform its work.
5. The Culebra as a Natural Barrier
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8. Natural Resources Near the WIPP
   - R-8 Performance assessment reports should accurately reflect the status of resource development near the WIPP site.

9. Oil and Gas Production Near the WIPP
   - R-9 The performance assessment effort should use the latest and verifiable data on oil and gas production near the WIPP, because the extent of oil and gas resources in this area is likely to be an important determinant of inadvertent human intrusion, and oil and gas production can potentially affect the hydrogeology at the WIPP site.

10. Gas Generation
   - R-10a The gas generation calculations should include
     - (a) *methane generation*,
     - (b) radiolytically generated hydrogen.
   - R-10b The relationships in the gas generation model should be validated before the gas generation model is incorporated into BRAGFLO.

11. Unanalyzed Scenarios
   - R-11.1 The criticality issue needs to be thoroughly evaluated before it can be concluded that its effects are negligible.
   - R-11.2 Subsidence effects need to be evaluated in much more detail and incorporated, in some manner, into the human intrusion scenarios.
   - R-11.3 Provide results of the abovementioned analyses, and include contaminated brine flow to the ground surface in future versions of human intrusion scenarios.
   - R-11.4 Perform a complete analysis of a brine-slurry release scenario. In addition, variants of the brine-slurry scenario in undisturbed performance and in the E2 scenario need to be better understood.
   - R-11.5 Performance Assessment should not assume perfect plugging of abandoned oil and gas wells near the WIPP. For the human intrusion borehole, the range of degraded permeabilities should span sand and gravel.

12. Analysis of Direct Discharge to the Ground Surface
   - R-12 Future performance assessments need to include erosion of waste by helical turbulent flow and the effect of sediment erosion. Also needed is analysis of other relevant scenarios, such as the E1E2 with brine slurry discharge to the surface.

13. Inventory
   - R-13.1 Include ^{135}Cs, ^{129}I and ^{99}Tc and other fission product nuclides as appropriate in future performance assessments.
   - R-13.2 Show the basis for inventories used.

14. Solubilities

R-14 In future performance assessments, limit the sampling range to the error bands in experimental data.

15. Transport Modeling of Volatile Organics

R-15 Two-phase transport of volatile organic compounds through gas-fractured interbeds should be analyzed in the future.

16. Corrensite Retardation in the Culebra

R-16 Abandon claiming credit for corrensite sorption as well as additional experiments with corrensite, unless the extent of corrensite or other clay minerals can be quantified along postulated flow paths.

17. Ideal Gas Assumption in VOC Migration

R-17 Unless there is experimental evidence that VOC vapors move as ideal gases and move with the low-molecular-weight gases generated by radiolysis, corrosion, or microbial action, movement of VOC vapors should not be modeled as ideal gas flow in showing compliance with 40 CFR 268.

I. INTRODUCTION

The Environmental Evaluation Group (EEG) has reviewed the WIPP *1992 Performance Assessment* (Sandia WIPP Performance Assessment Department, 1992). Although this performance assessment was released after the October 1992 passage of the WIPP Land Withdrawal Act (PL 102-579), the work preceded the Act. For individual and ground-water protection, calculations have been done for 1000 years post closure, whereas the U.S. Environmental Protection Agency's Standards (40 CFR 191) issued in 1993 require calculations for 10000 years.

This is the third iterative performance assessment of the Waste Isolation Pilot Plant (Sandia WIPP Performance Assessment Department, 1992; 1991; Bertram-Howery *et al.*, 1990). EEG believes the Sandia team should be commended for both the substance of this work, and a sound theoretical foundation for performance assessment. The *1992 Performance Assessment* continues to assimilate improved understanding of the geology and hydrogeology of the site, and evolving conceptual models of natural barriers. Progress has been made towards assessing WIPP's compliance with the U.S. Environmental Protection Agency's Standards (40 CFR 191).

The *1992 Performance Assessment* has addressed several items of major concern to EEG, outlined in our July 1992 review of the 1991 performance assessment (Neill *et al.*, 1992). In particular, we are pleased that some key results in this performance assessment, shown in Chapter 5 of volume 1, deal with sensitivity of the calculated complementary cumulative distribution functions (CCDF) to alternate conceptual models proposed by EEG—that flow in the Culebra be treated as single-porosity fracture-flow; with no sorption retardation unless substantiated by experimental data. We look forward to results of additional analysis using scenarios and assumptions that EEG has suggested in the past and hereinafter.

Our review is organized into Major Issues, and Detailed Comments.

II. MAJOR ISSUES

1. Claimed Improvements in the *1992 Performance Assessment*

The overall conclusions of the *1992 Performance Assessment* are stated in chapter 9 of volume 4. Several improvements over previous assessments are noted, and we discuss the claimed improvements below.

1.1 While the first major improvement noted is the coupling of repository creep closure modeling to gas generation and brine flow, the coupling is not entirely satisfactory. The geomechanical closure calculated by SANTOS is passed onto BRAGFLO although the two computer codes use different conceptual models, geometries, and time scale.

Recommendation 1.1. Apply available fully coupled codes to make explicit the relationship between the complex processes of gas generation, brine flow and creep closure.

1.2 The *1992 Performance Assessment* accounts for spatial variation of transmissivity in the Culebra using improved methods. Table 8.4-1 in volume 4 shows that variation in Culebra transmissivity fields accounted for a mere 6% of the variation in total integrated releases. The respective solubilities of Am, Np, Pu, Th and U accounted for more of the variation in release rates.

Recommendation 1.2 Abandon further statistical manipulation of transmissivity fields in the Culebra in favor of additional field and laboratory work to better define flow and transport characteristics, including flow and tracer tests (sorbing and non-sorbing) at additional locations.

1.3 The *1992 Performance Assessment* accounts for radionuclide transport in the Culebra "more accurately" [sic]. To be accurate implies the existence of an unique and correct standard which does not exist in this case. The *1992 Performance Assessment* considers three radionuclide retardation mechanisms in the Culebra: equilibrium sorption, matrix diffusion and clay sorption. For equilibrium sorption, the second modification of the Consultation and Cooperation Agreement between the Department of Energy (USDOE) and the State of New Mexico specifies that retardation coefficients shall be set to zero unless there are experimental data otherwise. The *1992 Performance Assessment* offers no experimental evidence for matrix diffusion. No clear evidence is given for the extent of corrensite in the calculated flow paths. Moreover, clay in fractures can act either as an additional sorption agent, or serve to block mass transfer between the fracture and the matrix. The *1992 Performance Assessment* has eliminated the latter role [vol. 2, p. 7-23, line 11]. This is double counting for a mechanism which may not exist. We deal with the role of corrensite in detail in 16.

Recommendation 1.3 Abandon claiming credit for matrix diffusion and corrensite sorption until experimental data can substantiate the claim.

The *1992 Performance Assessment*

> ...accounts for the effects of passive marker systems through time-varying drilling intensities within the Poisson model for calculating intrusion probabilities [vol. 4, p. 9-1].

What this means is that subjectively elicited probabilities of drilling intrusion that are orders of magnitude below the USEPA guidance (40 *CFR* 191, Appendix C) have been used. The EEG objects to the use of these probabilities as elicited. We deal with this topic in 3b below.

The *1992 Performance Assessment* states that the following improvements will be made in future performance assessments:

- modeling pressure fracturing of anhydrite interbeds,
- modeling three-dimensional flow in the Rustler, especially the effects of subsidence of potash mine excavations,
- incorporating plug degradation,
- modeling spalling in drilling intrusions,
- acquiring experimental data on actinide solubilities and retardation,
- determining the most appropriate conceptual model for radionuclide transport in the Culebra.

We have called for these improvements for several years, and welcome the commitment.

2. Displaying Uncertainty in Final Results

In previous performance assessments, the USDOE noted that the calculated CCDF's were at least an order of magnitude below the allowable limits in the USEPA Standards (Sandia WIPP Performance Assessment Department 1991). In the *1992 Performance Assessment*, for the case of total release from repository/shaft barrier only, and a [0, 30] sampled intrusion rate, the mean CCDF comes to within a factor of two or three of the USEPA containment requirement [vol. 4, Fig. 9-1, curve 1]. This suggests several vectors of CCDF lie in the zone of violation of the containment requirement. This mean CCDF is not as conservative as it may appear because subjectively elicited solubilities are incorporated. The non-conservative basis of curve 1 in Figure 9-1 is illustrated in Figure 1. Using BRAGFLO-calculated brine flow from the repository up to the Culebra (70 vectors for both the E2 and E1E2 scenarios), all actinide solubilities at 10^{-3}, 10^{-5} and 10^{-7} M, and the human intrusion rate sampled uniformly between 0 and 30 boreholes/km^2/10,000 years, the mean CCDFs are shown in Figure 1, along with curve 1 from Figure 9-1 (vol. 4). If the extremely low subjectively elicited solubilities are **not** used, then the mean CCDF for the case of engineered barriers alone may not meet the containment requirement. See also 14 below.

The EEG has also suggested to the USEPA that for comparison with the containment requirement, that the 90% curve be used to be conservative.

Recommendation 2. Show the full uncertainty band of CCDFs when comparison with the containment requirement (40 CFR 191) is made.

3. Use of Judgment in Performance Assessment

3.1 Beginning with the *1992 Performance Assessment*, "expert judgment" is used to estimate

a. solubilities of actinides;

b. retardation coefficients of radionuclides; and

c. probabilities of inadvertent intrusion.

Experimental programs are underway to measure solubility and retardation coefficients, for conditions relevant to the WIPP.

Recommendation 3.1. As experimental solubility values become available (e.g. Nitsche *et al.*, 1992; 1993), use them in performance assessment.

3.2 The second modification of the Cooperation and Consultation Agreement between the Department of Energy and the State of New Mexico specifies that retardation coefficients be set to zero unless experimental data shows otherwise. Results using zero and nonzero retardation coefficients appear in chapter 5 of volume 1.

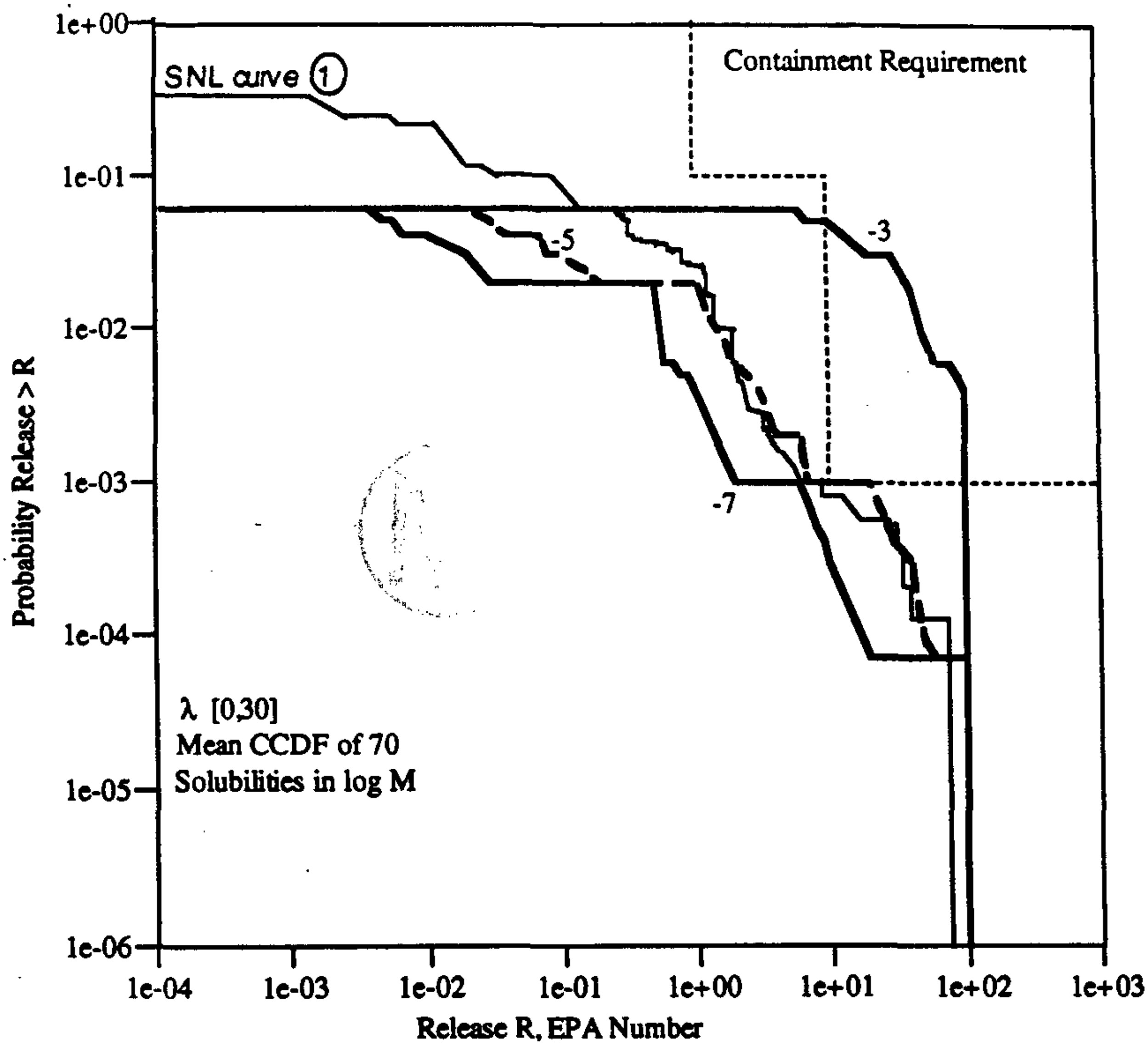

Figure 1. Comparison of mean CCDFs from the EEG scenario of direct ground discharge for all actinide solubilities set at 10^{-3}, 10^{-5}, and 10^{-7} M with Curve 1 from Figure 9-1 of SAND92-0700/4.

Recommendation 3.2. Use only experimental retardation coefficients.

3.3 EEG is concerned about the use of subjective probabilities in human intrusion analysis. While human judgment may be the only method of estimating these probabilities, we disagree with the procedure used in the *1992 Performance Assessment* to estimate human intrusion probabilities.

3.3.1 The disagreement between EEG and SNL centers around how the problem of subjective elicitation is to be formulated, whom to use as panelists and what information should be supplied to the panels. Elicitation should have been for the probability of future human intrusion by drilling for resources, the judges should have been people experienced in oil and gas and energy futures, and factual information should have been given to the judges during orientation.

Table I summaries the divergence.

Table I. Summary of Disagreement on Subjective Elicitation

Topic	SNL	EEG
Problem Formulation	Open	Focused
Required expertise	Knowledgeable in a subject	Knowledgeable in the focused subject
Briefing	Available information	Verified Information

SNL prefers to set no limits on the exercise, whereas EEG believes the problem must be well-defined. The divergence is clear from the SNL definition of an expert:

> An expert possesses exceptional knowledge about **a** subject [Hora to the Futures Panel, August 13, 1990 and to the Marker Panel, November 4, 1991].

EEG claims that the relevant definition should be

> An expert possesses exceptional knowledge about **the** subject.

3.3.2 The probabilities that have been elicited from panels for the purpose of estimating future intrusion intensity (Hora, von Winterfeldt and Trauth, 1991) are subjective probabilities. To call them "expert judgment" is to give them an aura of respectability they do not deserve. The methods for eliciting such probabilities come from statistics (Savage, 1954) and experimental psychology (Edwards, 1954). There are futurologists, such as Alvin Toffler or John Naisbitt, but the SNL Futures Panel was not composed of these people. While the elicitation of opinions is valid, the elicitation of expert opinion on the future is gratuitous. The WIPP Performance Assessment Department undertook an "extensive and impartial process" to select the panelists, but the process alone did not ensure the appropriateness of the chosen candidates. No attempt appears to have been made to establish the qualifications of the panel members as experts on the future. If the WIPP Performance Assessment Department had defined the problem properly, then it would be much easier to establish the expertise of the panelists.

3.3.3 The WIPP Performance Assessment Department invokes the interdisciplinary nature of an expert judgment panel as a reason to use such a panel. But "interdisciplinary" is not a synonym for "good" or "appropriate" any more than "single disciplinary" is a synonym for "bad" or "inappropriate." The advantage of multidisciplinary data interpretation over interpretation by an expert in a single discipline is not at all clear. For example, the marker panel (Rechard *et al.,* 1993; Table I) lists experts in materials science, architecture, linguistics, communications, etc. How is the judgment of a linguist on materials hardness and durability relevant? Either the linguist accepts the materials scientist's judgment, in which case the interpretation is not interdisciplinary, or the two differ in interpretation, in which case the materials scientist's interpretation is clearly the more valid and that judgment should not be diluted.

3.3.4 In the attempt to find general experts in lieu of futurologists, SNL might have empaneled representatives from diverse backgrounds, but failed to do so. The panels are not representative of modern United States, not representative of the modern world, and not representative of the historical continuity of the human race. While there were historians, sociologists and anthropologists, there was only one woman on the markers panels and none on the futures panels. There are no representatives of indigenous cultures of the southwestern United States.

In the USDOE response to the preliminary comments from the EEG, SNL stated

> The EEG should note, in fairness, that the range of organizations from which the experts were selected (Natural Resources Defense Council, universities, institutions,

etc.) provides rich diversity in political and environmental organizations.

This statement is counter to the claim that panelists were selected on the basis of their individual qualifications.

3.3.5 The elicitation process used was open-ended. While it is true that what will be mined over 10,000 years is unknown, let alone where to mine it, the problem is simpler for a specific area with known minerals. For example the Outer Continental Shelf Lands Act allows oil and gas drilling in the sea beyond the three-mile limit, but includes a clause for "other minerals." When the Outer Continental Shelf Lands Act was first passed in 1953, "other minerals" referred to sulfur. By the mid-1970s the focus of other minerals became construction aggregates around coastal cities, and in the early 1990s, manganese crusts. At a specific location, with geologic information, we know what can be mined now and in the future. The minerals to be mined will change only if society's needs change dramatically. If that had been borne in mind, the problem would have been much more circumscribed, and the results more realistic and reliable.

In the USDOE response to the preliminary comments from the EEG, SNL stated

> This comment [above] proposes that the experts be directed as to what potentially intrusive activities to study. We believe that this is inappropriate and would not stand up under peer review due to extensive direction by the analytic staff.

All elicitations have to be circumscribed, if only to ensure that the problem is within the expertise of the judges. Figure 2 is a reproduction of a SNL viewgraph shown to the panelists, demonstrating how the SNL analysts defined the problem and may have biased the panelists.

3.3.6 Results of the open-ended elicitation process used by Hora (Hora, von Winterfeldt and Trauth, 1991) appear to have been used selectively. If a more circumscribed process had been used, then the methods available to combat cognitive bias (Tversky and Kahneman, 1974) could have been used. Unfortunately, the results used in the *1992 Performance Assessment* strongly reflect the intervention of the analyst. The final result used a form

$$\lambda_t = d(1 - p_1 p_2) \tag{1}$$

where λ is the intrusion intensity, number of holes per time, d is the raw drilling intensity number of holes per time, p_1 is the probability of markers surviving, and p_2 is the probability

How Will the Expert Judgments Be Used in the WIPP Performance Assessment?

- **The findings of the expert teams will provide modes of intrusion. These modes will be grouped into similar types of intrusions and modeled.**

- **The frequencies of intrusion given by the experts will be encoded as rates and used as input to simulation studies.**

- **The expert judgments will be both analyzed separately and combined into a base case. The analyses will preserve the findings of the individual teams.**

Figure 2. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing SNL's formulation of the problem.

that surviving markers are effective in deterring drilling, all functions of time. The paradigm was not elicited from any one panel, but the result is a mixture of results from the panelists, who may not have understood how their inputs would be used.

The USDOE response to the preliminary comments from the EEG referred to a SNL viewgraph (Figure 3) entitled "Logic Tree for Deterrence by Markers Given Time, Society, Mode of Intrusion, and Marker Criteria." If one defines each of the branches in Figure 3 as p_1, p_2, p_3 and p_4, then deterrence is

$$p_1 p_2 p_3 p_4 \tag{2}$$

and eq. (1) does not obtain. Eq. (1) does NOT appear anywhere in the hundreds of viewgraphs shown to the Futures and Markers Panels.

An example of the intervention of the analyst occurred when elicited probabilities of the Washington A and B Teams and the Southwest Team for the period 0 to 100 years after closure were ignored. Professor Hora states [vol. 3, p. A-87]

> In contrast, the two Washington teams gave assessment beginning immediately after closure and thus did not allow for the period of continuing administrative control. **The performance assessment, however, assumes that the drilling rate is effectively nil during the first 100 years after closure** [emphasis supplied].

Clearly these three teams would not have agreed with SNL's use of their opinion in meeting the USEPA Standards (USEPA 1993).

3.3.7 A flagrant and important abuse of the analyst-assessor role occurred when the WIPP Performance Assessment Department assumed that there will be no intrusions after 2000 years (vol. 4, p. 2-19, lines 4 and 20). For consequence calculations, the *1992 Performance Assessment* considered only a single intrusion at 1000 years. This is clearly counter to the spirit and letter of analyzing human intrusions for the entire 10000-year regulatory period. If one assumes that the computer program by Professor Hora [vol. 3, p. A-92ff] captures the essence of the Futures and Markers Panels (which we do not) Appendix D of vol. 3 of the *1992 Performance Assessment* contains 12 pages of realizations of drilling intensity functions. The graphs in Appendix D show the intrusion rate and cumulative number of intrusions as a function of time to 10,000 years. Showing these graphs to 10,000 years is misleading because the WIPP Performance Assessment Department discarded the Panels'

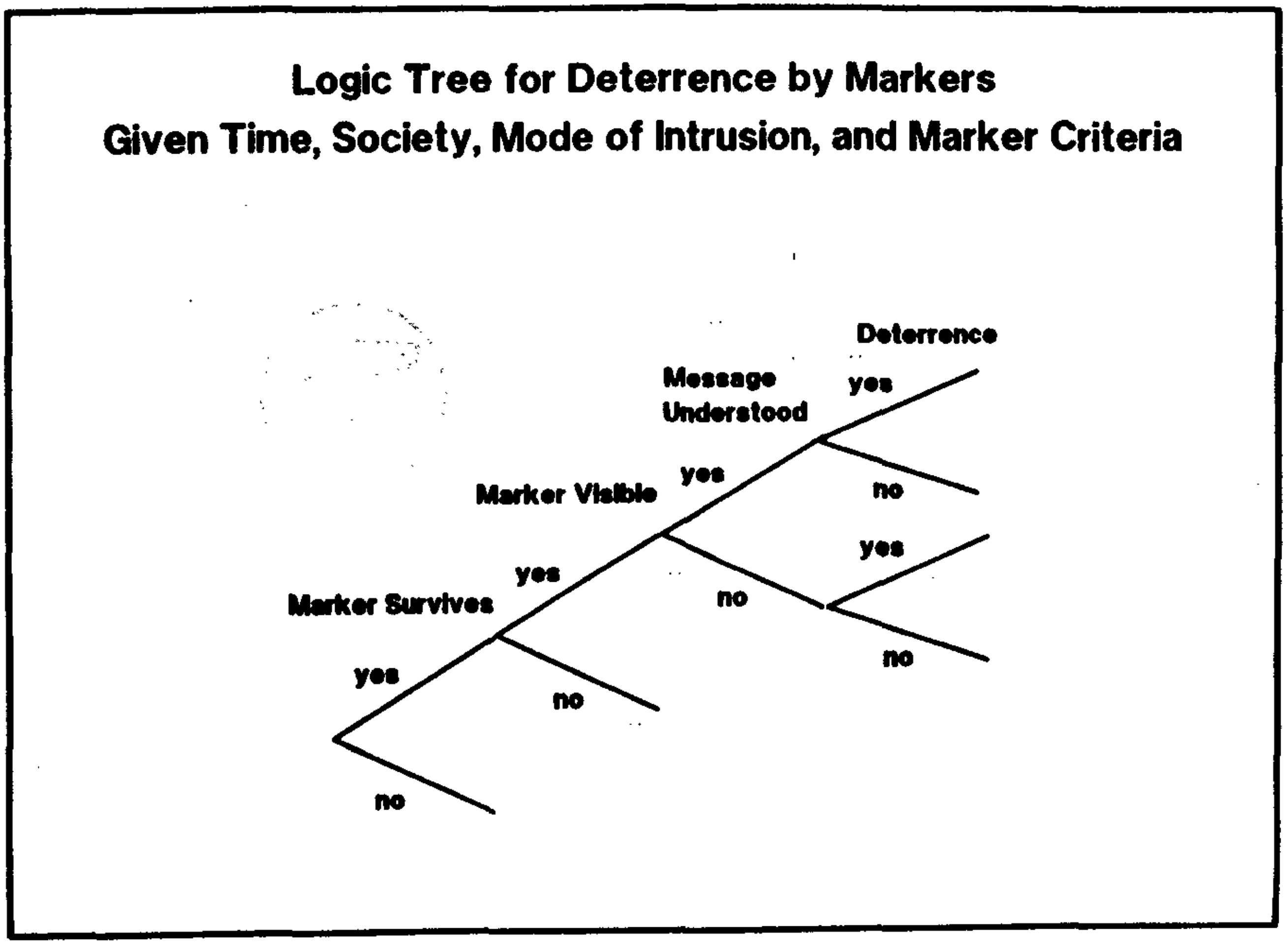

Figure 3. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing SNL's concept of the elicitation.

recommendations, assuming the intrusion rate to be zero after 2000 years.

3.3.8 The elicitation process is described in the Hora memo, vol. 3, pp. A-71 through A-99. The memo includes a FORTRAN program to sample among the panels, and produces realizations of intrusion intensities as functions of time for use in the 70 Monte Carlo runs. On page A-94, line 13, a three-dimensional array BOSTAB2 is undimensioned and undefined, thus the program cannot possibly work. In May 1993, EEG requested a working copy of this program, first from Professor Hora, then from WIPP Performance Assessment Department, and finally obtained a copy on December 31, 1993. This program creates Monte Carlo realizations of rates of human intrusion, drawn primarily from Prof. Hora's interpretation of the Futures and Markers Panels.

3.4 EEG suggests a simplified, focused and understandable alternative.

Figure 4 shows what EEG believes the exploratory drilling rate to be in any specific area, and illustrates the evolution of oil and gas drilling as a function of time.

Figure 4 shows a historical record of drilling in this area, a known rate, a holes per area per year, $a > 0$. The U.S. Environmental Protection Agency's guidance (40 *CFR* 141, Appendix C) of thirty boreholes per kilometer^2 over 10,000 years is such a rate.

Giving no credit for passive institutional control, because of recent experience (Silva 1994), we extend the historical drilling rate some time into the future, b years, $b > 0$. Geologic knowledge should be used for this extension. If there is current oil and gas drilling, then it is likely for the exploration and development to continue for some time. If there is no current drilling in this area, then there may not be any drilling until some new mineral is discovered in this area. This extension should extend beyond the period of active institutional control.

Given our present understanding of energy economics, we may postulate a decrease in oil and gas drilling, after a period of time, due to either exhaustion of the resource, or technological developments in some other fuel sources, or both. This decline can be represented by an exponential decay function, $y = y_0 \exp^{-ct}$. The rate of decrease is characterized by a single parameter, c.

For the long-term, there should be a rate of intrusion that is

(a) non-zero; and

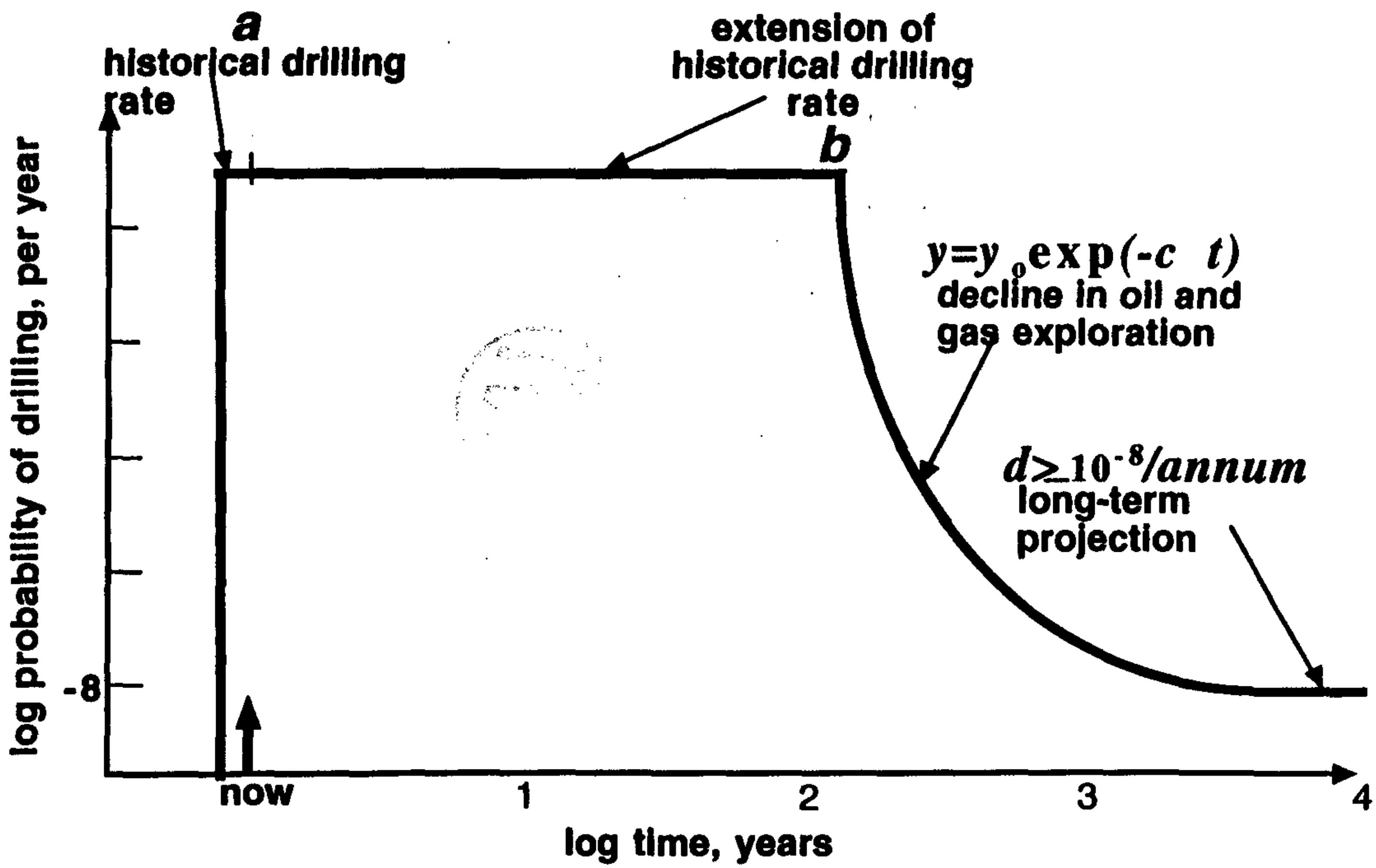

Figure 4. EEG's suggestion for a rate of human intrusion by drilling.

(b) above the USEPA threshold probability for events and scenarios to be considered, or 10^{-8} per year. Call the rate d holes per area per year, $d \geq 10^{-8}$ per year.

Because the waste will not have decayed to harmless levels after 10,000 years, and because the site may still contain resources, the intrusion rate should not be zero for any time within the regulatory period. To ignore such probabilities is to do an incomplete analysis.

The parameters a, b, c, and d completely specify the rate of inadvertent human intrusion in a readily understandable way. Subjective elicitation can now focus on these four parameters. The Department of Energy has experts in the history of oil and gas fields in the Energy Information Administration, and also experts in prospects for solar and other new energy sources.

In the USDOE response to EEG's preliminary comments, SNL stated four principles upon which to object to EEG's suggestion. In brief they are: Avoid Problem Definition, Avoid Bias, Put Rationale Before Results, and Do Elicitation Only on Physical Quantities.

A subjective elicitation requires problem definition. Figure 2 shows SNL's definition before the elicitations. Apparently SNL fitted the results of the elicitation into its preconceived structure. Although the EEG is not free of judgment, it focuses judgment on relevant parameters. SNL should heed its own advice about following USEPA's guidance and limit the elicitation to inadvertent drilling for minerals, without exploring irrelevant intrusion modes.

We will illustrate the bias that SNL imparted to the panelists on the topic of oil and gas resources at WIPP. In the orientations, SNL cited three different studies that there is no economically recoverable oil near WIPP, shown in Figures 5, 6, and 7, augmented by SNL's own conclusion that (Figure 8)

> Crude oil will not be the target for exploration unless the price is drastically higher than the present [1990].

Figure 9 shows the number of oil wells near the WIPP site in October 1993. Table II shows the recent history of wells in the same locations. Figure 9 and Table II belie the suggestion that there is no economically recoverable oil near WIPP. Actually, SNL did tell the panelists about oil and gas production near the WIPP. Figure 10 is a viewgraph shown to the panels by the speaker on cultural resources. That the panelists did not raise questions suggests that

TOTAL MINERAL AND ENERGY RESOURCES
(Brausch and others, 1982)

ESTIMATES ARE FOR ALL FOUR CONTROL ZONES

RESOURCE			
Caliche	185 MT	at surface	Not a reserve
Gypsum	1.3 BT	300-1,500 ft	Not a reserve
Salt	198 BT	500-4,000 ft	Not a reserve
Potash			
Sylvite	133.2 MT	1,600 ft	27.43 MT reserves
Langbeinite	351.0 MT	1,800 ft	48.46 MT reserves
Hydrocarbons			
Crude Oil	37.50 MB	4,000-20,000 ft	Not a reserve
Natural Gas	490 BCF	4,000-20,000 ft	44.62 BCF at 14K ft
Distillate	5.72 MB	4,000-20,000 ft	0.12 MB at 14K ft

Figure 5. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing the conclusion of a resource study.

ESTIMATES OF UNDISCOVERED HYDROCARBON RESOURCES--PROVINCE 092
(Mast and others, 1989)

RESOURCE	Mean	F95	F5
Crude Oil			
recoverable	0.02 BB	Negl.	0.05 BB
economically recoverable	0.02 BB	Negl.	0.05 BB
Natural Gas			
recoverable	0.24 TCF	0.05 TCF	0.67 TCF
economically recoverable	0.24 TCF	0.05 TCF	0.67 TCF
Natural-Gas Liquids			
recoverable	0.00	0.00	0.00
economically recoverable	0.00	0.00	0.00

Figure 6. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing the conclusion of a second resource study.

GEOLOGICAL CHARACTERIZATION REPORT
(Powers and others, 1978)

POTENTIAL RESOURCES EXAMINED

- **Caliche**
- **Gypsum**
- **Salt**
- **Uranium**
- **Sulfur**
- **Lithium**
- **Potash**
- **Hydrocarbons (crude oil, natural gas)**

CONCLUDED

Only potash and natural gas have potential as significant exploitable deposits.

Figure 7. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing the conclusion of a third resource study.

CONCLUSIONS ABOUT THE POTENTIAL FOR ECONOMICALLY IMPORTANT NATURAL RESOURCES AT THE WIPP

1. **Crude oil will not be the target for exploration unless the price is drastically higher than at present.**
2. **Natural gas in the Morrow Formation is the only hydrocarbon of potential economic importance in the area.**
3. **All currently recognized potash resources are confined to a zone above the waste-filled rooms and drifts.**
4. **Only the lowest grade of potash ore overlies part of two waste panels.**
5. **Other resources are present, but because of abundance and greater accessibility elsewhere, these resources at the WIPP are of no economic interest.**

Figure 8. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing SNL's conclusion on oil resources near the WIPP.

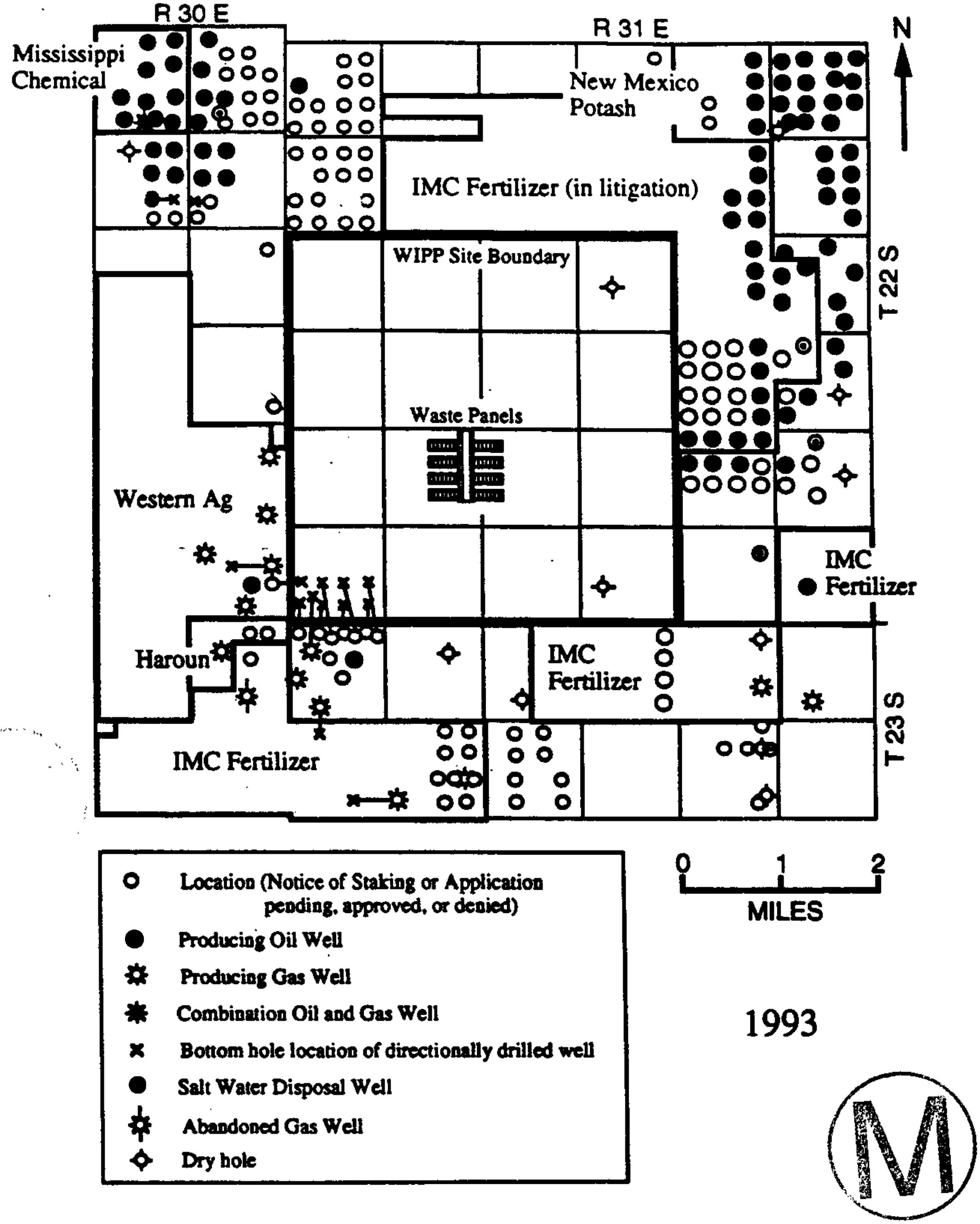

Figure 9. Oil and gas wells near the WIPP, October 1993.

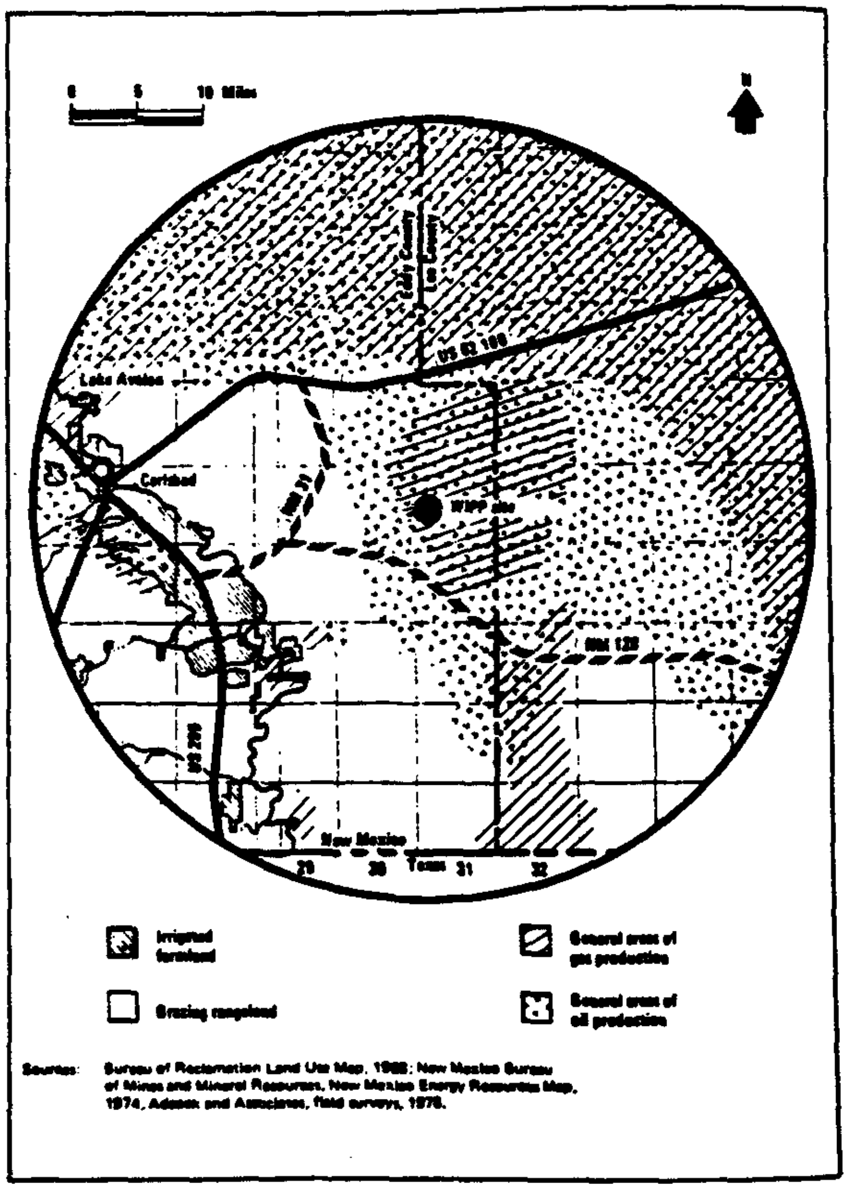

Figure 10. Reproduction of a map shown to the Future and Markers Panels by SNL, showing oil and gas resources near the WIPP.

Table II. Drilling rate for a 124 km^2 area immediately surrounding the WIPP*.

Year	Gas Wells	Oil Wells
1987	0	4
1988	0	2
1989	0	3
1990	0	13
1991	1	37
1992	1	23

*Source: Silva (1994)

SNL was successful in putting bias in the mind of the panelists.

To say that this elicitation puts rationale before numerical results belies the purpose of the effort. The emphasis on rationale may have prompted Prof. Hora to make arbitrary assumptions to obtain numerical results.

> The information for the drilling intensity from the Washington B team indicates that if minerals are extracted in the WIPP region, exploration will occur in the first 200 years or in the next 300 years, but not in both periods. **There does not seem to be adequate information from this team to model with dependence without making arbitrary assumptions**....[Sandia WIPP Performance Assessment Department 1992; vol. 3, p. A-87, emphasis supplied].

To object to elicitation for parameters without physical meaning is a surprise to us. One of the most frequently cited elicitation exercises is on perceived risk (Slovic, Fischhoff and Lichtenstein 1980), in which judges were asked to rank order risks from 40 technologies. The resulting ordinal ranking has no physical meaning. A greater surprise is that SNL would object to eliciting parameters on human intrusion when the entire Future and Markers Panels effort is attempting the same.

3.5 The Effect of Using Subjective Probabilities

We are now in a position to examine the consequences of using subjectively elicited probabilities. EEG has long maintained that a more reasonable conceptual model for intrusion would include a degrading plug, with the contaminated brine reaching the accessible environment at the ground surface, release Path b in Figure 11. Current oilfield practice in the Delaware Basin is to case the wells down to the top of the salt deposits, preventing contaminated brine from entering the water-bearing zones above the salt. Figure 12 shows CCDFs for the following conditions:

- Brine flow calculated for flow up the borehole, from the *1992 Performance Assessment*;
- Solubilities of all actinides set at 10^{-6} M;
- Intrusion probabilities from subjective elicitation, constant 30 boreholes/km^2/10000 years, or sampled between 0 and 30 boreholes/km^2/10000 years.

Figure 12 shows that if all actinide solubilities are 10^{-6} M, the mean CCDF of 70 would be very close to violating the containment requirement, unless subjective probabilities are used.

Recommendation 3.3. Discard the subjective probabilities for human intrusion used in the *1992 Performance Assessment* and adopt EEG's specific suggestion in Section 3.4.

4. Computer Code Documentation

4.1 The EEG has been concerned about the lack of documentation of computer codes used in the *1992 Performance Assessment*. Of the major codes used in the *1992 Performance Assessment*, as shown in vol. 1, Figure 4-4, only SANCHO and GENII-S have complete documentation. Ironically, no direct results from SANCHO and GENII are shown in the *1992 Performance Assessment*. In response to an EEG inquiry, USDOE provided the following schedule for complete documentation of computer codes shown in Figure 4-4 of vol. 1 (Arthur 1993):

Complete documentation is a requirement of Sandia's own software quality assurance program. For most of the codes shown in Figure 4-4, volume 1, only brief descriptions appear in the *1992 Performance Assessment*, and such descriptions do not present sufficient details for reviewers. As shown in our discussion of human intrusion, it is necessary to review the computational tools at that level of detail. In June 1994, EEG learned that complete documentation of all codes will be available by January 3, 1995.

Technical papers are no substitute for documentation, because technical papers and documentation have different purposes. Documentation is intended to communicate effectively

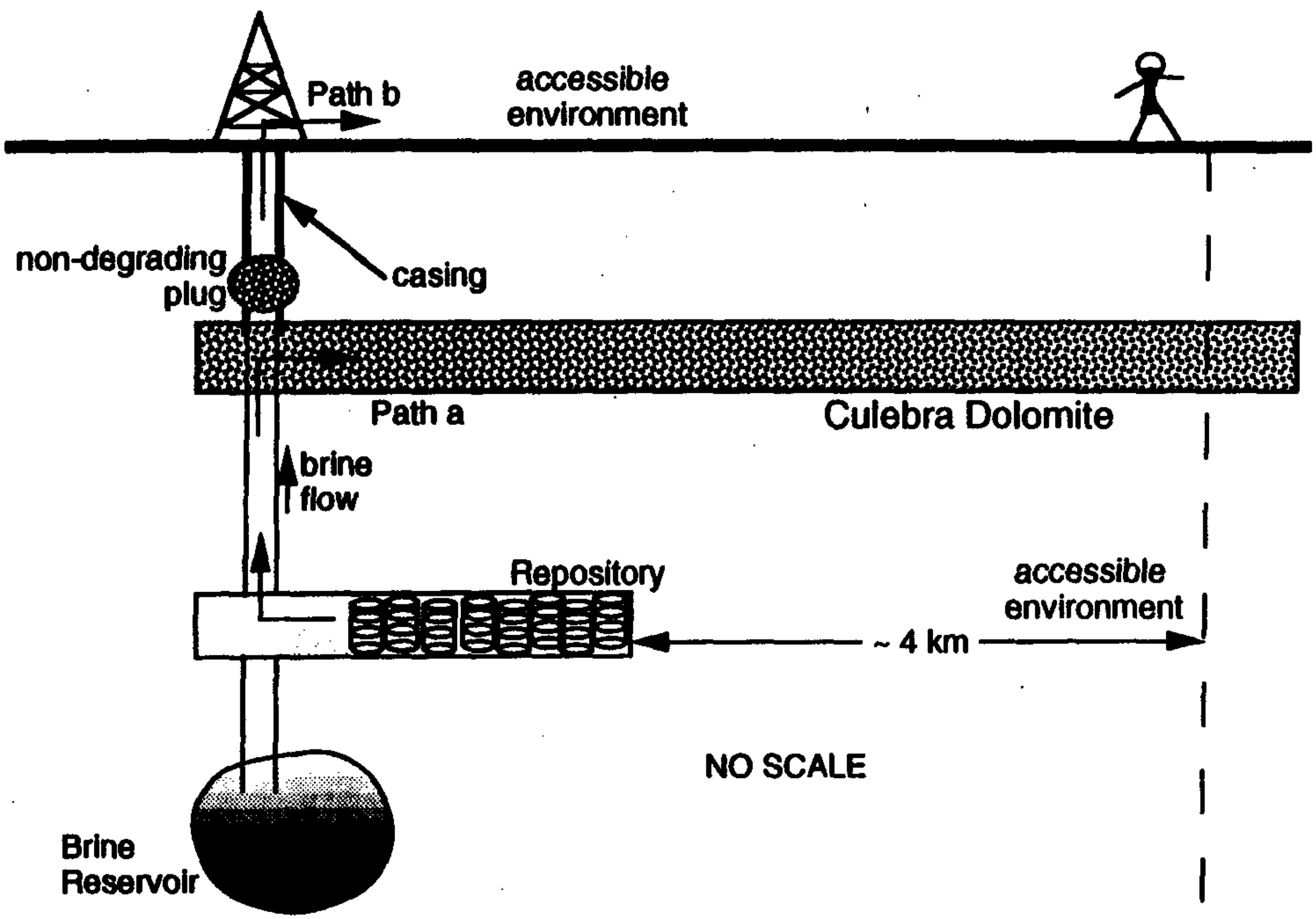

Figure 11. EEG scenario of direct discharge of contaminated brine to ground surface.

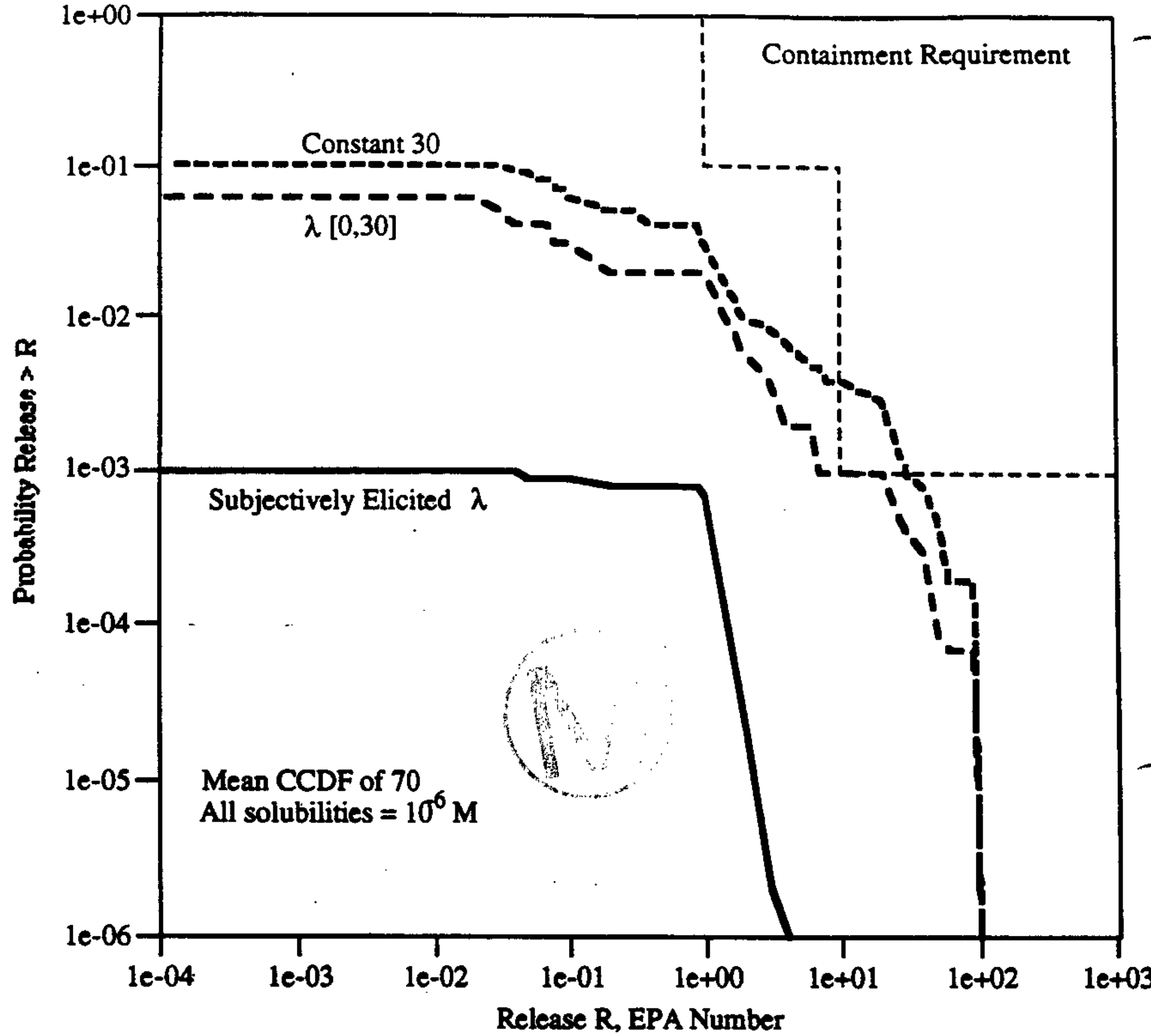

Figure 12. Mean CCDFs from the EEG scenario of direct ground discharge for all actinide solubilities set at 10^{-6} M, using 3 methods of deriving the rate of human intrusion, constant 30 boreholes/km^2/10,000 years, uniform sampling between 0 and 30 boreholes/km^2 /10,000 years, and subjectively elicited probabilites.

Table III. Schedule for Performance Assessment Computer Code Documentation

Code	Aug 9, 93*	Jun 10, 94*
BRAGFLO	DEC 97	Sep 1, 94
CCDFPERM	DEC 94	Dec 1, 94
CUTTINGS	DEC 96	Oct 1, 94
GENII	DEC 96	Jul 1, 94
PANEL	DEC 97	Oct 1, 94
SECOFL2D	DEC 97	Jul 1, 94
SECOTP2D	DEC 97	Jul 1, 94

* Dates of USDOE promise by letter.

the details of the code design and operation so that people with different interests can be convinced of the usefulness and validity of the computer code. Documentation presents the code's logical structure, equations and methods, assumptions and limitations affecting the code's applicability, essential for an effective review.

The brief descriptions in the *1992 Performance Assessment* are inadequate as documentation for the following reasons.

4.2 According to SAND92-0700/3, p. 1-36, PANEL calculates

$$\dot{M}_i = -QC_{di} - \lambda_i M_i + \lambda_{i-1} M_{i-1} \tag{3}$$

where M_i is the mass of the ith nuclide in dissolved form,
Q is the brine flow rate, and
λ is the nuclide's decay constant.

The concentration is calculated

$$C_{di} = \frac{M_i}{\sum_j M_j} S_i, \tag{4}$$

where S_i is the concentration in saturated solution, and this equation calculates the isotopic fraction of solubility over j isotopes.

According to the February 22, 1994 USDOE presentation to USEPA, PANEL actually solves

$$C_{di}(t) = \begin{cases} S_i, & \text{if } I_i(t)/V(t) \geq S_i \\ I_i(t)/V(t), & \text{if } I_i(t)/V(t) < S_i \end{cases} \tag{4a}$$

where $I_i(t)$ is the inventory of element i at time t, and

$V(t)$ is the brine volume in the panel at t. Eq. (4a) incorporates a different concept than eq. (4). This kind of information is needed to fully understand the *1992 Performance Assessment*.

4.3 The transport code SECOTP2D offers the best examples of the need for full documentation. Roache (1993) does not explain how the following important items are handled.

• SECOTP2D is a two-dimensional code. How does it handle the conversion of the source term from zeroth dimension, the solubility, to two dimensions? The source is Qc, where Q is the well injection rate. How is Q determined? Is Qc spread uniformly vertically, uniformly laterally to infinity, making it an infinite line source?

• Two types of matrix diffusion are claimed for the Culebra, in the dolomite and in the clay layer. Is the classic Neretnieks equation for matrix diffusion used for calculating these effects?

• Over the years several codes have been used for the calculation of flow and transport in the Culebra, such as SWIFT, and STAFF2D. Are there benchmarking results?

c. To further demonstrate the inadequacies of technical papers as documentation, the following comments are offered on the Roache paper.

• The paper touts the TVD algorithm but failed to define TVD.

• The algorithm begins with a variable transformation. A key variable J in the transformation is not defined.

• No results are given for verification of the dual porosity option.

Finally, it is often claimed that because a computer code is undergoing continuous development, its documentation cannot be released. This is simply not the case. A calculation done with a computer code is made with a specific version. Subsequent calculations may use the next version. However, for the purpose of documentation, a calculation and the tool (computer code) are inextricably intertwined. For a meaningful review, the code version used and the extant documentation must be made available.

Recommendation 4. Establish a workable system to provide EEG with relevant documentation, so that EEG has reasonable access to perform its work.

5. The Culebra as a Natural Barrier

The *1992 Performance Assessment* elucidates the role of the Culebra as an isolation barrier. Figure 5-6 of vol. 1, claims that WIPP can meet the USEPA's containment requirement (USEPA 1993) without the Culebra as an isolation barrier. That is, if the USEPA containment limit is applied where brine is diverted into the Culebra, WIPP would still be in compliance. With matrix diffusion and sorption, the Culebra would contribute additional isolation.

Recommendation 5. Quantify the extent of matrix diffusion and sorption through accelerated experimentation.

6. Effects of Gas Generation

While the USDOE has analyzed the beneficial effects of gas generation, the EEG continues to be concerned that the deleterious effect of gas generation, particularly the opening of new discharge pathways, has not been analyzed.

Recommendation 6. In future analysis, the deleterious effect of gas generation should be included.

7. Correlation Among Variables

No correlation has been assumed between sampled variables using Latin Hypercube sampling. In real life, many of the variables are related. For example, there is an inverse correlation between VWOOD, the fraction of waste that is wood, and VMETAL, the fraction of waste that is metal.

Recommendation 7. The performance assessment should either give reasons why physical correlations have been ignored, or show results with correlations.

8. Natural Resources Near the WIPP

The *1992 Performance Assessment* is unclear on the extent of natural resources extraction near the WIPP site, and particularly the possible impact of human intrusion. In vol. 1, Section 2.2 an incorrect statement is made:

> About 56 productive oil and gas wells are located within a radius of 16 km (10 mi) from the WIPP; the wells generally tap Pennsylvanian strata, about 4,200 m (14,000 ft) deep (p.2-4).

This statement is incorrect because there are many more oil and gas wells. The estimate of 56 producing oil and gas wells is based on 1986 data. EEG showed (Silva and Channell, 1992) that some of the 1986 data were incorrect. Furthermore, if the USDOE wishes to take credit for current and accurate public records, then USDOE should have used current information and not obsolete information. Given the importance of drilling for oil and gas on the performance assessment calculations, future iterations should use a more accurate representation of the drilling activity near the WIPP facility. One method of so doing is to show up-to-date and accurate locations of oil and gas wells on a map. Most of the oil and gas wells drilled in the last four years do not tap the deeper Pennsylvanian Formation, but produce from various shallow (1200 to 2400 m) zones within the Delaware Mountain Group Formation.

The statement in the *1992 Performance Assessment* continues:

> The hydrocarbon well closest to the land withdrawal boundary is about 3 km (2 mi) to the south-southwest of the waste panels, and has produced natural gas since 1982 (Silva and Channell, 1992). The surface location of the well is outside the land-withdrawal boundary, but the borehole is slanted to withdraw gas from rocks below the WIPP horizon within the boundary. Except for this well, resource extraction is not allowed within the proposed land-withdrawal boundary (vol. 1, p.2-4).

The 1992 WIPP Land Withdrawal Act recognizes the validity of two specific oil and gas leases in section 31, within the WIPP Site Boundary. The owner of one of these leases has recently filed an application for permits to drill eight directionally drilled oil wells that would be completed within the WIPP Site Boundary but at depths greater than 2,000 m (6,000 ft) to produce oil from within the WIPP Site Boundary. While there was no restriction on drilling within the WIPP Site Boundary contained in the Consultation and Cooperation Agreement between the USDOE and the State of New Mexico, the second modification restricted slant drilling.

The following statement appears in vol. 1, section 3.3.3 (p. 3-10):

> ... the DOE agreed to prohibit further subsurface mining, drilling, slant drilling under the withdrawal area, or resource exploration unrelated to the WIPP Project from the land surface to 6,000 feet (1,830 m) in the subsurface for the 16 square miles under DOE control.

The second modification to the Cooperation & Consultation Agreement has been incorrectly interpreted. The Agreement is not limited to the first 6,000 feet (2,000 m) of depth. The Agreement states "The DOE will not permit subsurface mining, drilling, ..."

Recommendation 8. Performance assessment reports should accurately reflect the status of resource development near the WIPP site.

9. Oil and Gas Production Near the WIPP

In vol. 1, section 5.3.5, the following statement is made regarding the Assurance Requirement (40 *CFR* 191.14) for natural resources:

> Future societies might attempt to exploit natural resources near the WIPP and thereby create the potential for a release of radionuclides into the accessible environment. These issues have been evaluated in several reports (USDOE, 1980, 1981b; USDOE and State of New Mexico, 1981, as modified; Brausch et al., 1982; Weart, 1983; USDOE, 1990a). A recent report summarizes these earlier reports (USDOE, 1991a), and the DOE will continue to document information about natural resources that was used in making the decision to proceed with the WIPP Project (I, p. 5-20).

A detailed reading of the references cited does not appear to support the text.

Silva and Channell (1992) showed that the ***USDOE Implementation of the Resource Disincentive Plan in 40 CFR 191.14(e) at the Waste Isolation Pilot Plant*** (USDOE, 1991a) is inconsistent in reporting the number of oil and gas leases within the WIPP Site Boundary and the production status of those leases.

The No-Migration Variance Petition (USDOE, 1990a) states:

> Oil and gas exploration has been and continues to occur around the WIPP site. The target horizons for this type of exploration are below the Castile. Oil and

gas exploratory drilling requires permits from the state, and it is unlikely that prospective future well drillers would not be informed about the existence of WIPP. As an additional protective measure, the DOE has purchased all oil and gas leases in the area of the WIPP site to prevent any exploration now and in the future (Section 6.3.2).

The last sentence above is incorrect. Weart (1983), Brausch *et al.* (1982) and Weart *et al.* (1991) failed to recognize the potential crude oil resources for this area. Crude oil is now being produced from the former control zone IV.

Recommendation 9. The performance assessment effort should use the latest and verifiable data on oil and gas production near the WIPP, because the extent of oil and gas resources in this area is likely to be an important determinant of inadvertent human intrusion, and oil and gas production can potentially affect the hydrogeology at and near the WIPP repository.

10. Gas Generation

10.1 BRAGFLO is one of the most important codes in the WIPP performance assessment. A brief summary of BRAGFLO is given in vol. 3, section 1.4.1. Equations 1.4.1-1 and 1.4.1-2 use rate constants and mole fractions (called "stoichiometry factors") to calculate the rate of gas generation. These factors, although not specifically referenced in this section, are referred to in the discussion on pp. 3-44 to 3-45. Median corrosion gas production rates are given as 6.3 $\times 10^{-9}$ moles H_2/m^2-s for inundated steel and 0.1 [-] for humid steel under aerobic conditions, and 0.5 [-] for inundated steel under anoxic conditions. An analogous set of rates are given for microbial gas generation, with units of moles of gas/kg cellulosics given only for inundated conditions. It should be noted that in the development of the equations on pp. 1-24 to 1-26, the rate constants and stoichiometric factors are given with acceptable units. Why aren't the dimensions the same for all these rates, if they are used for the same variable in BRAGFLO? How can a corrosion rate have the units of moles per unit area of exposed substrate in one case and no units in another? How can a dimensionless variable be used interchangeably with a variable with units?

10.2 A more serious question arises about the use of these results. The gas generation rates and stoichiometry factors cited are those calculated by a model and are thus th result of model inputs rather than experimental data. Table IV summarizes the results of the SNL scientific investigations into gas generation, and distinguishes model calculations from experimental measurements. Model results are only as good as model inputs. Some model inputs include unsupported assumptions, such as the failure to include methane. Experimental data exist - see Table IV- but have not been used in modeling. Moreover, as the Table IV shows, models give different gas generation rates when given different inputs and assumptions, and the median of such calculated rates has little validity.

Although the assumption that radiolysis will contribute only negligible hydrogen formation at WIPP appears to have found general acceptance, the data developed by Kosiewicz (1981) show this need not be the case. In fact, the gas generation problem was first noticed in stored drums of TRU waste in which hydrogen had been generated by radiolysis. Moreover, the microbial generation model does not recognize the dependence of the microbial gas generation rate on the initial and continued presence and availability of microbes. Radiolysis can be the principal source of gas from Pu-238 heat source waste.

Recommendation 10a. The gas generation calculations should include

(a) methane generation,

(b) radiolytically generated hydrogen.

Recommendation 10b. The relationships in the gas generation model should be validated before the gas generation model is incorporated into BRAGFLO.

11. Unanalyzed Scenarios

As Helton (1993) so aptly pointed out, the formulation of scenarios is an integral part of performance assessment. There are a number of assumptions used in the human intrusion scenarios to date that EEG believes need to be reconsidered and either changed or better justified. These have all been related to USDOE in previous written comments and discussed in meetings. For completeness of the record, all significant items are mentioned below.

Some scenarios not currently analyzed in performance assessment need to be considered. See especially the lower half of Figure 4-1 (vol. 2) in the *1992 Performance Assessment*.

Table IV. Gas Generation as Modeled and Tested

	Source	Gas From	Result moles/drum/a	Gas from 1050 drums in an alcove (moles/a)	Pressure P_0 (atm)	$P = nRT/V$ per annum (atm)	Gas Pressure at end of year one $P_1 = P_0 + P$
H_2	Brush *et al.*, (1993)	anoxic corrosion	2.0	2,100	1.0	0.0568	1.06
Total gas	Brush *et al.*, (1993)	microbio. deg.	1.0	1,050	1.0	0.0284	1.03
H_2 - 3 mos.	Brush *et al.*, (1993)	anoxic corrosion	1.97×10^{-6}	0.0	1.0	0.0	1.0
H_2 - 6 mos.	Brush *et al.*, (1993)	anoxic corrosion	1.72×10^{-6}	0.0	1.0	0.0	1.0
H_2 - 12 mos.	Brush *et al.*, (1993)	anoxic corrosion	1.23×10^{-6}	0.0	1.0	0.0	1.0
H_2 - 24 mos.	Brush *et al.*, (1993)	anoxic corrosion	9.9×10^{-7}	0.0	1.0	0.0	1.0
Total gas	Brush *et al.*, (1993)	aerobic microbes	0.5	525	1.0	0.0142	1.01
Total gas	Brush *et al.*, (1993)	anaerobic microbes	1.21	1271	1.0	0.0343	1.03
Total gas	Bixler (1989)		0.3	315	1.0	0.0085	1.01
Total gas	Molecke & Lappin (1990)	Calculated	0.05	52.5	1.0	0.0014	1.00
			0.5	525	1.0	0.06	1.06
			5.0	5,250	1.0	0.59	1.59
Total gas	Kosiewicz (1980)	radiolysis	0.3	315	1.0	0.04	1.04
			0.11	770	1.0	0.01	1.01
			0.016	115	1.0	0.0031	1.00

11.1 A Scenario Involving Nuclear Criticality

In 1984 S. Cohen, an EEG consultant, analyzed potential nuclear criticality in the Culebra Aquifer and concluded that this needed to be thoroughly evaluated by USDOE.

The potential nuclear criticality could occur if:

(1) sufficient quantities of a fissile radionuclide such as Pu-239 or U-233 are adsorbed on a large enough volume of aquifer matrix;

(2) there is sufficient hydrogen or other moderator available in the brine or matrix;

(3) the matrix or brine does not contain sufficient quantities of stable nuclides that can "poison" the reaction.

EEG's analysis indicated that, with the expected elemental composition of the brine and the Culebra aquifer matrix, nuclear criticality could occur in a block 7 m high x 0.5 m wide x 1 m long if the product of the distribution coefficient (K_d, mL/g) and plutonium solubility (S, moles/L) was greater than about 5.6×10^{-5} moles/g.

The possibility of a K_dS product of $> 5.6 \times 10^{-5}$ moles/g is credible. For example, the probability distributions for K_d and solubility from volume 3 of SAND 91-0893 (pages 2-104 and 3-64) have approximate probabilities of occurrence given in Table V.

Table V. Probabilities of Criticality From Sorbed Fissionable Species

Species	Probability $K_dS > 5.6 \times 10^{-5}$ moles/g
Pu^{5+}	0.025
Pu^{4+}	5×10^{-6}
U^{6+}	0.25
U^{4+}	0.11

In response to EEG's comments on the *1990 Preliminary Comparison*, SNL responded that

> A performance assessment task has been initiated to examine the potential for nuclear criticality from post closure processes.

Two pages were devoted to discussing nuclear criticality in the *1991 Preliminary Comparison* (vol. 1, page 4-52). SNL recognized that sorption can also occur in the backfill and at certain components of the seal system as well as in the Culebra Aquifer. The very remote possibility of a high-yield nuclear explosion is also discussed. We find no analysis of nuclear criticality in the *1992 Performance Assessment*. No schedule has been given for performing additional criticality evaluations.

EEG also believes the possibility of a high-yield nuclear explosion is very remote. One concern is with an instantaneous criticality excursion in which there is a brief burst of energy, neutrons, and gamma radiation. Perhaps more likely in this situation, where fissile material is being added very slowly in a solution, is a delayed criticality where the system does not become promptly critical. Such a system would behave much like a nuclear reactor and could produce fissions, perhaps in bursts, for extended periods of time. This phenomenon has occurred in several process criticality accidents in the U.S., e.g. at Hanford in 1962 one system boiled for 37 hours (Thomas 1978). The Oklo "natural reactor" in Gabon is believed to have operated in a similar fashion.

It is not obvious that a criticality accident would have a significant effect on a repository waste disposal system, even if a criticality accident occurs. Considerable heat would be produced, some brine would be vaporized, and minor amounts of fission products would be formed. It takes 8×10^{20} fissions to produce one curie of Cs-137. Also, the relatively high K_d values that would be necessary to make criticality possible are otherwise a benefit because they retard radionuclide transport.

Recommendation 11.1 The criticality issue needs to be thoroughly evaluated before it can be concluded that its effects are negligible.

11.2 Subsidence

Subsidence could occur in the area overlying the WIPP some time after repository decommissioning. Subsidence can also occur from nearby potash mining. The *1992 Performance Assessment* identifies an event **TS** which is subsidence from mining of potash, but **TS** has not been analyzed.

SNL discussed the potential for subsidence in the *1990 Preliminary Comparison*. They recognized that "subsidence could in turn conceivably affect the disposal system in three ways: by increasing hydraulic conductivity of the Salado Formation, by creating fractures through the Salado Formation, or by disturbing the surface drainage and groundwater flow in overlying units." The incorporation of the effects of subsidence into the performance assessment is still planned. In the *1991 Preliminary Comparison* SNL presented an analysis of possible caving and subsidence over the waste storage areas from room closure.

SNL's analysis of subsidence concluded that no problems were likely to result for the waste disposal system. The maximum subsidence at the surface was calculated to be only 0.13 meter over an area of 1.54×10^6 m^2. The affected area at the surface was determined by assuming an angle of draw of 35°. It was further stated that if the Rustler-Salado contact residuum had (historically) lost about 400 meters due to dissolution without disrupting the confined water-producing Culebra and Magenta dolomite aquifers, subsidence should not be a problem.

No evaluation has yet been made of subsidence from potash mining. There are significant potash resources within the WIPP site boundary. However, the USEPA Standards requires analysis of only resource exploration drilling on site. However, it is appropriate to consider subsidence effects from potash mining offsite.

Offsite potash mining is highly probable. There are reserves on all sides of the site. Sections to the south of the site are already leased, sections to the north and east are under litigation for potash leases, and the entire western border is leased or expected to be leased. Because the areas leased or expected to be leased to the north and south include the flow path of the Culebra Aquifer across the waste storage area, a potential exists for both upstream and downstream effects on the Culebra. Catchment areas could be formed to the north from subsidence and shafts could provide access to the Culebra for recharge. To the south there could be increased transmissivity from subsidence effects. With the assumption that mining occurs up to the site boundary and the angle of draw is 35° the extent of influence at the Culebra Aquifer horizon would be about 200 meters onto the site. Another possibility is that mining activity near the South Boundary could result in vertical drainage (via shafts or boreholes) from the Culebra Aquifer into underlying mined out areas. This could significantly increase the hydraulic gradient between the injection point of contaminated brine and the site boundary.

Recommendation 11.2 Subsidence effects need to be evaluated in much more detail and incorporated, in some manner, into the human intrusion scenarios. Some scenarios currently analyzed in performance assessment should be re-formulated.

11.3 Contaminated Brine Flows to the Surface

The E1, E2 and E1E2 scenarios assume that the only material reaching the surface is drill-bit cuttings and some "cavings" from the annulus about the drill bit in the waste storage room. Brine flowing to the surface from an encounter with a pressurized Castile brine reservoir was not assumed. EEG believes that brine flows to the surface should be assumed and that the consequences could be significant for the E1E2 scenario.

Sandia and USDOE have described typical drilling practices elsewhere (Appendix C of SAND 89-0462 and in USDOE February 7, 1990 response to EEG's comments on the Draft Supplement EIS). These responses explain how it is possible to have very little flow to the surface by closing in blow-out preventers within a few minutes, determining the pressure, and then preparing drilling mud of sufficient density to stop the flow before resuming drilling. For example, USDOE stated in a February 7, 1990 letter that only 51 barrels flowed at WIPP-12 before shut in by a blow-out preventer.

The February 7, 1990 USDOE letter went on to say that at WIPP-12 an additional 49,224 barrels flowed during deepening, geophysical logging, and further deepening before it was finally shut in for subsequent hydrologic testing. This additional flow was described as resulting from a "conscious decision."

Virtually every time a pressurized Castile brine reservoir was encountered in the vicinity of WIPP, "conscious decisions" were made to allow varying amounts of brine to flow to the surface. Table VI, extracted from two WIPP reports (USDOE 1981a; 1983), describes the remedial measures taken. Although the available data are not as detailed or as quantitative as one would like, it is clear that drilling practice through 1982 included release of brine at the surface whenever pressurized Castile brine reservoirs were encountered. There has been considerable drilling activity around the WIPP Site in the last few years, and brine has been reported in seven wells. In two of these wells brine was reported to have flowed for three hours before being stopped, and in another, brine flowed for at least 12 hours. Records did not indicate how long the remaining wells flowed. It appears that, in most cases, significant amounts of brine flow to the surface before being controlled and performance assessment scenarios should assume that any intruding driller will face similar situations. Also, minor flows may not always be recorded in drilling logs, or perhaps even recognized. Furthermore, it is likely that not all Castile brine encounters have been reported.

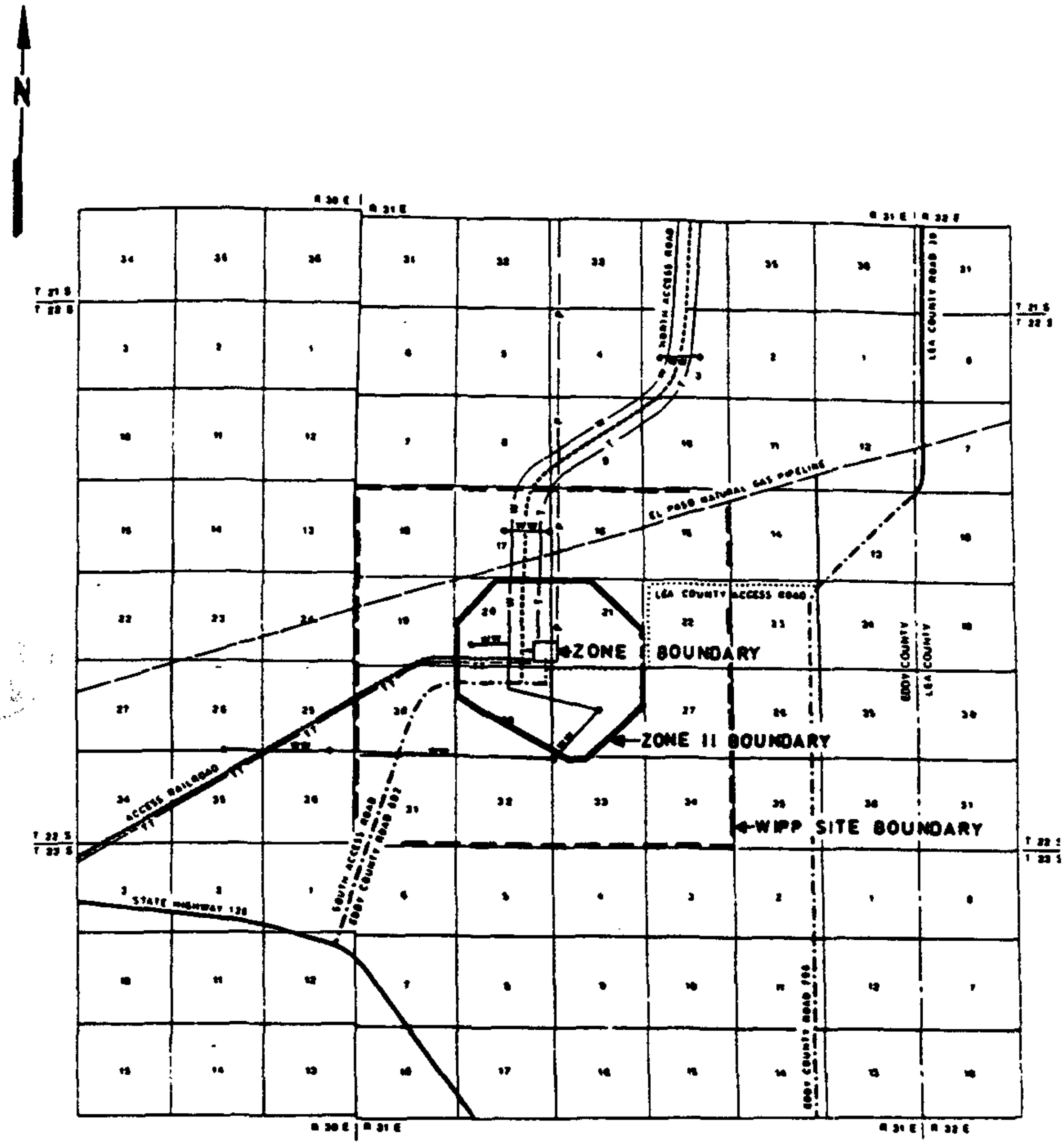

Figure 1. 1990 Zone I, Zone II, and WIPP Site Boundaries. From Figure 2.1-3, WIPP FSAR. (U.S. DOE, 1990a, reproduced with permission).

Although the designations of Zone III and Zone IV are no longer used, they merit a brief description because much of the initial WIPP documentation refers to these zones. The location of Zones III and IV are shown in Figure 2.

Zone III essentially provided a one-mile (1.6 kilometer) buffer around Zone II. In Zone III, all mining, other than for the repository, and deep drill holes penetrating through the evaporites were prohibited (U.S. DOE, 1980, p. 8-4).

Zone IV provided a one-mile (1.6 kilometer) buffer around Zone III. Within Zone IV, conventional potash mining would be permitted but solution mining was prohibited. Deep drill holes were also allowed but water flooding and massive hydrofracture for hydrocarbon recovery would not be permitted. The Final Environmental Impact Statement also noted existing oil and gas wells producing in this zone will be permitted to continue through their useful lives. To protect the repository, they will be sealed as prescribed by the DOE when abandoned. New wells for oil and gas production may be drilled in conformance with DOE standards to facilitate eventual plugging (U.S. DOE, 1980, p. 8-4).

When Zone IV was relinquished by DOE as being unnecessary, the Zone III boundary was "squared off" and the new site boundary extended into the former Zone IV at the four corners (Weart, 1990). Hence, the current four mile (6.44 kilometers) by four mile WIPP Site Boundary[2] also provides the one-mile buffer originally established as Zone III.

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[2]Throughout this report, the term "WIPP Site Boundary" refers to the four mile by four mile area described above and the term "WIPP Site Area" refers to the approximately thirty-two square mile area that includes all of Zone IV.

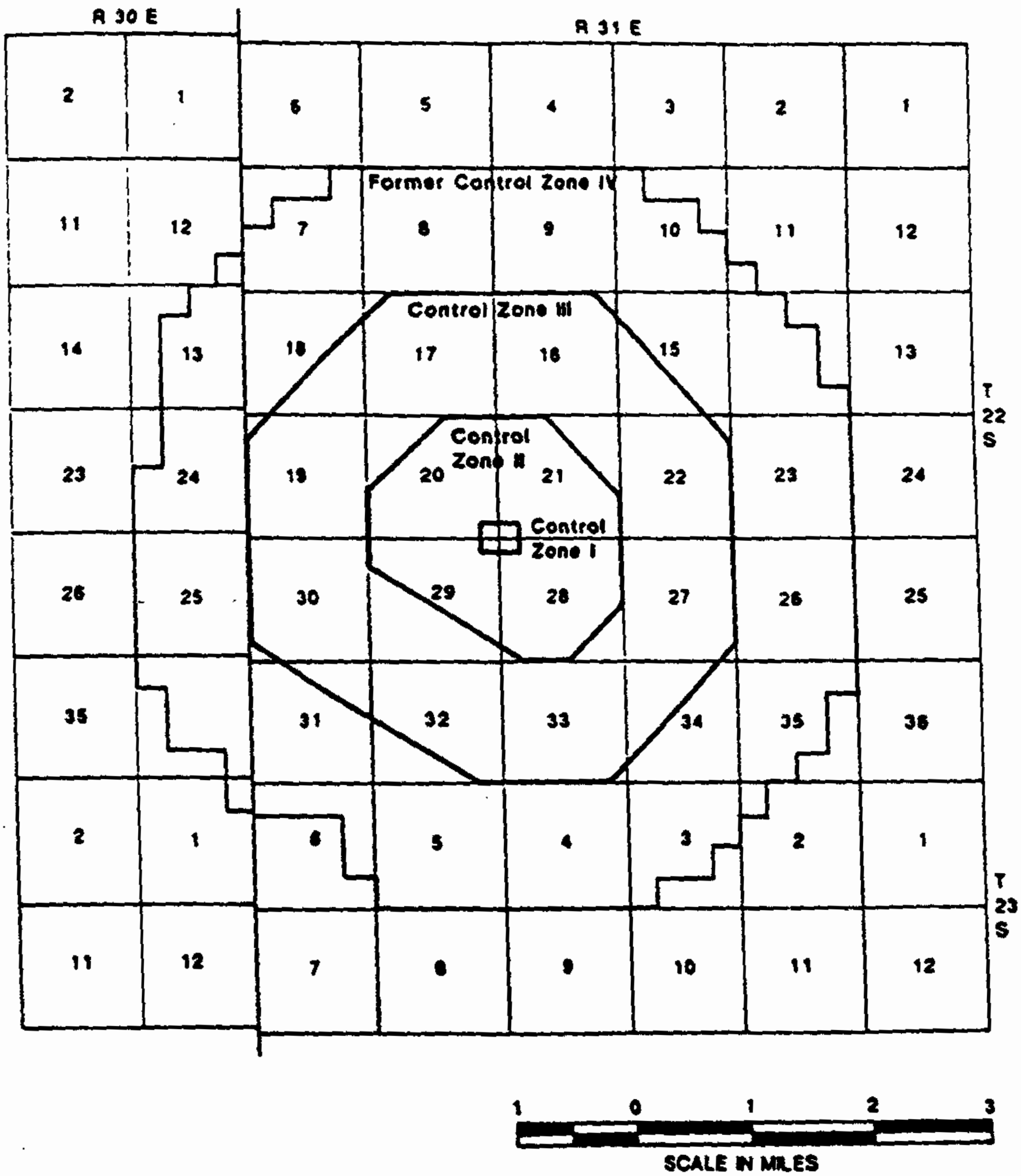

Figure 2. 1980 Control Zones at the WIPP Site. (FSEIS, U.S. DOE, 1990d, reproduced with permission).

3.0 REPORTS ON PETROLEUM RESOURCES AND LEASES

EPA's requirements for establishing a repository in a resource rich area were clearly stated in 40 CFR 191.14(e):

> Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites. Resources to be considered shall include minerals, petroleum or natural gas.... Such place shall not be used for disposal of the wastes covered by this part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future (U.S EPA, 1985).

From 1976 through 1980, SNL published several reports on the mineral resources in the Los Medaños area. Each discussed oil and gas resources.

A report by the petroleum consulting firm of Sipes, Williamson, and Aycock, Inc. (Keesey, 1976) focused on estimating the remaining economically recoverable oil and gas reserves underlying the proposed disposal site. The evaluation was intended to serve as a guideline to SNL in determining the acceptability of the "site area" and the potential value to the owners of the hydrocarbon rights.

Griswold's (1977) subsequent evaluation of site selection and mineral resources incorporated the information provided by Keesey (1976).

Powers, et al. (1978) prepared the geological characterization report for the WIPP citing the work of Keesey (1976) and Griswold (1977) as well as earlier work by Foster (1974).

Keesey (1977) provided a more detailed analysis of the hydrocarbon resources including those in Section 31, T22S, R31E, the section containing the active gas leases in the southwest corner of the current WIPP Site Boundary. The study was limited to surface and subsurface rights to 6,000 feet (1829 meters), which were eventually condemned and purchased by the federal government in 1979. The evaluation did not include the deeper resources.

Keesey (1979a) evaluated the feasibility of directionally drilling for oil and gas reserves under the WIPP Site Area, which, by previous definition, included Zone IV. It was technologically feasible to drill into gas and condensate reserves underlying the WIPP Site Area from outside the WIPP Site Area.

Keesey (1979b) updated the estimated potential hydrocarbon reserves and associated costs and incomes for oil and gas underlying the WIPP. The estimates were intended for use in the Environmental Impact Statement for the WIPP being prepared by Westinghouse Electric Corporation. The estimates were not intended to represent future net revenue values normally used by the petroleum industry to determine the fair market value of oil and gas producing properties. The undiscounted value of the gas and condensate reserves underlying the WIPP Site Area (including Zone IV) was determined to be $287,502,346 (Keesey, 1979b, p. 6; U.S. DOE, 1980, p. 7-72).

4.0 HISTORY OF NATURAL GAS EXPLORATION AND PRODUCTION

The WIPP site is situated in the northern portion of the Delaware Basin. While there were no oil or gas wells within the 32 square miles (8288 hectares) of Zone IV in 1976, oil and gas were being produced from 60 wells in a 368 square-mile (95 312 hectares) area surrounding the site. Although the area was considered to be potentially rich in hydrocarbon reserves, extensive deep drilling had not been ventured in the New Mexico portion of the Delaware Basin. Only 10 to 15 percent of the available acreage had been investigated. The lack of more complete drilling and development was attributed to several factors including historically restrained gas prices, a higher exploration risk due to the varying depositional environment, a lack of readily available pipelines during earlier periods, and moratoriums on drilling in the potash areas to prevent methane gas from entering potash mines (Keesey, 1976; Powers et al., 1978).

As noted by Griswold (1977), the energy crisis of the mid-1970's had driven up the price of natural gas at least fourfold in just two years, prompting a renewed interest in previously unattractive areas. In 1977, deep exploratory drilling for natural gas was underway throughout the Delaware Basin. Just prior to the publication of Griswold's report, three different companies applied for drilling permits in the Los Medaños site area.

Known petroleum production in the area extended from the Delaware Formation (mean depth 4,200 feet; 1280 meters) down to the Morrow Formation (mean depth 13,400 feet; 4084 meters). The deeper Morrow sandstones and the overlying Atoka sandstones of the Pennsylvanian series held the best promise for commercial natural gas production (Griswold, 1977).

In addition to several single well fields, there were two major producing fields in the Los Medaños area. Five wells were producing gas from the Morrow Formation in the Cabin Lake field just northwest of the WIPP site. A five-well field, the Los Medaños Field, was producing gas from both the Morrow and the Atoka Formations just southwest of the WIPP site.

4.1 Shell James Ranch Unit No. 1 - A Prolific Gas Well

A very productive gas well is located two thousand feet (610 meters) west of the WIPP site in the southwest corner of Section 36, T22S, R30E. The location is shown in Figure 3. Known as the Shell James Ranch Unit No. 1, the well was drilled, in 1957, to a total depth of 17,555 feet. The well was completed in the 12,920 to 12,929 foot (3938 to 3940 meters) interval for production of gas and oil condensate from the Los Medaños-Atoka Formation and has been producing since 1958.

The well has been prolific throughout its production history. Initial twenty-four hour production was 9,000 MCF gas and 104 BBLs condensate.[3] As of mid-1976 cumulative production exceeded 17,000,000 MCF (481 000 000 cubic meters) of gas and 200,000 barrels (32 000 cubic meters) of condensate. The gas production rate from that single well in 1976, was over 100,000 MCF (2 800 000 cubic meters) per month. Keesey (1976) calculated the James Ranch Unit No. 1 would ultimately recover 35,900,000 MCF (1 billion cubic meters) of gas and 425,000 barrels (68 000 cubic meters) of condensate.[4] The history of gas and condensate production since 1970 is shown in Figure 4.

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[3]An MCF is equal to one thousand standard cubic feet (28.32 cubic meters) of gas. A BBL is equal to one barrel (0.159 cubic meters) of oil or condensate.

[4]As of August 1, 1991, production records filed with the U.S. BLM for the James Ranch Unit No. 1 show that cumulative gas production has exceeded 25,000,000 MCF and condensate oil production has exceeded 270,000 BBLs.

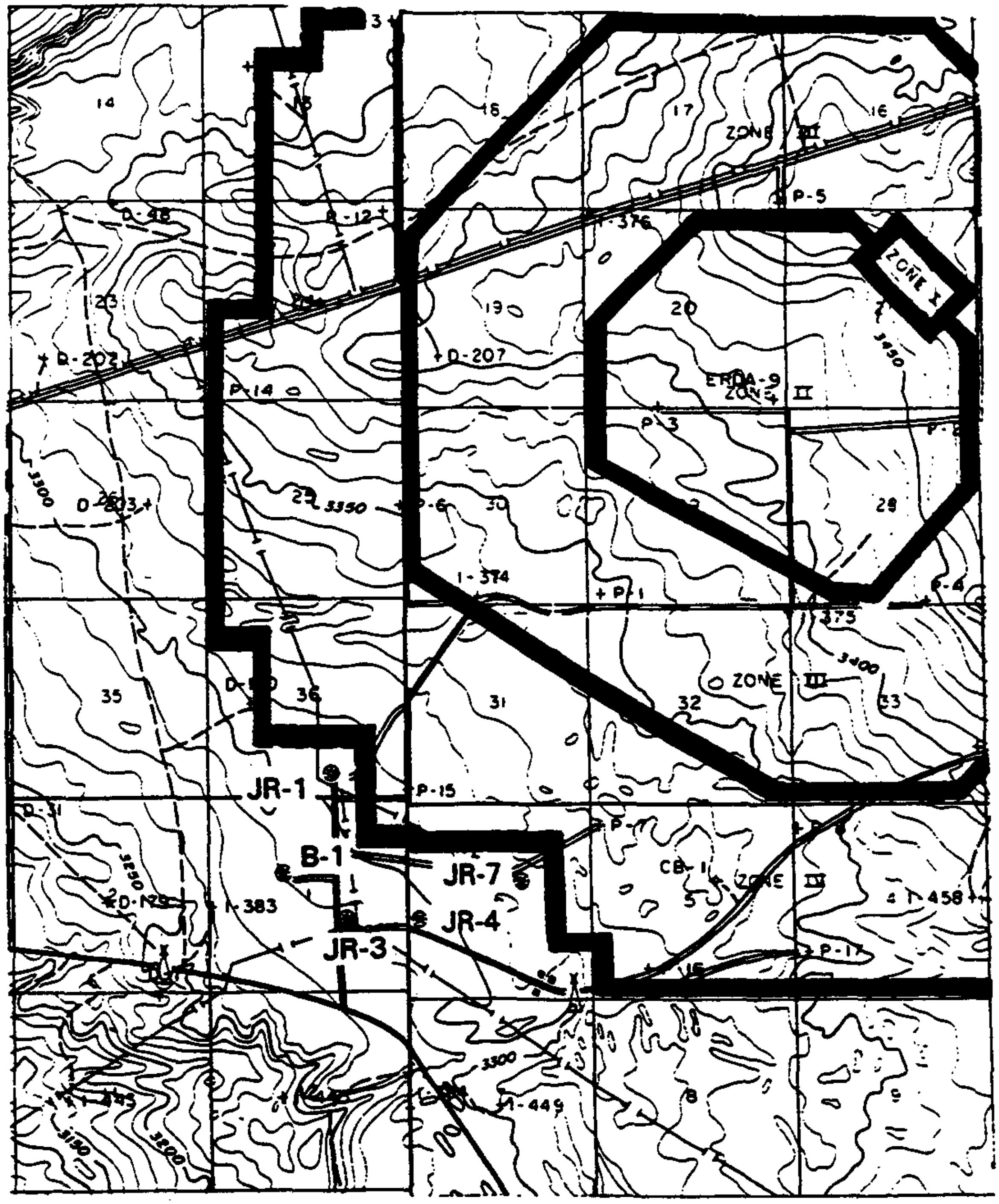
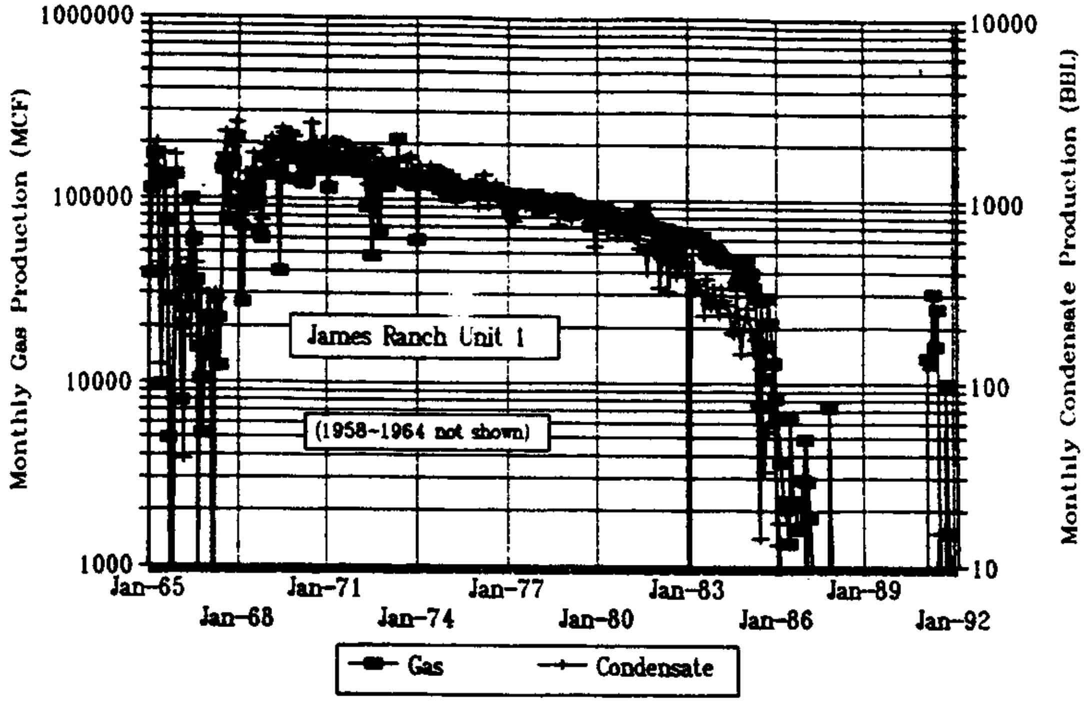


Figure 3. Five Gas Wells Outside Southwest Corner of WIPP Site in 1977. James Ranch Unit No's 1, 3, 4, 7 and Hudson Federal No. 1 (B-1). (after Griswold, 1977, Figure 4, highlighted and reproduced with permission.)



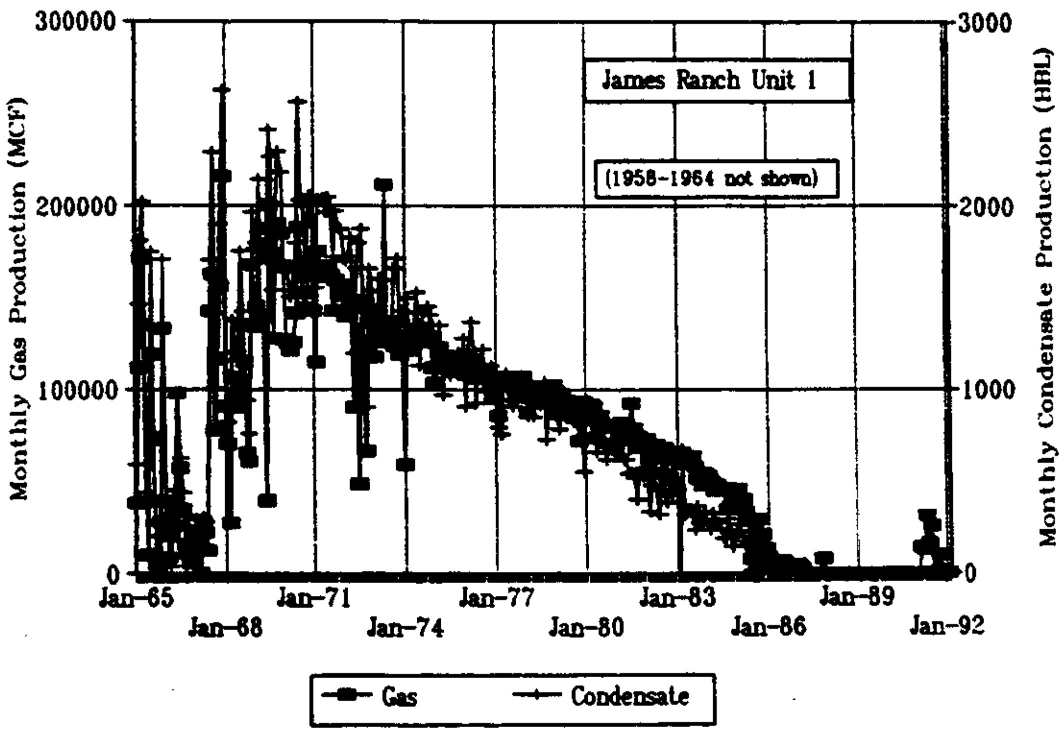


Figure 4. Gas and Oil Production from 1965 - 1991; James Ranch Unit No. 1. Data provided by Roswell District Office, U.S. BLM, 1992.

By 1977, the Shell James Ranch Unit No. 1 was flanked by an arc of four other wells on the south and west that essentially failed to tap the Atoka reservoir. The four wells were initially completed in the deeper Morrow Formation (Griswold, 1977). Figure 3 shows these wells included the Hudson Federal No. 1, Belco's James Ranch Unit No. 3, Belco's James Ranch Unit No. 4, and Conoco's James Ranch Unit No. 7.

4.2 Natural Gas Beneath the WIPP Site

A faulted anticline controls the Morrow reservoir in the Los Medaños field, southwest of the WIPP site. This same structure probably persists up into the Atoka and both reservoirs probably extend toward the northeast (Griswold, 1977).

Analysis of production decline curves through 1976 for the James Ranch No. 1 well indicated the well was probably draining at least five square miles (1300 hectares). That observation, coupled with the favorable geologic structure and the failure of wells drilled to the west and south, further suggested that wells drilled to the north-east would have a high chance of success (Keesey, 1976; Griswold, 1977; U.S. DOE, 1980).

As part of the hydrocarbon resource evaluation, potential drilling sites were selected based on the structure contours of the Morrow Formation. Depending on the geologic structure and distance from producing wells, the potential drilling sites were ranked as either 1) proved undeveloped, 2) probable, or 3) possible. Proved undeveloped reserves identified commercially recoverable hydrocarbons to be recovered from new wells on undrilled acreage or from existing wells requiring a major expenditure for recompletion or new facilities for fluid injection. (Keesey, 1976; Griswold, 1977, U.S. DOE, 1980).

The two locations ranked as "proven undeveloped" were north and east of the Shell James Ranch No. 1, as shown in Figure 5. The production data and geologic information available in 1976 indicated that much of the natural gas being produced from the Atoka Formation came from beneath the defined WIPP Site Boundary and the best place to drill a well would be in Section 31, T22S, R31E, which is precisely where the two active gas leases beneath the WIPP site are located.

Keesey (1976) noted that the drilling and completion of additional wells northeast of the Shell James Ranch No. 1 would only enhance the rate of recovery of the Atoka reservoir now being drained by the one well. Ultimate recovery would remain about the same.

4.3 Early History of Leases

In May 1952, Continental Oil Inc. (Conoco) obtained an oil and gas lease (NMPM Lease # NM 02953) that included all 640 acres (259 hectares) of Section 31, T22S, R31E. In June 1953, the area was approved by the U.S. Geological Survey (U.S.G.S.) as the James Ranch Unit. Sid Richardson and Perry R. Bass were designated Unit Operators.[5]

As discussed above, Shell Oil Company drilled the James Ranch Unit No. 1 in 1957, on Section 36 just west of the Conoco lease. Shell began prolific production of gas and condensate from the newly discovered resources in the Atoka Formation in March 1958.

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[5]Information about drilling applications, completion records, pipeline connections, production records, and official memoranda concerning these leases was obtained from U.S. Bureau of Land Management Offices in Roswell, New Mexico and Santa Fe, New Mexico.

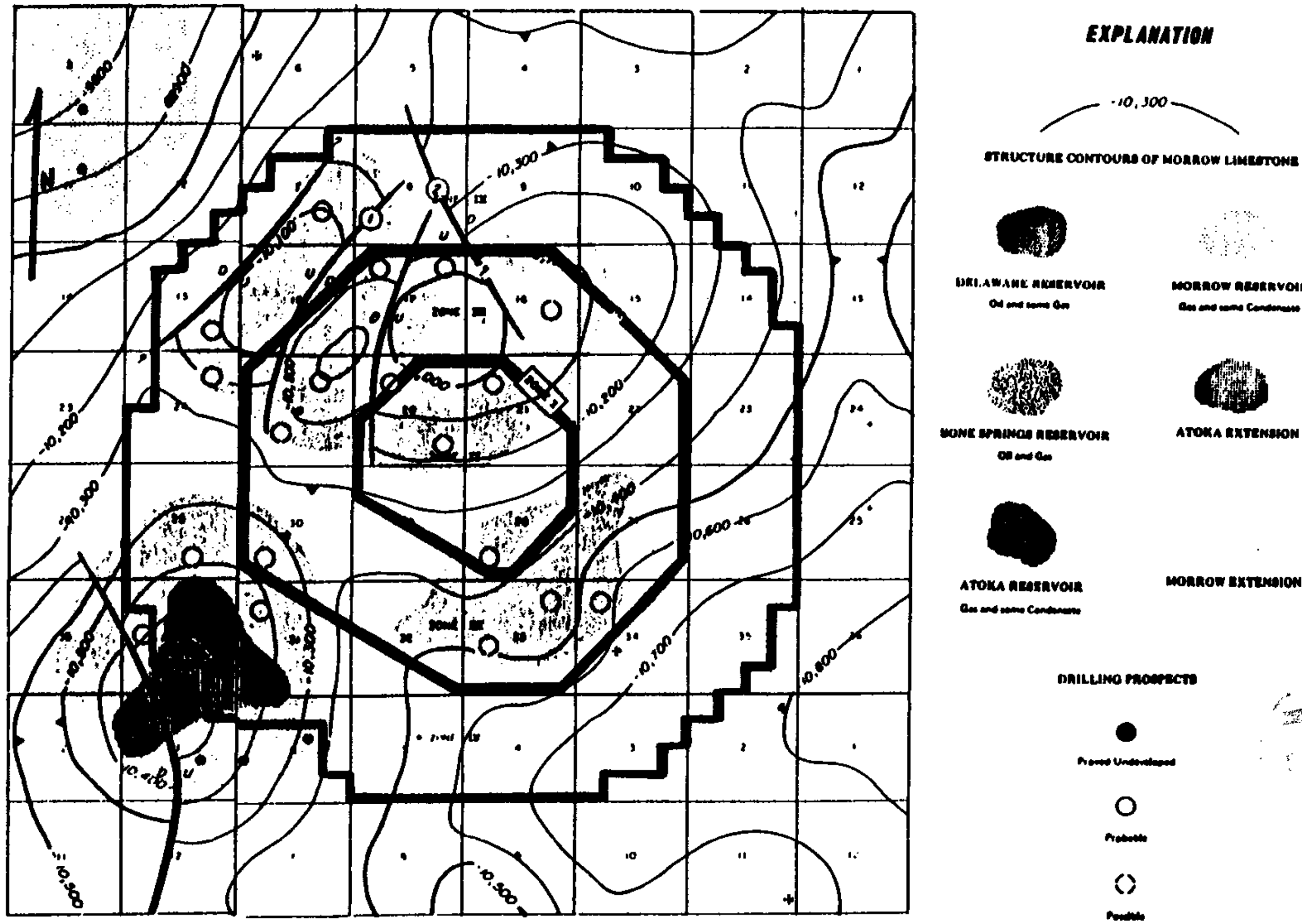

Figure 5. Hydrocarbon Resources and Possible Extensions (Griswold, 1977, Figure 32, reproduced with permission).

In February 1959 the Conoco lease on Section 31 was divided. The north half of the section remained with Conoco and the south half was assigned to Richardson and Bass under lease NM 02953-C. Perry R. Bass was designated the Unit Operator, in March 1961.

Keesey (1976) completed the analysis of hydrocarbon reserves for SNL, effective September 1, 1976, in which he concluded:

> that the Los Medaños (Atoka) reservoir extends north and northeast underneath the 'site area' in section 31-22S-31E [Conoco's and Bass's undeveloped leases] and 36-22S-30E [Shell's producing lease] (Keesey, 1976, p. 16).

4.4 <u>1976 Application to Drill For Natural Gas Beneath the WIPP Site</u>

On November 7, 1976, Bass formally filed for a permit with the U.S. Geological Survey to drill a well on Section 31. Three days later, November 10, 1976, Conoco was designated as the operator and local agent for Bass "with full authority to act in his behalf in complying with the terms of the lease and regulations...." (Bass, 1976).

On November 11, 1976, the District Engineer for the U.S.G.S., routinely notified the New Mexico Division of Lands and Minerals Program and Land Office in Santa Fe, New Mexico, of the intent of Bass Enterprises Production company to commence drilling operations.

On December 10, 1976, a withdrawal notice appeared in the *Federal Register*. The Energy Research and Development Administration (ERDA, precursor of the DOE) applied for withdrawal of 17,000 acres (6880 hectares) of public lands in New Mexico for a nuclear waste disposal site including the land containing the Bass lease.

On January 20, 1977, the U.S.G.S Area Oil and Gas Supervisor, James W. Sutherland, approved the Bass application to drill for oil and gas .

4.5 Court Condemnation of Oil and Gas Leases at the WIPP Site

On February 9, 1977, the U.S. Government, at the request of the Acting Administrator for the ERDA, filed a complaint in civil court (Case # CIV 77-071 B) against Bass Enterprises et al. condemning their oil and gas lease from the surface to a depth of 6,000 feet (1829 meters) for the southern half of section 31.

On April 4, 1977, the U.S. BLM Assistant Solicitor of Lands, John J. McHale, informed the Director of the U.S. BLM that an attorney for the U.S. ERDA in New Mexico had inquired by telephone about the impact of the Federal Land Policy and Management Act (FLPMA) on the land status because the issue had been raised in litigation. The lessee (Bass) was contending in court that the condemnation of oil and gas leases by the Government was illegal, arguing that the Government can only terminate the lease through the lease provisions. The Assistant Solicitor had advised the ERDA attorney, that in BLM's judgment, the land should never have been taken (McHale, 1977).

On December 7, 1977, an additional complaint was filed in civil court (Case # CIV 77-776 B) by the U.S. Government against Conoco Inc. condemning their oil and gas lease from the surface to a depth of 6,000 feet (1829 meters) for the northern half of Section 31.

On February 12, 1979, both cases were settled jointly. The court condemned the oil and gas lease from the surface to 6,000 feet (1829 meters) and assigned $1,350,000 to Conoco, Bass Enterprises, and other defendants as just compensation for these leases.

4.6 1981 Application to Drill Natural Gas Well Beneath the WIPP Site

On December 11, 1981, Bass Enterprises filed a formal application to drill a wildcat well, James Ranch Unit No. 13, on Section 6, T-23-S, R-31-E (#NM 02887-D) with the intent to deviate north into Section 31, T-22-S, R-31-E. This section, would fall entirely within the defined WIPP Site Boundary fourteen months later.

On December 14, 1981, James Pettengill, geologist with the U.S.G.S. Office in Roswell, filed a review of the drilling application with the U.S.G.S. District Engineer in Artesia. The review noted that the "completion location is within the boundaries of the Department of Energy's proposed Waste Isolation Pilot Project (WIPP)" (Pettengill, 1981).

On December 16, 1981, the U.S.G.S. District Supervisor in Roswell, James Gillham, issued a memo to the U.S.G.S. Deputy Conservation Manager of Oil and Gas transmitting the request to drill and commenting that the "drillsite is not considered to be in a politically sensitive area" (Gillham, 1981).

On December 18, 1981, the U.S.G.S Area Manager for the Carlsbad Resource Area notified the DOE WIPP Project Manager of Bass's application to drill and requested advice on any special stipulations or concerns by December 28, 1981 (Koski, 1981).

The DOE December 30, 1981, response noted that the Department had obtained exclusive use of the surface and uppermost 6,000 feet (1829 meters) of subsurface for the specific purpose of preventing any drilling activity in Section 6, N½,NW¼, T23S, R31E and Section 31, T22S, R31E. The letter cautioned the BLM that "the approval to drill must include the stipulation that Perry R. Bass is not permitted to drill into the areas described above" (McGough, 1981) .

Following the January 11, 1982, approval by the U.S.G.S. (Reitz, 1982) to drill, drilling started on February 6, 1982. On September 13, 1982, the well was tested and produced 141 MCF of gas for an eight hour period. On September 21, 1982, drilling was completed. On February 14, 1983, the Natural Gas Pipeline Company of America connected to the well, James Ranch Unit No. 13, for the purpose of purchasing gas. The wellhead is shown in Figure 6 with the WIPP Waste Handling Building in the background.

4.7 Zone Designation and Resource Recovery Control

On February 17, 1983, the DOE WIPP Project Manager notified the Director of the Environmental Evaluation Group (EEG) that:

> the configuration of WIPP surface control zones has changed as a result of the cost reduction program, the DOE resource management policy and Bureau of Land Management land withdrawal action.... Descriptions of the new control zones are also enclosed (McGough, 1983a).

On February 24, 1983, the DOE WIPP Project Manager further informed the EEG Director that:

> the DOE does not plan to exercise any control over resource recovery activities outside the Site boundary and will rely, primarily, on other Federal and State regulatory agencies to assure that the WIPP boundaries are not violated (McGough, 1983b).

On October 28, 1983, the EEG requested a clarification on the DOE's conflicting descriptions of the Zone III boundaries and a clarification on the interim controls on resource recovery. The EEG was puzzled by the DOE's reference to the new WIPP site boundary as Zone III. The EEG was also concerned the restriction against drilling into the first 6,000 feet (1829 meters) was not included in the BLM/DOE

Figure 6. James Ranch Unit No. 13 with WIPP Waste Handling Building in Background.

Memorandum of Understanding or in the Resource Management Plan. Hence, EEG suggested that there was no apparent reason for the BLM to enforce the restriction (Neill, 1983a).

On December 7, 1983, the DOE WIPP Project Manager acknowledged that:

> 1. Our February 24, 1983 letter incorrectly identified the WIPP Site boundary as being the Zone III when in fact the Zone III boundary has not changed from that shown in the FEIS. The zone being controlled as regards mineral extraction, is the 16 full sections of land as shown in the sketch enclosed in our February 17, 1983 letter. These 16 sections comprise the area identified in the June 29, 1983 administrative land withdrawal.
>
> 2. All lease rights which have been purchased by the DOE within the site boundary have been purchased in their entirety or alternatively we acquired only the upper 6,000 feet of the leases to reduce the acquisition cost to the DOE and to allow access to potential hydrocarbon resources below the WIPP Site. It was not considered necessary to detail this information in the DOE/BLM Memorandum of Understanding (MOU) or Resource Management Plan because the BLM is required to enforce mineral leasing laws which prohibit violation of adjacent (in this case, DOE's) lease boundaries (McGough, 1983c).

In evaluating the suitability of the WIPP Site, the EEG (Neill et al., 1983, p. iii) recommended that

> no potash mining will be allowed in Zones I, II, and III of the WIPP site. Deviated drilling for oil and gas from outside the WIPP site to reach under the WIPP site at depths greater than 6,000 feet may be allowed. The federal government shall exercise active institutional control at the site for this purpose for at least 100 years after repository decommissioning.

The recommendation was reiterated on December 6, 1983, in a letter from the EEG Director (Neill, 1983b) to the WIPP Project Manager on the suggested wording for the First Modification to the Consultation and Cooperation (C&C) Agreement between the U.S. Department of Energy and the State of New Mexico. On November 14, 1984, the State of New Mexico and the U.S. Department of Energy agreed that:

> During facility construction and operation the DOE will not allow subsurface mining, drilling or resource exploration from within the WIPP site. The 'WIPP site' as used here means the 4 x 4 mile (10,240 acres) area consisting of sections 15, 16, 17, 18, 19, 20, 21, 22, 27, 28, 29, 30, 31, 32, 33, and 34 of Township 22 South, Range 31 East, NMPM, in Southeastern New Mexico.
>
> Deviated drilling for oil and gas from outside the WIPP may be allowed so long as the subsurface of the WIPP site is not penetrated above a depth of 6,000 feet from the surface.

EEG's recommendation to include a statement that the federal government shall exercise active institutional control at the site for at least 100 years after repository decommissioning was not included in the modification. Rather, the First Modification to the C&C agreement stated that:

> the consultation process concerning the length and extent of the post-closure institutional control, shall be negotiated and resolved by the parties in the future, and at least one year prior to the start of the decontamination and decommissioning of WIPP.

5.0 THE FORGOTTEN GAS LEASES AND WELL BENEATH THE WIPP SITE

The 1984 agreement between the U.S. Department of Energy and the State of New Mexico to allow slant drilling under the WIPP Site changed on August 4, 1987, in the second modification to the C&C agreement (U.S. DOE and NM, 1987), which states:

> The DOE will not permit subsurface mining, drilling, or resource exploration unrelated to the WIPP Project on the WIPP site during facility construction, operation, or after decommissioning. This prohibition also **precludes slant drilling**[6] under the site from within or from outside the site.

Several important DOE documents are either incorrect, silent, or inconsistent on the existence of the two oil and gas leases and the gas well. For example, the Final Environmental Impact Statement (FEIS, U.S. DOE, 1980, pp. 8-8—8-10) identifies the oil and gas leases held by ten companies in March 1979, yet the 1952 Conoco and 1957 Bass leases in the southwest corner of the WIPP Site on Section 31 are not mentioned. The WIPP Final Safety Analysis Report (WIPP FSAR, U.S. DOE, 1990a, Section 2.1.1.1), incorrectly states that there are no active oil and gas leases within the WIPP Site Boundary. Moreover, the WIPP FSAR (U.S. DOE, 1990a, Figure 2.2-1) fails to chart the intruding well on its map of producible oil and gas wells. The DOE No-Migration Variance Petition to EPA incorrectly states that the DOE has purchased all oil and gas leases in the area of the WIPP site to prevent any exploration now and in the future (U.S. DOE, 1990b). Revisions 1 through 5 of the Secretary of Energy's Decision Plan were monitoring the status of an active potash lease until it was purchased by the DOE. Yet Revisions 6 through 10 remained silent on the active oil and gas lease issue even after the article in the Albuquerque Journal raised the issue (McCutcheon, 1990). The recently published DOE Implementation

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[6]Emphasis added.

of the Resource Disincentive document, (U.S. DOE, 1991) is inconsistent on the number of active oil and gas leases within the WIPP Site Boundary and on the production status of the forgotten gas well.

5.1 1980 WIPP Final Environmental Impact Statement

The WIPP Final Environmental Impact Statement (U.S. DOE, 1980) identifies the gas and oil leases held by ten companies in March 1979 at the WIPP Site. Figure 7 (reproduced from the 1980 WIPP FEIS) does not show the Bass and Conoco leases on Section 31. While those two leases were condemned in February 1979 from the surface to 6,000 feet (1829 meters), the oil and gas leases below 6,000 feet (1829 meters) did remain valid.

5.2 1990 WIPP Final Safety Analysis Report

The DOE's stated commitment to prohibit slant drilling and the loss of knowledge is also documented in the WIPP Final Safety Analysis Report (U.S. DOE, 1990a) which the DOE describes as the top level document in the hierarchy of the WIPP safety documents. The WIPP FSAR states:

> The area of land that lies within the WIPP Site Boundary and committed to the WIPP facility is a square four miles on a side. It contains 10,240 acres (16 mi^2) including Sections 15-22 and 27-34 in township T22S, R31E....
>
> The DOE will not permit subsurface mining, drilling, or resource exploration unrelated to the WIPP Project within the WIPP Site Boundary during facility operation or after decommissioning. This prohibition **precludes slant drilling**[7] under the WIPP facility from within or outside the WIPP facility. (U.S. DOE, 1990a, Section 2.1.1.1).

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[7]Emphasis added.

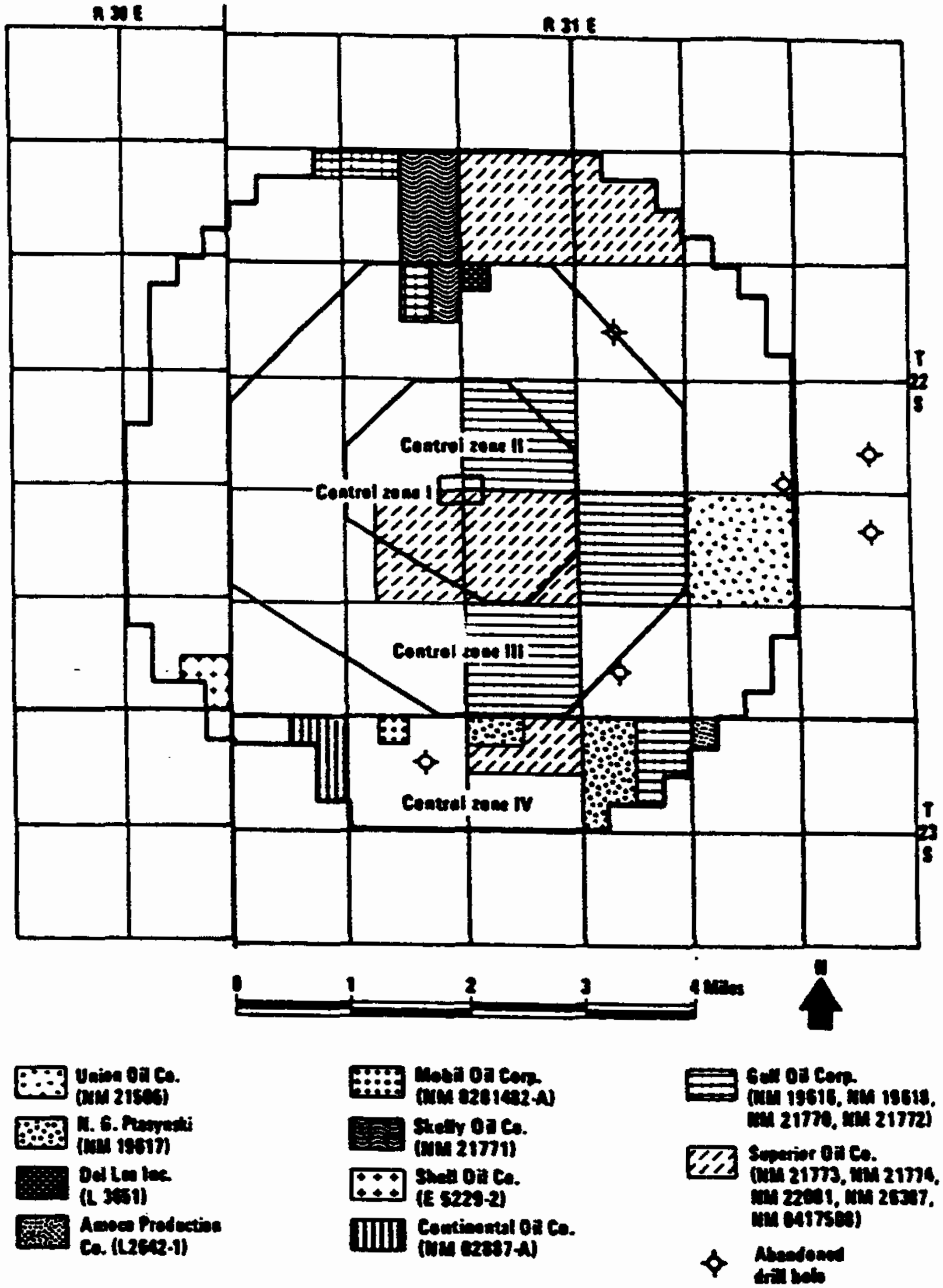


Figure 7. Oil and Gas Leases Within the WIPP Site according to the DOE FEIS, (U.S. DOE, 1980, Figure 8-6, reproduced with permission).

The WIPP Final Safety Analysis Report also incorrectly states:

> ... all oil and gas leases within the WIPP Site Boundary have expired (U.S. DOE, 1990a, Section 2.1.2.1.3).

Furthermore, Figure 2.2-1 (Figure 8 in this report) of the WIPP FSAR fails to show all of the 1986 operable natural gas and oil wells within a ten mile (16.1 kilometers) radius. This figure shows seven wells just outside the southwest corner of the site - James Ranch Unit Nos. 1, 3, 4, 7, 10, 11 and Hudson Federal No. 1. James Ranch Unit No. 3 appears to be plotted in the wrong location. At least two wells, James Ranch Unit Nos. 13 and 14 shown in Figure 9, both slant drilled wells, are not shown in the WIPP FSAR. James Ranch Unit No. 13 and James Ranch Unit No. 14 were not only operable, but each was producing through the entire year of 1986, as shown in Figures 10 and 11.

Table 1 (prepared from data provided by the Roswell District Office of the U.S. BLM) lists the gas and condensate production from the James Ranch Unit No. 13. Production was stopped for one month in July 1985 and again for three extended periods of several months beginning in April 1987. Nonetheless, gas and condensate were produced for several months in 1987, 1988, and again in 1991. To date this well has produced over 3,000,000 MCF gas. The latest available production records in the Roswell District Office of the U.S. BLM show production of 27,618 MCF gas and 164 BBLs condensate for February 1992 (U.S. BLM, 1992).

James Ranch Unit No. 14 was slant drilled in 1983. The top of the well is located in Section 6, T23S, R31E and completed in the Los Medaños-Morrow Formation in Section 7, T23S, R31E. Since production began in December 1983 records through February 1992 show this well has produced gas every month except for a two month period in 1987.

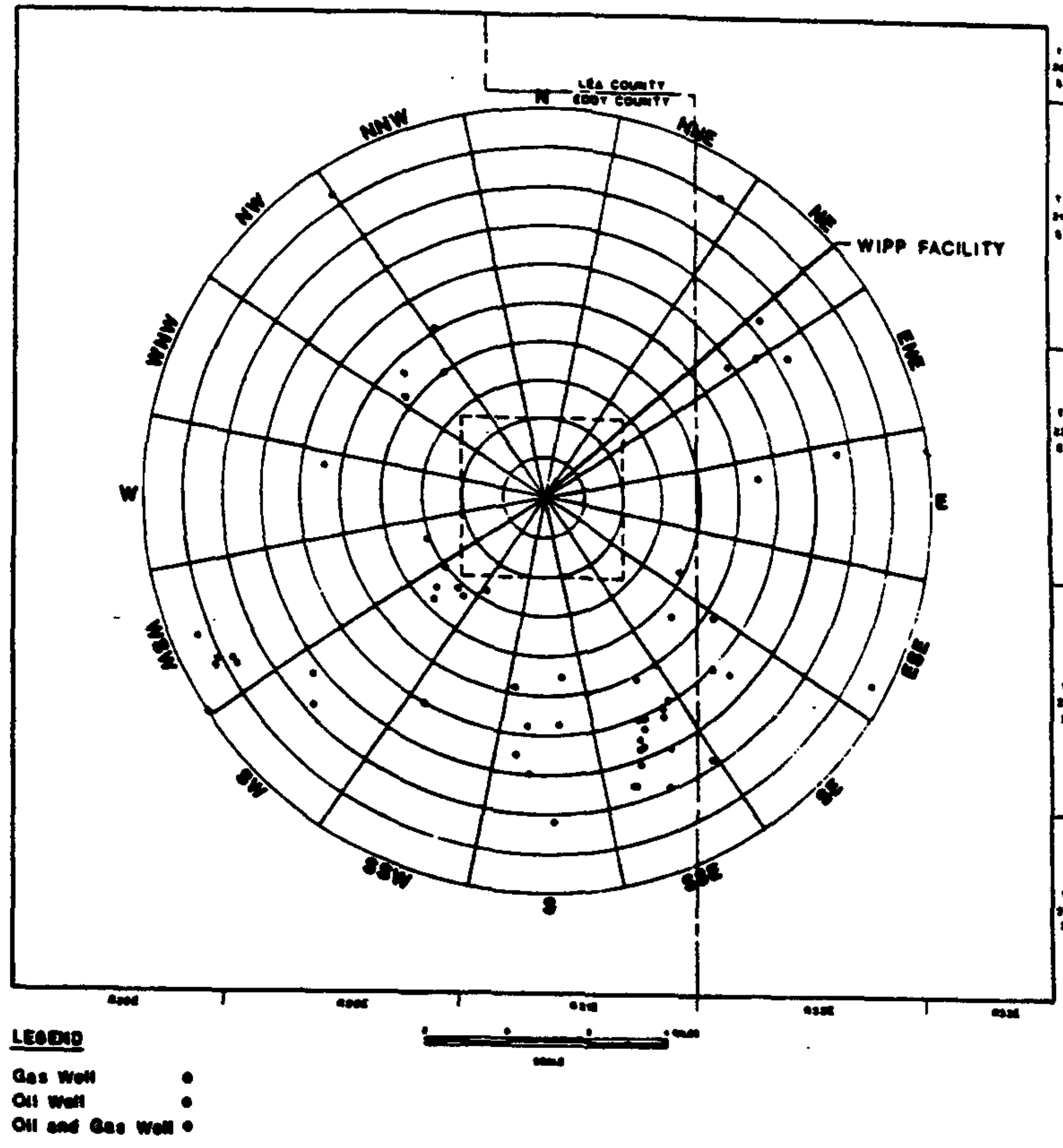


Figure 8. 1986 Operable Natural Gas and Oil Wells, within 10 Mile Radius (WIPP FSAR, U.S. DOE, 1990a, Figure 2.2-1, reproduced with permission).

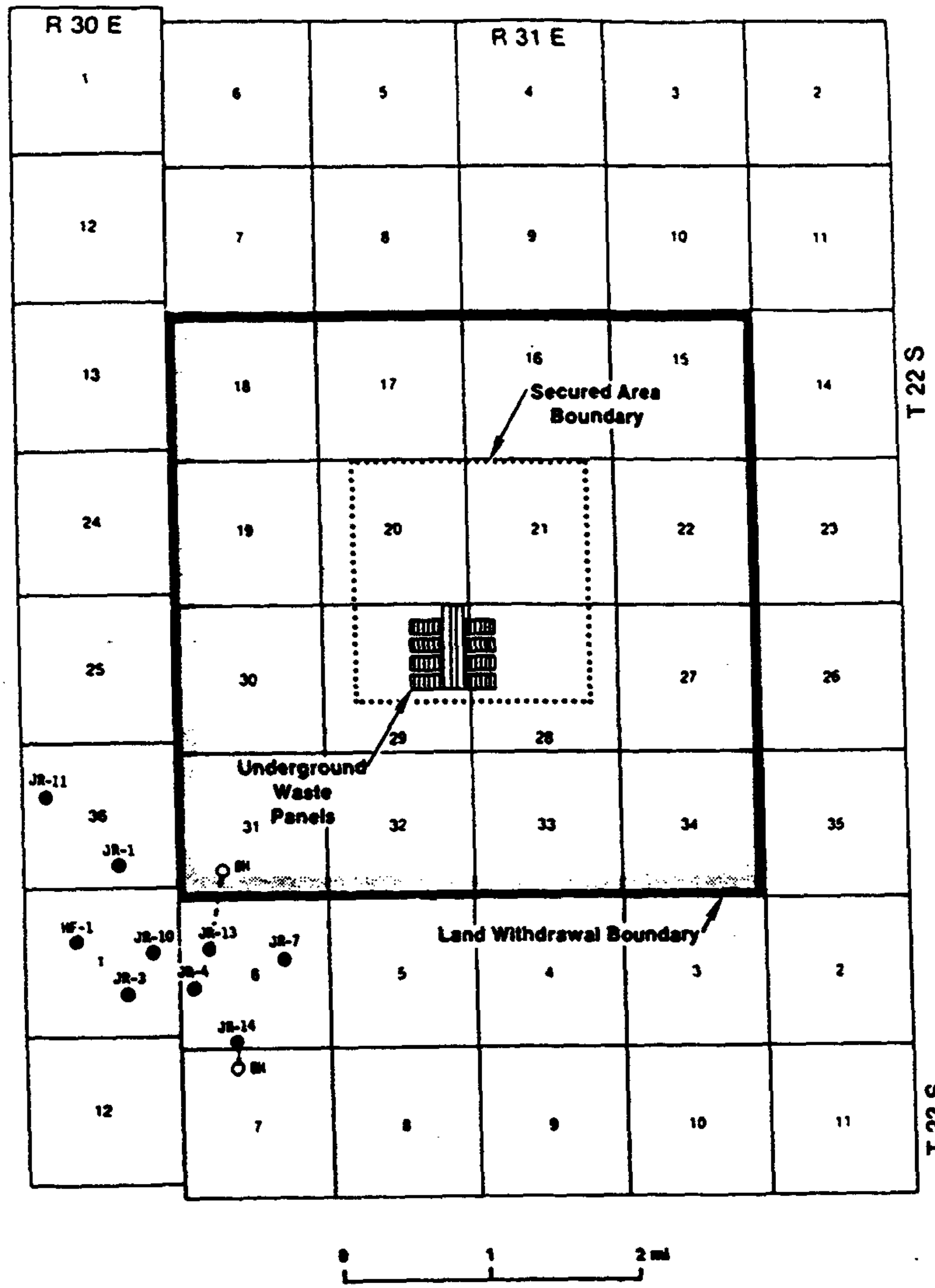
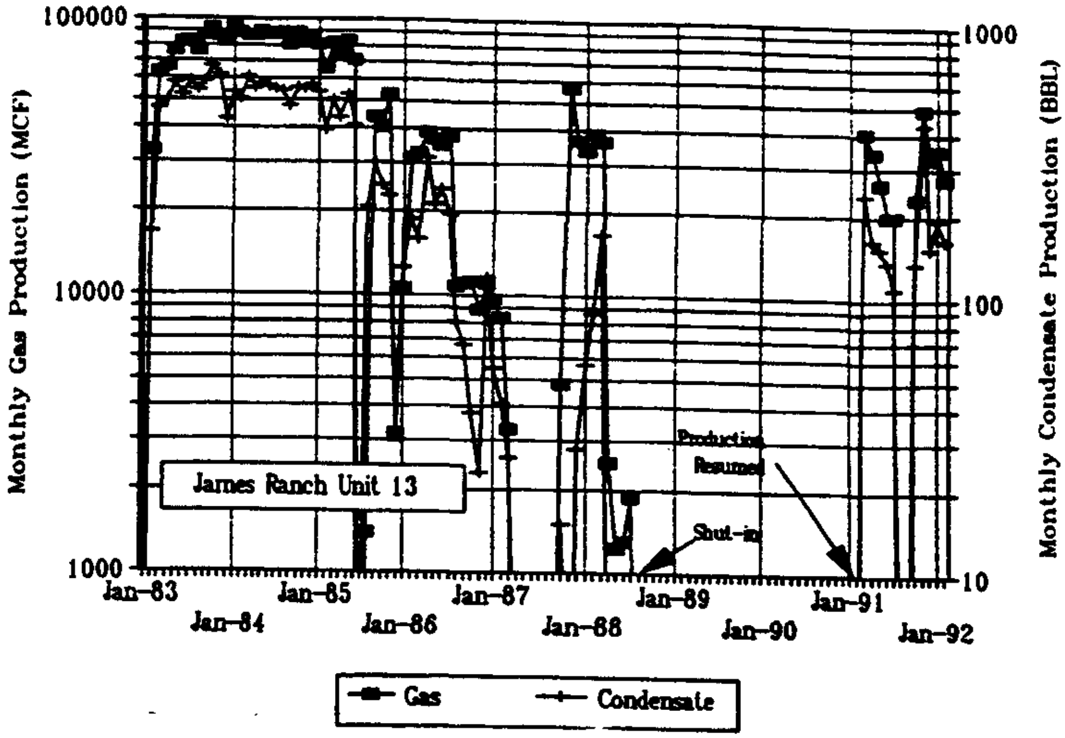


Figure 9. Gas and Condensate Wells at Southwest Corner of WIPP Site. Well locations plotted from U.S. BLM records.



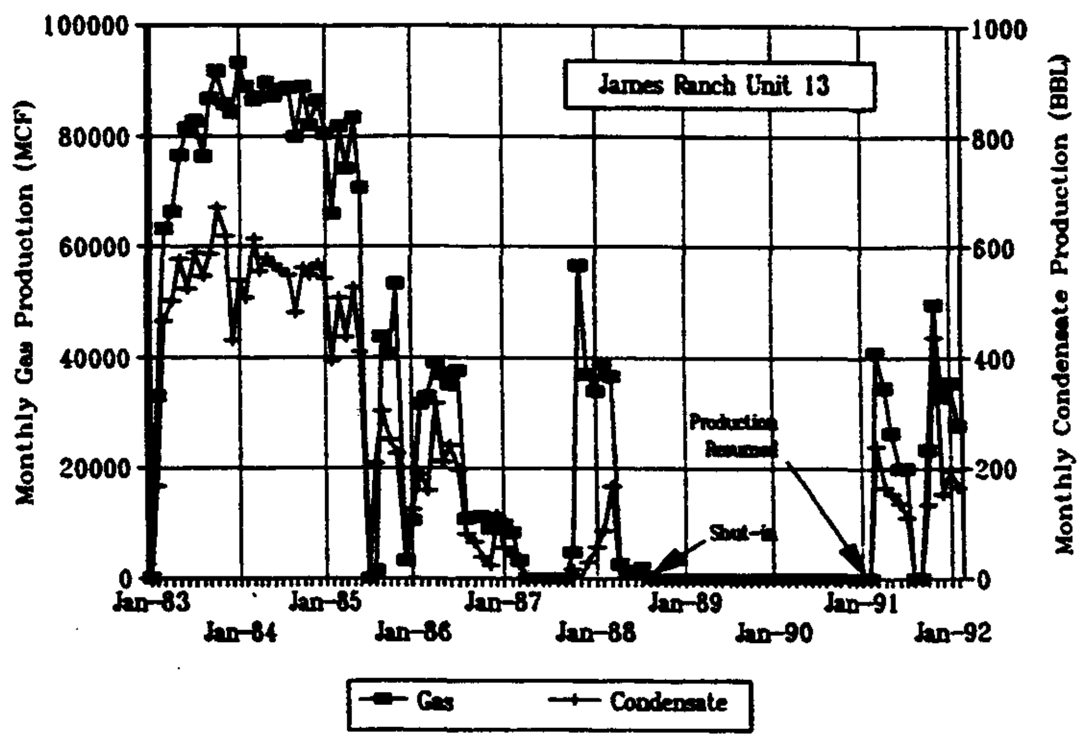
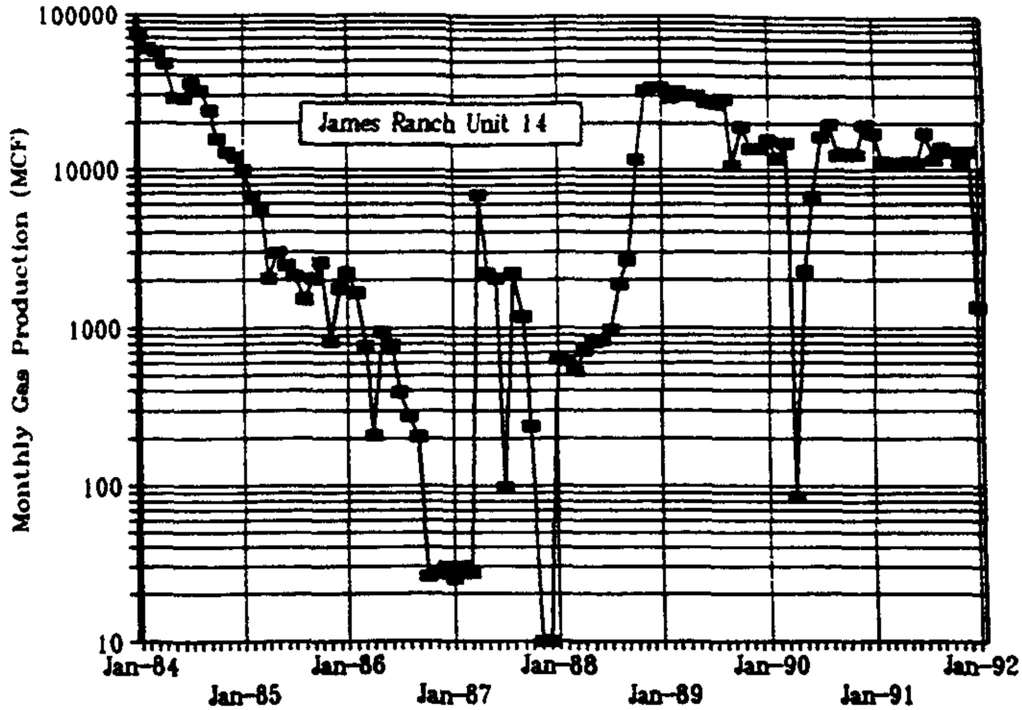


Figure 10. Production History of James Ranch Unit No. 13. Data provided by Roswell District Office, U.S. BLM, 1992.



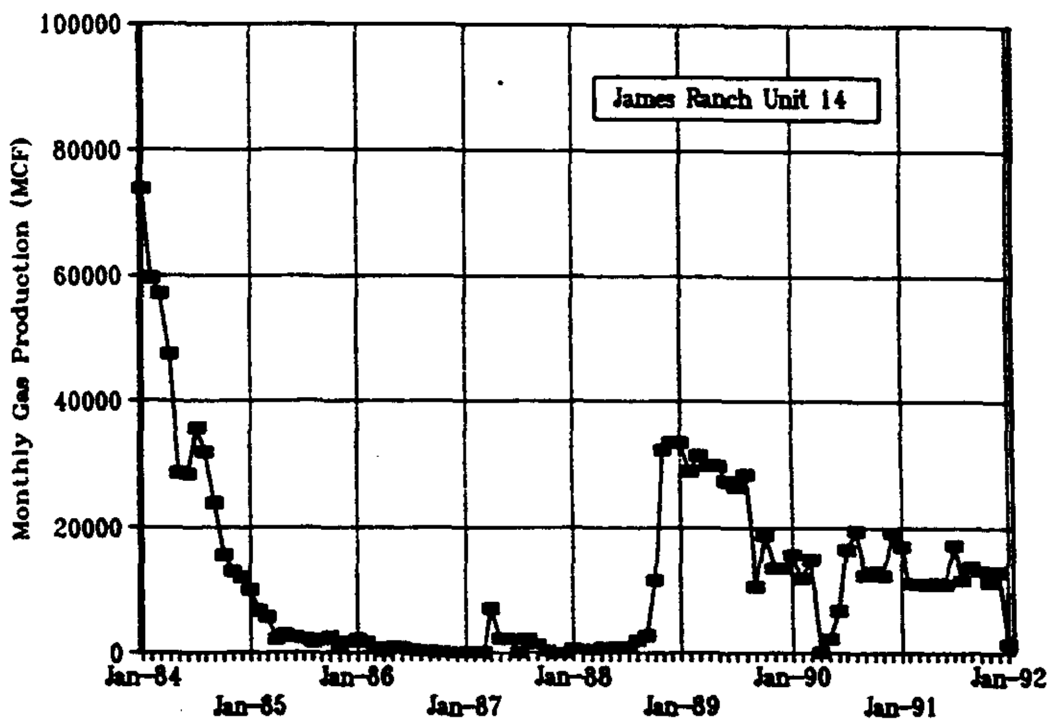


Figure 11. Production History of James Ranch Unit No. 14. Data provided by Roswell District Office, U.S. BLM, 1992.

TABLE 1: PRODUCTION HISTORY OF JAMES RANCH UNIT NO. 13

DATE	OIL (BBL)	GAS (MCF)	WATER (BBL)
01/31/83	0	0	0
02/28/83	167	32970	17
03/31/83	467	63373	31
04/30/83	501	66425	27
05/31/83	579	76613	30
06/30/83	524	81409	30
07/31/83	589	82734	31
08/31/83	546	76421	31
09/30/83	588	86647	30
10/31/83	672	91799	31
11/30/83	619	85720	30
12/31/83	431	84334	29
01/31/84	539	93266	31
02/29/84	508	88828	29
03/31/84	615	86519	30
04/30/84	555	86971	30
05/31/84	580	89612	31
06/30/84	567	87216	30
07/31/84	557	88357	31
08/31/84	548	88778	31
09/30/84	481	80027	29
10/31/84	562	89005	31
11/30/84	549	82072	30
12/31/84	569	86411	31
01/31/85	543	80505	30
02/28/85	393	65972	26
03/31/85	507	81783	31
04/30/85	437	74131	58
05/31/85	526	83292	31
06/30/85	410	70727	28
07/31/85	0	0	0
08/31/85	207	1391	16
09/30/85	302	43919	17
10/31/85	250	40550	17
11/30/85	227	53275	21
12/31/85	33	3112	14
01/31/86	126	10583	4
02/28/86	189	31505	10
03/31/86	160	32865	13
04/30/86	316	38991	17
05/31/86	212	36926	30
06/30/86	241	35085	16

TABLE 1 (continued)

07/31/86	196	37753	16
08/31/86	81	10837	5
09/30/86	67	11113	5
10/31/86	38	11235	5
11/30/86	23	8979	5
12/31/86	117	10951	6
01/31/87	55	9701	7
02/28/87	41	8374	24
03/31/87	26	3305	3
04/30/87	0	0	0
05/31/87	0	0	0
06/30/87	0	0	0
07/31/87	0	0	0
08/31/87	0	0	0
09/30/87	0	0	0
10/31/87	15	4824	4
11/30/87	0	56786	22
12/31/87	28	36952	36
01/31/88	57	33926	30
02/29/88	87	38970	32
03/31/88	167	36552	28
04/30/88		2518	4
05/31/88		1219	2
06/30/88		1297	4
07/31/88		1872	
08/31/88	0	0	0
09/30/88	0	0	0
10/31/88	0	0	0
11/30/88	0	0	0
12/31/88	0	0	0
01/31/91	0	0	0
02/28/91	0	0	0
03/31/91	240	40888	0
04/30/91	164	34513	30
05/31/91	153	26441	0
06/30/91	136	20034	26
07/31/91	110	20043	31
08/31/91	0	0	
09/30/91	0	0	
10/31/91	135	23393	
11/30/91	436	49658	29
12/31/91	153	32782	31
01/31/92	196	35364	
02/29/92	164	27618	

5.3 No-Migration Variance Petition to EPA

The DOE No-Migration Variance Petition (U.S. DOE, 1990b) to the EPA states in the section on human intrusion:

> Oil and gas exploration has been and continues to occur around the WIPP site. The target horizons for this type of exploration are below the Castile. Oil and gas exploratory drilling requires permits from the state, and it is unlikely that prospective future well drillers would not be informed about the existence of WIPP. As an additional protective measure, **the DOE has purchased all oil and gas leases in the area of the WIPP site**[a] to prevent any exploration now and in the future (U.S. DOE, 1990b, Section 6.3.2).

With respect to petroleum exploration and the human intrusion issue, the last sentence in this paragraph provided incorrect information to the EPA. The EPA subsequently granted a variance to the DOE in November 1990 (U.S. EPA, 1990).

5.4 New Mexico Energy and Minerals Department Report

The 1984 report published by the New Mexico Energy and Minerals Department (NMEMD) Task Force on Natural Resources (NMEMD, 1984) stated that the DOE had acquired several oil and gas leases at a cost of over $19.6 million dollars. The report stated that "As a result of these lease acquisitions, only one hydrocarbon lease remains within the WIPP Site Boundary... an 80-acre tract held by Skelly Oil Company...." (NMEMD, 1984, p. 27). The report did not identify the active gas and oil leases in Section 31, deeper than 6,000 feet (1829 meters).

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[a]Emphasis added.

5.5 1990 Memorandum of Understanding between BLM and DOE

The U.S. Department of Energy and the U.S. Department of Interior's BLM signed the Memorandum of Understanding on October 26, 1990, recognizing that:

> **BLM will prohibit directional drilling underneath the WIPP site boundary, except as may be required for the development of the two leases located under Section 31;**[9] drilling may be allowed below 6,000 feet of the surface.

Hence, it appears the DOE entered into an agreement in 1990 to honor these leases despite commitments to preclude slant drilling in the 1987 C&C Agreement with New Mexico and the 1990 WIPP FSAR.[10] Apparently, the DOE accepted the *fait accompli* without considering the commitments in the C&C Agreement and the WIPP FSAR.

5.6 Department of Energy Position

On November 3, 1990, the Albuquerque Journal reported the discovery of the forgotten natural gas well completed within the WIPP Site Boundary. (McCutcheon, 1990).

On November 15, 1990, the Assistant Manager for Energy and Special Programs of the Albuquerque Operations Office of the Department of Energy sent a letter to the

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[9]Emphasis added.

[10]On January 22, 1991, the Assistant Secretary of the Interior signed 43 CFR Public Lands Order 6826 (Administrative Land Withdrawal). That Administrative Land Withdrawal Order cites the October 26, 1990 Memorandum of Understanding between the U.S. Department of Energy and the U.S. Department of the Interior BLM as the guiding document regarding resource management.

Chairman of the New Mexico Radioactive Waste Consultation Task Force. The letter maintained:

> ...at the time this deviated well was drilled, the section 31 bottom hole was within what was formerly termed "zone IV" of the WIPP site. A 1980 report prepared by Sandia National Laboratories (SNL) concluded that extraction from within zone IV would have no technical impact on repository performance. The 1980 Environmental Impact Statement for the WIPP stated that the DOE would permit drilling for natural gas in zone IV. Accordingly, in 1981 when Bass Enterprises filed an application to drill the well, the DOE stated it had no objection, so long as the operator did not encroach upon the surface or the first 6,000 feet condemned by the United States. Recent review by SNL confirms that the existence of this bottom hole more than 14,000 feet below section 31 does not affect the performance of the repository.
>
> We do not believe that the existence of this 1982 well contravenes the August 4, 1987 Second Modification to our Agreement for Consultation and Cooperation in which we previously agreed to prospectively preclude "subsurface mining, drilling, or resource exploration unrelated to the WIPP Project on the WIPP site" [including "slant drilling under the site from within or from outside the site"].... (Bickel, 1990a).

The DOE response requires further explanation because it cited a "1980 report" from Sandia National Laboratories and a "recent review by SNL." The "1980 report" was a **draft** of a position paper on Zone IV. The 1980 memo of transmittal accompanying those draft pages also recommended that:

> well selected, realistic scenarios addressing the consequences of mining and drilling in Zone IV should be a part of the Zone IV position paper (Weart, 1980).

The cited "recent review by SNL" described in the November 15, 1990, DOE letter was a November 5, 1990, memo (Weart, 1990) prepared at the DOE's request. The one and one-half page memo reexamined the reasoning from the 1980 draft in light of the new dilemma and current regulatory requirements. The memo correctly stated:

> the portion of the hole that penetrates the salt is outside the site boundary and thus beyond the boundary at which compliance with the standards will be evaluated (Weart, 1990).

and concluded that:

> even though the Bass drill hole is bottomed within the site boundary, it is much more than a mile from the waste zone and therefore exceeds the technical safety requirements (Weart, 1990).[11]

The DOE Albuquerque Operations Office November 16, 1990, letter to the Coordinator of the New Mexico Radioactive Waste Task Force stated:

> there is one producing well allowed in each 320-acre production unit. The south half of Section 31 has its one well, James Ranch Unit No. 13 (Bickel, 1990b).

However, the letter failed to note current drilling practices in New Mexico would allow additional deep gas wells to be drilled into Section 31 including the south half

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[11]Initially, the selection of a site required that the repository be located at least two miles from a borehole penetrating the Salado formation. The two mile requirement was believed to be conservative but was also arbitrary (Schueler, 1980). The two mile requirement was reduced to one mile after the site at the ERDA 6 borehole was found to be unacceptable (Neill et al., 1979, Appendix III, p. 6). The Geologic Characterization Report (Powers et al., 1979, p.2-12) stated that justification for a one mile criteria was based on reports by Snow and Chang (1975), Walters (1975), Fader (1973), and Griswold (1977). However, EEG questioned the pertinence of these studies and, hence, questioned the justification for the reduction to a one mile criteria (Neill et al., 1979, Appendix III, pp. 6,7).

of that section. The lessee can request permission to drill on tighter spacing by demonstrating to the New Mexico Oil Conservation Division that the tighter spacing is required to efficiently produce the gas from the formation. For example, if a reservoir exhibits retrograde condensate behavior, the buildup of liquid around the well bore can reduce, sometimes seriously, the flow rate as the pressure declines below the dew point (Craft and Hawkins, 1959, p. 73). Hence, efficient production may require more wells on a tighter spacing.

Also, the existing well in Section 31 could be deepened. That activity would constitute exploratory drilling.

Furthermore, the lessee is still entitled to slant drill an exploratory hole into the north half of Section 31, which has yet to be developed. In summary, as long as the lessee maintains the leases, the U.S. BLM can not deny them access to their oil and gas in Section 31, the southwestern section of the WIPP Site.

5.7 SNL WIPP Performance Assessment Division

The SNL WIPP Performance Assessment Division issues an annual report on the status of the demonstration of the extent of compliance with 40 CFR Part 191. The December 1990 annual report stated:

> About 56 oil and gas wells are within a radius of 16 km (10 mi); the wells generally tap Pennsylvanian strata, about 4,200 m (14,000 ft) deep. The nearest well is about 3 km (2 mi) to the south-southwest of the waste panels (Bertram-Howery, 1990, p. I-20).

There was no discussion on the status of that well. For 1991, the SNL WIPP Performance Assessment Division added:

The surface location of the well, which is capable of producing gas, is outside the proposed land-withdrawal boundary, but the borehole is slanted to withdraw gas from rocks within the boundary. Except for this well, resource extraction is not allowed within the proposed land-withdrawal boundary (Sandia National Laboratory, 1991, p. 1-15).

The 1991 document also stated in the discussion on natural resources:

In order to gain control over the development of hydrocarbons at the WIPP, the DOE acquired the oil and gas leases within all the WIPP control zones. The only leases that are still intact are in Section 31. These leases only allow resource production by entry of the proposed land withdrawal area below 6000 feet. **One of these leases is currently in production.**[12] The upper 6000 feet of the leases was taken by the DOE in 1979. Current policy does not allow any further resource development inside the proposed land withdrawal boundary (Sandia National Laboratory, 1991, p. 8-7).

5.8 The Secretary of Energy's Decision Plan

While the Secretary of Energy's Decision Plan for the WIPP had carefully tracked an active potash lease until it was purchased, successive Revisions 6 through 10 did not document the existence of the active oil and gas leases even after the issue had been raised. The potash lease purchase was noted in Revision 5 (U.S. DOE, August 15, 1990). The failure of subsequent revisions to mention the rediscovered gas leases incorrectly suggests that there were no outstanding leases in the WIPP Site Boundary other than the one potash lease.

[12]Emphasis added.

5.9 DOE Implementation of the Resource Disincentive Plan

The *DOE Implementation of the Resource Disincentive Plan in 40 CFR 191.14(e) at the Waste Isolation Pilot Plant* (U.S. DOE, 1991) is inconsistent in reporting the number of oil and gas leases within the WIPP Site Boundary and the production status of those leases. First it incorrectly states that:

> Only one lease currently exists within the WIPP site boundary (U.S. DOE, 1991, p.32).

However, there are two active gas and oil leases within the WIPP site boundary — the Conoco lease on the north half of Section 31 and the Bass lease on the south half of Section 31.

The Resource Disincentive Plan then states:

> This lease, **currently shut in for production of oil and gas,**[13] is being exploited by a well that was initiated outside the WIPP site boundary and was deviated to under the site only after the depth was below 6000 feet (U.S. DOE, 1991, p.32).

The document then reverses its position on the number of leases and their production status:

> In order to gain control over the development of hydrocarbons within the WIPP site area, the DOE acquired the oil and gas leases within all the WIPP control zones. These acquisitions were necessary to keep the salt beds intact. The only leases that are still intact are in section 31. These leases only allow

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[13]Emphasis added.

the production of resources by entry below 6000 feet. **One of these leases is currently in production**[14] (U.S. DOE, 1991, p.50).

The U.S. Bureau of Land Management (U.S. BLM, 1992) records show the well produced 141,919 MCF of natural gas from March 1991 through July 1991 as shown in Table 1, and was shut-in effective August 1991 - coincidently, the issue date of the Disincentive Plan. The latest available records from the Roswell District Office of the U.S. BLM indicate production resumed in October 1991.

5.10 Comments on Credit for Active and Passive Institutional Control

In terms of active institutional control, the leases were forgotten by the DOE in spite of the lease, drilling, and production records filed with the federal government, a condemnation suit filed in civil court by the federal government, agreements between the State of New Mexico and the federal government, technical reports to the federal government on area oil and gas resources, and the existence of a producible gas well visible from the south access highway into the WIPP facility.

The loss of knowledge in just a short few years is cause for concern. There were no major changes in society, government, language, culture, or technology. Yet the WIPP project lost knowledge of this gas well and the active oil and gas leases. The current wording in the EPA Standards permits the assumption that active institutional control can completely deter inadvertent human intrusion for up to 100 years.

We believe that present assumptions about the effectiveness of active institutional control needs to be reconsidered because of this experience of the forgotten oil and gas leases and a forgotten gas well. First, the EPA should reexamine whether full credit for 100 years active institutional control is reasonable given the actual experience of inaccurate record keeping. Second, the DOE should examine the basis

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[14]Emphasis added.

for assuming full credit for 100 years control and consider using a lesser value to reflect the actual experience of the WIPP project. Third, the EPA Standards should require the implementing agency to publish specific plans on how the agency intends to maintain active institutional control. Fourth, even in the absence of such a requirement, the DOE should publish plans now that specify in detail how the Department intends to maintain full control of activities in the area of the repository for 100 years after decontamination and decommissioning and how that control will completely deter human intrusion.

At this time the DOE commitment is effectively limited to a statement in the First Modification to the C&C Agreement which states:

> the post-closure institutional control, shall be negotiated and resolved by the parties in the future, and at least one year prior to the start of the decontamination and decommissioning of WIPP (U.S. DOE, 1981).

In the Second Modification to the C&C Agreement, the DOE agreed to provide a plan by February 1, 1988, which would:

> contain an estimated schedule and a description of the process DOE will use to: identify needed active institutional controls, gather data for the implementation of such controls, develop and implement a monitoring plan for passive institutional controls, determine the barriers to be used, assess the selection of the WIPP site in view of the resources at the site, and review the recoverability of the waste for a reasonable period after disposal.

However, the DOE Plan:

> merely describes the steps that the DOE will undertake to implement compliance to one portion of the Standard [40 CFR 191 Subpart B]. For most of the Assurance Requirements, the information needed to specify detailed plans and activities for implementation is not yet available.... Other

information will not be available until close to the time that the Project has completed its mission and the WIPP is closed (U.S. DOE, 1987, p.1).

Furthermore, the remanded EPA Standards allow credit for the use of passive institutional controls to deter inadvertent human intrusion (U.S. EPA, 1985, p. 38080). However, excessive credit for passive controls, such as markers and public records, could reduce the estimated probability of inadvertent human intrusion in the performance assessment calculations and underestimate the actual risk. As discussed above, there is inaccurate information in key DOE documents which can be considered public records. There was the presence of a gas wellhead, visible from the south access highway and availability of lease and production records in the Roswell District Office of the U.S. BLM. Yet that marker and these public records were not effective in notifying the preparers of the DOE documentation of the gas and condensate production activity beneath the WIPP site and the existince of active leases with the WIPP Site Boundary.

6.0 PROPOSED CONGRESSIONAL LEGISLATION

The issue of allowing the existing oil and gas leases and a well to produce hydrocarbons from beneath the WIPP Site has been addressed by the U.S. Congress in the various bills for the WIPP land withdrawal.

The bill passed by the Senate (S. 1671) would:

- ♦ prohibit slant drilling from within or without the site
- ♦ require the Department of the Interior, in consultation with the Department of Energy, to determine the effects of the oil and gas leases on the activities at the WIPP and to recommend as to the advisability of trading or cancelling the leases.
- ♦ authorize funds to be appropriated to the Department of Energy for the cancellation of the leases.

The House Armed Services Committee Bill (H.R. 2637) is identical to S. 1671 except that it does not authorize funds to cancel the lease.

The bills passed by the House Committee on Interior and Insular Affairs (H.R. 2637) and the House Committee on Energy and Commerce (H.R. 2637) would both:

- ♦ prohibit slant drilling from outside the WIPP boundary,
- ♦ provide funds for the DOE to acquire the leases.

7.0 CONCLUSIONS

Several U.S. Department of Energy documents failed to record the existence of two active oil and gas leases and a producible gas well within the WIPP Site Boundary. In its performance assessment calculations, the WIPP project has assumed that active institutional control would deter human intrusion for 100 years after decommissioning. The EPA should reexamine whether full credit for 100 years active institutional control is reasonable given the actual experience of inaccurate record keeping. The DOE should also examine the basis for assuming full credit for 100 years control and consider using a lesser amount to reflect the actual experience of the WIPP Project. The EPA Standards should require the implementing agency to publish specific plans on how the agency intends to maintain active institutional control. Even in the absence of such a requirement, the DOE should publish plans now that specify in detail how the Department intends to maintain full control of activities in the area of the repository for 100 years after decontamination and decommissioning and describe how that control will completely deter human intrusion. Finally the DOE needs to describe in detail their passive institutional control system and describe how it will provide a deterrence to inadvertent human intrusion after 100 years.

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9.0 LIST OF ACRONYMS

BBL	Barrels
BLM	Bureau of Land Management
C&C	Consultation and Cooperation
CFR	Code of Federal Regulations
CH-TRU	Contact-Handled TRU (waste)
DOE	U.S. Department of Energy
EEG	Environmental Evaluation Group
EPA	U.S. Environmental Protection Agency
ERDA	Energy Research and Development Administration
FEIS	Final Environmental Impact Statement
FSAR	Final Safety Analysis Report
MCF	Thousand standard cubic feet
MOU	Memorandum of Understanding
NMEMD	New Mexico Energy and Minerals Department
RH-TRU	Remote-Handled TRU (waste)
SNL	Sandia National Laboratories
TRU	Transuranic
U.S.G.S	U.S. Geological Survey
WIPP	Waste Isolation Pilot Plant

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EEG-57

AN APPRAISAL OF THE 1992 PRELIMINARY PERFORMANCE ASSESSMENT FOR THE WASTE ISOLATION PILOT PLANT

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Environmental Evaluation Group
New Mexico

September 1994

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EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volumes I and II, December 1978.

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DOE/AL/58309-57

AN APPRAISAL OF THE 1992 PRELIMINARY PERFORMANCE ASSESSMENT FOR THE WASTE ISOLATION PILOT PLANT

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FOREWORD

This is the Environmental Evaluation Group's (EEG) appraisal of the 1992 performance assessment for the Waste Isolation Pilot Plant. Performance assessments have been performed by Sandia National Laboratories for the U. S. Department of Energy to predict the long-term safety of the Waste Isolation Pilot Plant. The 1992 Performance Assessment, entitled *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992,* is in five volumes:

vol. 1: Third Comparison with 40 CFR 191, Part B;

vol. 2: Technical Basis;

vol. 3: Model Parameters;

vol. 4: Uncertainty and Sensitivity Analysis for 40 CFR 191, Part B;

vol. 5: Uncertainty and Sensitivity Analysis for Gas and Brine Migration for Undisturbed Performance.

This current appraisal incorporates EEG's preliminary comments on volumes 1, 2, and 3 transmitted to the U. S. Department of Energy on September 13, 1993, and volumes 4 and 5 received October 27, 1993.

The purpose of the New Mexico Environmental Evaluation Group is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure the protection of the public health and safety and the environment. The WIPP Project, located in southeastern New Mexico, is being constructed as a repository for the disposal of transuranic (TRU) radioactive wastes generated by the national defense programs. The EEG was established in 1978 with funds provided by the U.S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and continued the original contract DE-AC04-79AL10752 through DOE contract DE-ACO4-89AL58309. The National Defense Authorization Act for Fiscal Year 1994, Public Law 103-160, continues the authorization.

EEG performs independent technical analyses of the suitability of the proposed site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria and the generator sites' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP. Another important function of EEG is the independent environmental monitoring of background radioactivity in air, water, and soil, both on-site and off-site.

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EXECUTIVE SUMMARY

The Environmental Evaluation Group (EEG) has reviewed the WIPP *1992 Performance Assessment*. The Sandia team should be commended for both the substance of this work, and a sound theoretical foundation. Progress has been made towards assessing WIPP's compliance with the U.S. Environmental Protection Agency's Standards for high-level and transuranic waste. Our comments on the *1992 Performance Assessment* are organized into Major Issues, and Detailed Comments. Specific recommendations on major issues follow.

1. Claimed Improvements in the *1992 Performance Assessment.*
   - R-1.1 Apply available fully coupled codes to make explicit the relationship between the complex processes of gas generation, brine flow and room closure.
   - R-1.2 Abandon further statistical manipulation of transmissivity fields in the Culebra in favor of additional field and laboratory work to better define multi-well flow and transport characteristics, including flow and tracer tests (sorbing and non-sorbing) at additional locations.
   - R-1.3 Abandon claiming credit for matrix diffusion and corrensite sorption until experimental data can substantiate the claim.
2. Displaying Uncertainty in Final Results
   - R-2 Show the full uncertainty band of CCDFs when comparison with the containment requirement (40 CFR 191) is made.
3. Use of Judgment in Performance Assessment
   - R-3.1 As experimental solubility values become available (e.g. Nitsche *et al.,* 1992; 1993), use them in performance assessment.
   - R-3.2 Use only demonstrable retardation coefficients in performance assessment.
   - R-3.3 Discard the subjective probabilities for human intrusion used in the *1992 Performance Assessment* and adopt the specific suggestion in Section 3.4.
4. Computer Code Documentation
   - R-4 Establish a workable system to provide EEG with relevant documentation, so that EEG has reasonable access to perform its work.
5. The Culebra as a Natural Barrier
   - R-5 Quantify the extent of matrix diffusion and sorption through accelerated experimentation.
6. Effects of Gas Generation
   - R-6 In future analysis, the deleterious effect of gas generation should be included.
7. Correlation Among Variables
   - R-7 The performance assessment should either give reasons why physical correlations have been ignored, or show results with correlations.

8. Natural Resources Near the WIPP
   - R-8 Performance assessment reports should accurately reflect the status of resource development near the WIPP site.
9. Oil and Gas Production Near the WIPP
   - R-9 The performance assessment effort should use the latest and verifiable data on oil and gas production near the WIPP, because the extent of oil and gas resources in this area is likely to be an important determinant of inadvertent human intrusion, and oil and gas production can potentially affect the hydrogeology at the WIPP site.
10. Gas Generation
    - R-10a The gas generation calculations should include
      - (a) methane generation,
      - (b) radiolytically generated hydrogen.
    - R-10b The relationships in the gas generation model should be validated before the gas generation model is incorporated into BRAGFLO.
11. Unanalyzed Scenarios
    - R-11.1 The criticality issue needs to be thoroughly evaluated before it can be concluded that its effects are negligible.
    - R-11.2 Subsidence effects need to be evaluated in much more detail and incorporated, in some manner, into the human intrusion scenarios.
    - R-11.3 Provide results of the abovementioned analyses, and include contaminated brine flow to the ground surface in future versions of human intrusion scenarios.
    - R-11.4 Perform a complete analysis of a brine-slurry release scenario. In addition, variants of the brine-slurry scenario in undisturbed performance and in the E2 scenario need to be better understood.
    - R-11.5 Performance Assessment should not assume perfect plugging of abandoned oil and gas wells near the WIPP. For the human intrusion borehole, the range of degraded permeabilities should span sand and gravel.
12. Analysis of Direct Discharge to the Ground Surface
    - R-12 Future performance assessments need to include erosion of waste by helical turbulent flow and the effect of sediment erosion. Also needed is analysis of other relevant scenarios, such as the E1E2 with brine slurry discharge to the surface.
13. Inventory
    - R-13.1 Include ^{135}Cs, ^{129}I and ^{99}Tc and other fission product nuclides as appropriate in future performance assessments.
    - R-13.2 Show the basis for inventories used.
14. Solubilities

R-14 In future performance assessments, limit the sampling range to the error bands in experimental data.

15. Transport Modeling of Volatile Organics

R-15 Two-phase transport of volatile organic compounds through gas-fractured interbeds should be analyzed in the future.

16. Corrensite Retardation in the Culebra

R-16 Abandon claiming credit for corrensite sorption as well as additional experiments with corrensite, unless the extent of corrensite or other clay minerals can be quantified along postulated flow paths.

17. Ideal Gas Assumption in VOC Migration

R-17 Unless there is experimental evidence that VOC vapors move as ideal gases and move with the low-molecular-weight gases generated by radiolysis, corrosion, or microbial action, movement of VOC vapors should not be modeled as ideal gas flow in showing compliance with 40 CFR 268.

I. INTRODUCTION

The Environmental Evaluation Group (EEG) has reviewed the WIPP *1992 Performance Assessment* (Sandia WIPP Performance Assessment Department, 1992). Although this performance assessment was released after the October 1992 passage of the WIPP Land Withdrawal Act (PL 102-579), the work preceded the Act. For individual and ground-water protection, calculations have been done for 1000 years post closure, whereas the U.S. Environmental Protection Agency's Standards (40 CFR 191) issued in 1993 require calculations for 10000 years.

This is the third iterative performance assessment of the Waste Isolation Pilot Plant (Sandia WIPP Performance Assessment Department, 1992; 1991; Bertram-Howery *et al.*, 1990). EEG believes the Sandia team should be commended for both the substance of this work, and a sound theoretical foundation for performance assessment. The *1992 Performance Assessment* continues to assimilate improved understanding of the geology and hydrogeology of the site, and evolving conceptual models of natural barriers. Progress has been made towards assessing WIPP's compliance with the U.S. Environmental Protection Agency's Standards (40 CFR 191).

The *1992 Performance Assessment* has addressed several items of major concern to EEG, outlined in our July 1992 review of the 1991 performance assessment (Neill *et al.*, 1992). In particular, we are pleased that some key results in this performance assessment, shown in Chapter 5 of volume 1, deal with sensitivity of the calculated complementary cumulative distribution functions (CCDF) to alternate conceptual models proposed by EEG—that flow in the Culebra be treated as single-porosity fracture-flow; with no sorption retardation unless substantiated by experimental data. We look forward to results of additional analysis using scenarios and assumptions that EEG has suggested in the past and hereinafter.

Our review is organized into Major Issues, and Detailed Comments.

II. MAJOR ISSUES

1. Claimed Improvements in the *1992 Performance Assessment*

The overall conclusions of the *1992 Performance Assessment* are stated in chapter 9 of volume 4. Several improvements over previous assessments are noted, and we discuss the claimed improvements below.

1.1 While the first major improvement noted is the coupling of repository creep closure modeling to gas generation and brine flow, the coupling is not entirely satisfactory. The geomechanical closure calculated by SANTOS is passed onto BRAGFLO although the two computer codes use different conceptual models, geometries, and time scale.

Recommendation 1.1. Apply available fully coupled codes to make explicit the relationship between the complex processes of gas generation, brine flow and creep closure.

1.2 The *1992 Performance Assessment* accounts for spatial variation of transmissivity in the Culebra using improved methods. Table 8.4-1 in volume 4 shows that variation in Culebra transmissivity fields accounted for a mere 6% of the variation in total integrated releases. The respective solubilities of Am, Np, Pu, Th and U accounted for more of the variation in release rates.

Recommendation 1.2 Abandon further statistical manipulation of transmissivity fields in the Culebra in favor of additional field and laboratory work to better define flow and transport characteristics, including flow and tracer tests (sorbing and non-sorbing) at additional locations.

1.3 The *1992 Performance Assessment* accounts for radionuclide transport in the Culebra "more accurately" [sic]. To be accurate implies the existence of an unique and correct standard which does not exist in this case. The *1992 Performance Assessment* considers three radionuclide retardation mechanisms in the Culebra: equilibrium sorption, matrix diffusion and clay sorption. For equilibrium sorption, the second modification of the Consultation and Cooperation Agreement between the Department of Energy (USDOE) and the State of New Mexico specifies that retardation coefficients shall be set to zero unless there are experimental data otherwise. The *1992 Performance Assessment* offers no experimental evidence for matrix diffusion. No clear evidence is given for the extent of corrensite in the calculated flow paths. Moreover, clay in fractures can act either as an additional sorption agent, or serve to block mass transfer between the fracture and the matrix. The *1992 Performance Assessment* has eliminated the latter role [vol. 2, p. 7-23, line 11]. This is double counting for a mechanism which may not exist. We deal with the role of corrensite in detail in 16.

Recommendation 1.3 Abandon claiming credit for matrix diffusion and corrensite sorption until experimental data can substantiate the claim.

The *1992 Performance Assessment*

> ...accounts for the effects of passive marker systems through time-varying drilling intensities within the Poisson model for calculating intrusion probabilities [vol. 4, p. 9-1].

What this means is that subjectively elicited probabilities of drilling intrusion that are orders of magnitude below the USEPA guidance (40 *CFR* 191, Appendix C) have been used. The EEG objects to the use of these probabilities as elicited. We deal with this topic in 3b below.

The *1992 Performance Assessment* states that the following improvements will be made in future performance assessments:

- modeling pressure fracturing of anhydrite interbeds,
- modeling three-dimensional flow in the Rustler, especially the effects of subsidence of potash mine excavations,
- incorporating plug degradation,
- modeling spalling in drilling intrusions,
- acquiring experimental data on actinide solubilities and retardation,
- determining the most appropriate conceptual model for radionuclide transport in the Culebra.

We have called for these improvements for several years, and welcome the commitment.

2. Displaying Uncertainty in Final Results

In previous performance assessments, the USDOE noted that the calculated CCDF's were at least an order of magnitude below the allowable limits in the USEPA Standards (Sandia WIPP Performance Assessment Department 1991). In the *1992 Performance Assessment*, for the case of total release from repository/shaft barrier only, and a [0, 30] sampled intrusion rate, the mean CCDF comes to within a factor of two or three of the USEPA containment requirement [vol. 4, Fig. 9-1, curve 1]. This suggests several vectors of CCDF lie in the zone of violation of the containment requirement. This mean CCDF is not as conservative as it may appear because subjectively elicited solubilities are incorporated. The non-conservative basis of curve 1 in Figure 9-1 is illustrated in Figure 1. Using BRAGFLO-calculated brine flow from the repository up to the Culebra (70 vectors for both the E2 and E1E2 scenarios), all actinide solubilities at 10^{-3}, 10^{-5} and 10^{-7} M, and the human intrusion rate sampled uniformly between 0 and 30 boreholes/km^2/10,000 years, the mean CCDFs are shown in Figure 1, along with curve 1 from Figure 9-1 (vol. 4). If the extremely low subjectively elicited solubilities are **not** used, then the mean CCDF for the case of engineered barriers alone may not meet the containment requirement. See also 14 below.

The EEG has also suggested to the USEPA that for comparison with the containment requirement, that the 90% curve be used to be conservative.

Recommendation 2. Show the full uncertainty band of CCDFs when comparison with the containment requirement (40 CFR 191) is made.

3. Use of Judgment in Performance Assessment

3.1 Beginning with the *1992 Performance Assessment*, "expert judgment" is used to estimate

a. solubilities of actinides;

b. retardation coefficients of radionuclides; and

c. probabilities of inadvertent intrusion.

Experimental programs are underway to measure solubility and retardation coefficients, for conditions relevant to the WIPP.

Recommendation 3.1. As experimental solubility values become available (e.g. Nitsche *et al.*, 1992; 1993), use them in performance assessment.

3.2 The second modification of the Cooperation and Consultation Agreement between the Department of Energy and the State of New Mexico specifies that retardation coefficients be set to zero unless experimental data shows otherwise. Results using zero and nonzero retardation coefficients appear in chapter 5 of volume 1.

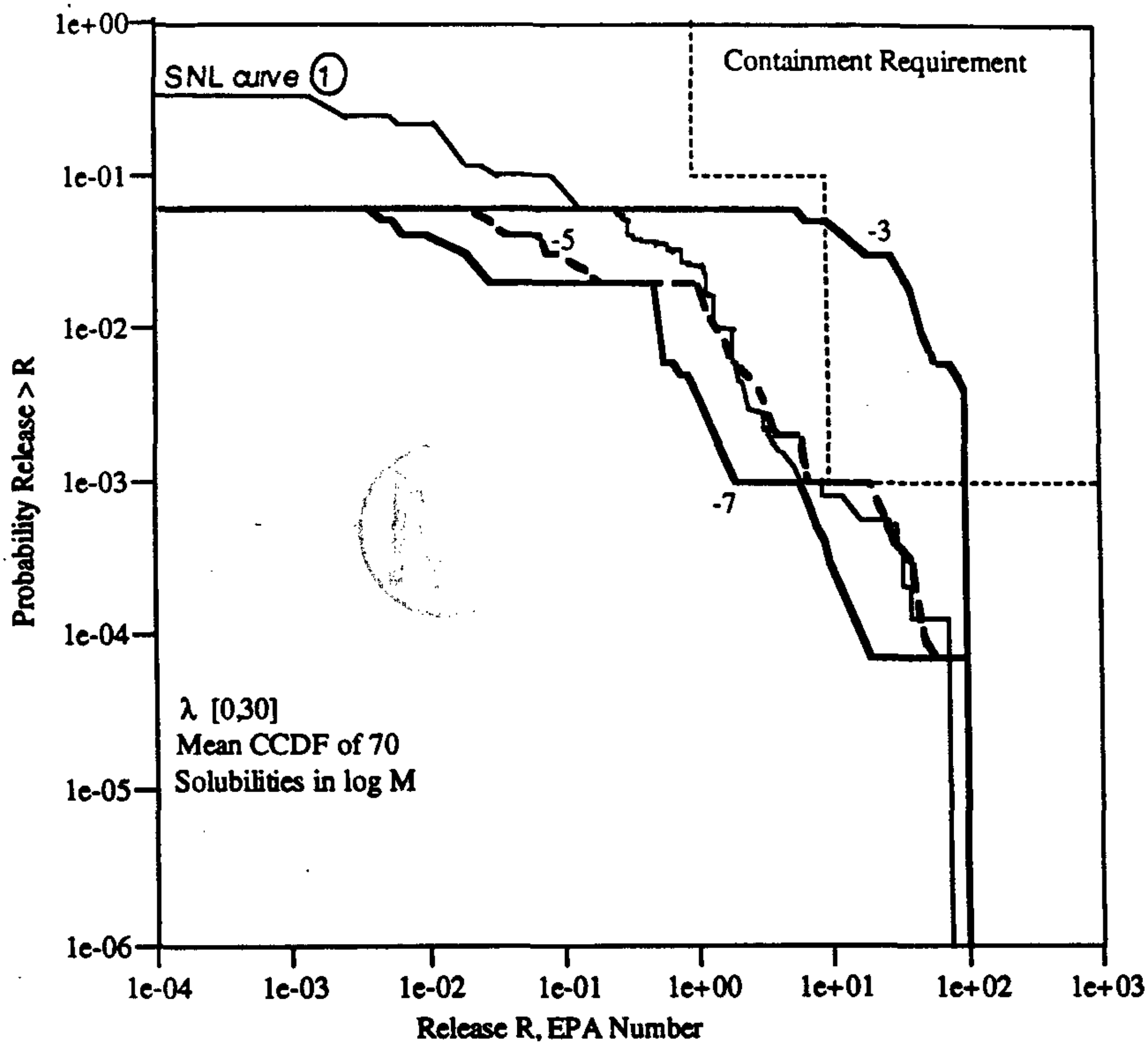

Figure 1. Comparison of mean CCDFs from the EEG scenario of direct ground discharge for all actinide solubilities set at 10^{-3}, 10^{-5}, and 10^{-7} M with Curve 1 from Figure 9-1 of SAND92-0700/4.

Recommendation 3.2. Use only experimental retardation coefficients.

3.3 EEG is concerned about the use of subjective probabilities in human intrusion analysis. While human judgment may be the only method of estimating these probabilities, we disagree with the procedure used in the *1992 Performance Assessment* to estimate human intrusion probabilities.

3.3.1 The disagreement between EEG and SNL centers around how the problem of subjective elicitation is to be formulated, whom to use as panelists and what information should be supplied to the panels. Elicitation should have been for the probability of future human intrusion by drilling for resources, the judges should have been people experienced in oil and gas and energy futures, and factual information should have been given to the judges during orientation.

Table I summaries the divergence.

Table I. Summary of Disagreement on Subjective Elicitation

Topic	SNL	EEG
Problem Formulation	Open	Focused
Required expertise	Knowledgeable in a subject	Knowledgeable in the focused subject
Briefing	Available information	Verified Information

SNL prefers to set no limits on the exercise, whereas EEG believes the problem must be well-defined. The divergence is clear from the SNL definition of an expert:

> An expert possesses exceptional knowledge about **a** subject [Hora to the Futures Panel, August 13, 1990 and to the Marker Panel, November 4, 1991].

EEG claims that the relevant definition should be

> An expert possesses exceptional knowledge about **the** subject.

3.3.2 The probabilities that have been elicited from panels for the purpose of estimating future intrusion intensity (Hora, von Winterfeldt and Trauth, 1991) are subjective probabilities. To call them "expert judgment" is to give them an aura of respectability they do not deserve. The methods for eliciting such probabilities come from statistics (Savage, 1954) and experimental psychology (Edwards, 1954). There are futurologists, such as Alvin Toffler or John Naisbitt, but the SNL Futures Panel was not composed of these people. While the elicitation of opinions is valid, the elicitation of expert opinion on the future is gratuitous. The WIPP Performance Assessment Department undertook an "extensive and impartial process" to select the panelists, but the process alone did not ensure the appropriateness of the chosen candidates. No attempt appears to have been made to establish the qualifications of the panel members as experts on the future. If the WIPP Performance Assessment Department had defined the problem properly, then it would be much easier to establish the expertise of the panelists.

3.3.3 The WIPP Performance Assessment Department invokes the interdisciplinary nature of an expert judgment panel as a reason to use such a panel. But "interdisciplinary" is not a synonym for "good" or "appropriate" any more than "single disciplinary" is a synonym for "bad" or "inappropriate." The advantage of multidisciplinary data interpretation over interpretation by an expert in a single discipline is not at all clear. For example, the marker panel (Rechard *et al.,* 1993; Table I) lists experts in materials science, architecture, linguistics, communications, etc. How is the judgment of a linguist on materials hardness and durability relevant? Either the linguist accepts the materials scientist's judgment, in which case the interpretation is not interdisciplinary, or the two differ in interpretation, in which case the materials scientist's interpretation is clearly the more valid and that judgment should not be diluted.

3.3.4 In the attempt to find general experts in lieu of futurologists, SNL might have empaneled representatives from diverse backgrounds, but failed to do so. The panels are not representative of modern United States, not representative of the modern world, and not representative of the historical continuity of the human race. While there were historians, sociologists and anthropologists, there was only one woman on the markers panels and none on the futures panels. There are no representatives of indigenous cultures of the southwestern United States.

In the USDOE response to the preliminary comments from the EEG, SNL stated

> The EEG should note, in fairness, that the range of organizations from which the experts were selected (Natural Resources Defense Council, universities, institutions,

etc.) provides rich diversity in political and environmental organizations.

This statement is counter to the claim that panelists were selected on the basis of their individual qualifications.

3.3.5 The elicitation process used was open-ended. While it is true that what will be mined over 10,000 years is unknown, let alone where to mine it, the problem is simpler for a specific area with known minerals. For example the Outer Continental Shelf Lands Act allows oil and gas drilling in the sea beyond the three-mile limit, but includes a clause for "other minerals." When the Outer Continental Shelf Lands Act was first passed in 1953, "other minerals" referred to sulfur. By the mid-1970s the focus of other minerals became construction aggregates around coastal cities, and in the early 1990s, manganese crusts. At a specific location, with geologic information, we know what can be mined now and in the future. The minerals to be mined will change only if society's needs change dramatically. If that had been borne in mind, the problem would have been much more circumscribed, and the results more realistic and reliable.

In the USDOE response to the preliminary comments from the EEG, SNL stated

> This comment [above] proposes that the experts be directed as to what potentially intrusive activities to study. We believe that this is inappropriate and would not stand up under peer review due to extensive direction by the analytic staff.

All elicitations have to be circumscribed, if only to ensure that the problem is within the expertise of the judges. Figure 2 is a reproduction of a SNL viewgraph shown to the panelists, demonstrating how the SNL analysts defined the problem and may have biased the panelists.

3.3.6 Results of the open-ended elicitation process used by Hora (Hora, von Winterfeldt and Trauth, 1991) appear to have been used selectively. If a more circumscribed process had been used, then the methods available to combat cognitive bias (Tversky and Kahneman, 1974) could have been used. Unfortunately, the results used in the *1992 Performance Assessment* strongly reflect the intervention of the analyst. The final result used a form

$$\lambda_t = d(1 - p_1 p_2) \tag{1}$$

where λ is the intrusion intensity, number of holes per time, d is the raw drilling intensity number of holes per time, p_1 is the probability of markers surviving, and p_2 is the probability

How Will the Expert Judgments Be Used in the WIPP Performance Assessment?

- The findings of the expert teams will provide modes of intrusion. These modes will be grouped into similar types of intrusions and modeled.
- The frequencies of intrusion given by the experts will be encoded as rates and used as input to simulation studies.
- The expert judgments will be both analyzed separately and combined into a base case. The analyses will preserve the findings of the individual teams.

Figure 2. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing SNL's formulation of the problem.

that surviving markers are effective in deterring drilling, all functions of time. The paradigm was not elicited from any one panel, but the result is a mixture of results from the panelists, who may not have understood how their inputs would be used.

The USDOE response to the preliminary comments from the EEG referred to a SNL viewgraph (Figure 3) entitled "Logic Tree for Deterrence by Markers Given Time, Society, Mode of Intrusion, and Marker Criteria." If one defines each of the branches in Figure 3 as p_1, p_2, p_3 and p_4, then deterrence is

$$p_1 p_2 p_3 p_4 \tag{2}$$

and eq. (1) does not obtain. Eq. (1) does NOT appear anywhere in the hundreds of viewgraphs shown to the Futures and Markers Panels.

An example of the intervention of the analyst occurred when elicited probabilities of the Washington A and B Teams and the Southwest Team for the period 0 to 100 years after closure were ignored. Professor Hora states [vol. 3, p. A-87]

> In contrast, the two Washington teams gave assessment beginning immediately after closure and thus did not allow for the period of continuing administrative control. **The performance assessment, however, assumes that the drilling rate is effectively nil during the first 100 years after closure** [emphasis supplied].

Clearly these three teams would not have agreed with SNL's use of their opinion in meeting the USEPA Standards (USEPA 1993).

3.3.7 A flagrant and important abuse of the analyst-assessor role occurred when the WIPP Performance Assessment Department assumed that there will be no intrusions after 2000 years (vol. 4, p. 2-19, lines 4 and 20). For consequence calculations, the *1992 Performance Assessment* considered only a single intrusion at 1000 years. This is clearly counter to the spirit and letter of analyzing human intrusions for the entire 10000-year regulatory period. If one assumes that the computer program by Professor Hora [vol. 3, p. A-92ff] captures the essence of the Futures and Markers Panels (which we do not) Appendix D of vol. 3 of the *1992 Performance Assessment* contains 12 pages of realizations of drilling intensity functions. The graphs in Appendix D show the intrusion rate and cumulative number of intrusions as a function of time to 10,000 years. Showing these graphs to 10,000 years is misleading because the WIPP Performance Assessment Department discarded the Panels'

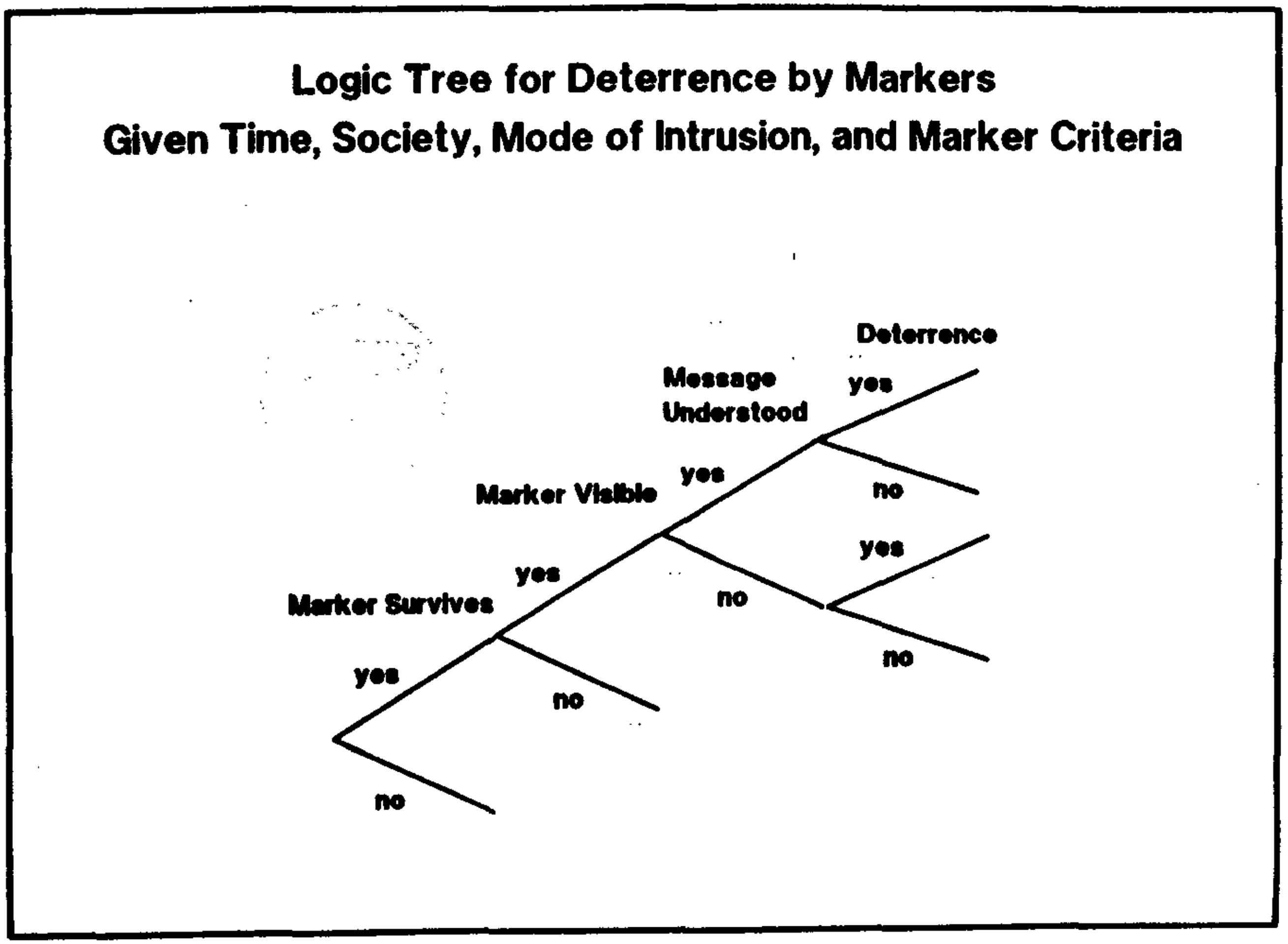

Figure 3. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing SNL's concept of the elicitation.

recommendations, assuming the intrusion rate to be zero after 2000 years.

3.3.8 The elicitation process is described in the Hora memo, vol. 3, pp. A-71 through A-99. The memo includes a FORTRAN program to sample among the panels, and produces realizations of intrusion intensities as functions of time for use in the 70 Monte Carlo runs. On page A-94, line 13, a three-dimensional array BOSTAB2 is undimensioned and undefined, thus the program cannot possibly work. In May 1993, EEG requested a working copy of this program, first from Professor Hora, then from WIPP Performance Assessment Department, and finally obtained a copy on December 31, 1993. This program creates Monte Carlo realizations of rates of human intrusion, drawn primarily from Prof. Hora's interpretation of the Futures and Markers Panels.

3.4 EEG suggests a simplified, focused and understandable alternative.

Figure 4 shows what EEG believes the exploratory drilling rate to be in any specific area, and illustrates the evolution of oil and gas drilling as a function of time.

Figure 4 shows a historical record of drilling in this area, a known rate, a holes per area per year, $a > 0$. The U.S. Environmental Protection Agency's guidance (40 *CFR* 141, Appendix C) of thirty boreholes per kilometer^2 over 10,000 years is such a rate.

Giving no credit for passive institutional control, because of recent experience (Silva 1994), we extend the historical drilling rate some time into the future, b years, $b > 0$. Geologic knowledge should be used for this extension. If there is current oil and gas drilling, then it is likely for the exploration and development to continue for some time. If there is no current drilling in this area, then there may not be any drilling until some new mineral is discovered in this area. This extension should extend beyond the period of active institutional control.

Given our present understanding of energy economics, we may postulate a decrease in oil and gas drilling, after a period of time, due to either exhaustion of the resource, or technological developments in some other fuel sources, or both. This decline can be represented by an exponential decay function, $y = y_0 \exp^{-ct}$. The rate of decrease is characterized by a single parameter, c.

For the long-term, there should be a rate of intrusion that is

(a) non-zero; and

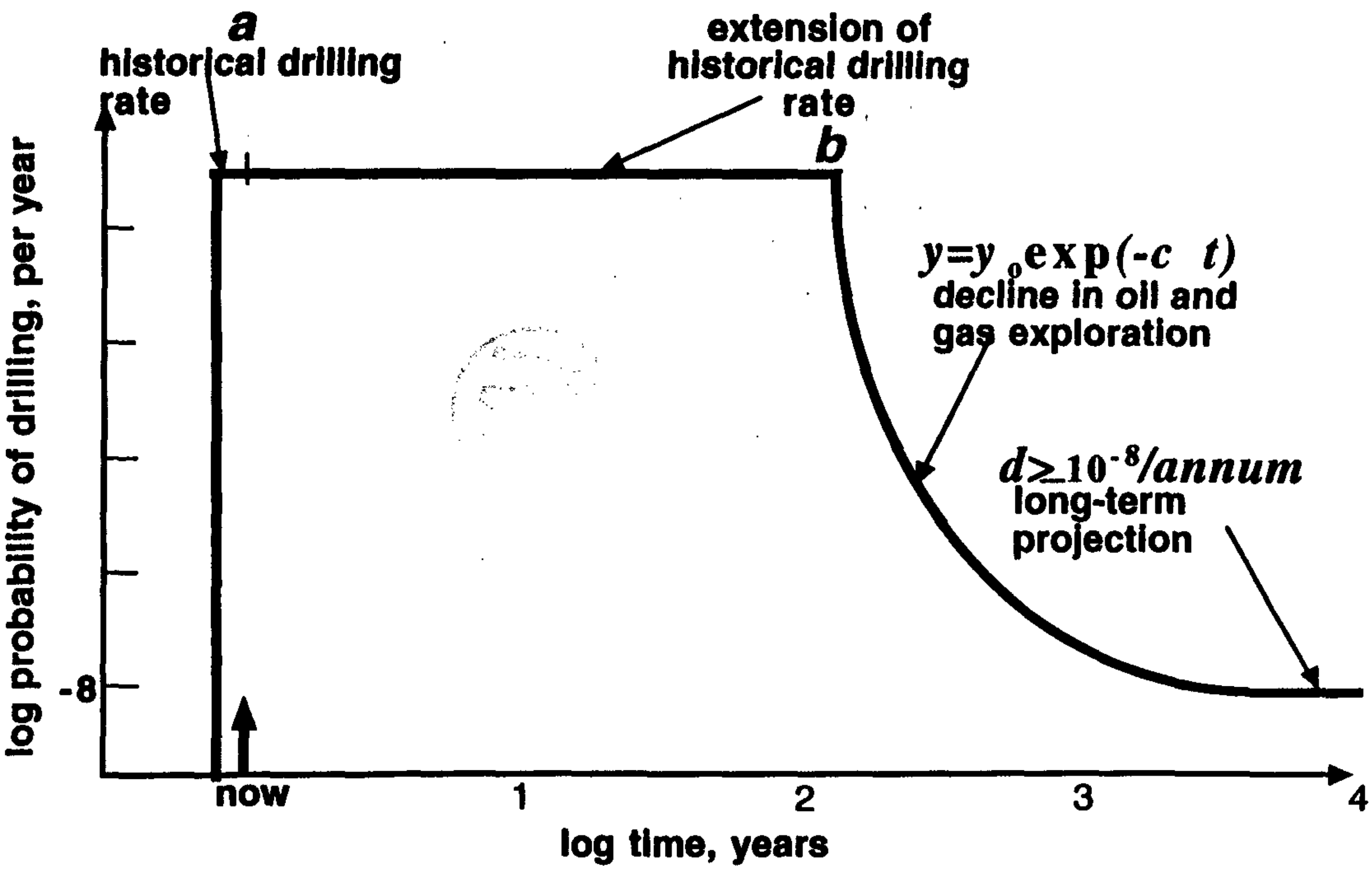

Figure 4. EEG's suggestion for a rate of human intrusion by drilling.

(b) above the USEPA threshold probability for events and scenarios to be considered, or 10^{-8} per year. Call the rate d holes per area per year, $d \geq 10^{-8}$ per year.

Because the waste will not have decayed to harmless levels after 10,000 years, and because the site may still contain resources, the intrusion rate should not be zero for any time within the regulatory period. To ignore such probabilities is to do an incomplete analysis.

The parameters a, b, c, and d completely specify the rate of inadvertent human intrusion in a readily understandable way. Subjective elicitation can now focus on these four parameters. The Department of Energy has experts in the history of oil and gas fields in the Energy Information Administration, and also experts in prospects for solar and other new energy sources.

In the USDOE response to EEG's preliminary comments, SNL stated four principles upon which to object to EEG's suggestion. In brief they are: Avoid Problem Definition, Avoid Bias, Put Rationale Before Results, and Do Elicitation Only on Physical Quantities.

A subjective elicitation requires problem definition. Figure 2 shows SNL's definition before the elicitations. Apparently SNL fitted the results of the elicitation into its preconceived structure. Although the EEG is not free of judgment, it focuses judgment on relevant parameters. SNL should heed its own advice about following USEPA's guidance and limit the elicitation to inadvertent drilling for minerals, without exploring irrelevant intrusion modes.

We will illustrate the bias that SNL imparted to the panelists on the topic of oil and gas resources at WIPP. In the orientations, SNL cited three different studies that there is no economically recoverable oil near WIPP, shown in Figures 5, 6, and 7, augmented by SNL's own conclusion that (Figure 8)

> Crude oil will not be the target for exploration unless the price is drastically higher than the present [1990].

Figure 9 shows the number of oil wells near the WIPP site in October 1993. Table II shows the recent history of wells in the same locations. Figure 9 and Table II belie the suggestion that there is no economically recoverable oil near WIPP. Actually, SNL did tell the panelists about oil and gas production near the WIPP. Figure 10 is a viewgraph shown to the panels by the speaker on cultural resources. That the panelists did not raise questions suggests that

TOTAL MINERAL AND ENERGY RESOURCES
(Brausch and others, 1982)

ESTIMATES ARE FOR ALL FOUR CONTROL ZONES

RESOURCE			
Caliche	185 MT	at surface	Not a reserve
Gypsum	1.3 BT	300-1,500 ft	Not a reserve
Salt	198 BT	500-4,000 ft	Not a reserve
Potash			
Sylvite	133.2 MT	1,600 ft	27.43 MT reserves
Langbeinite	351.0 MT	1,800 ft	48.46 MT reserves
Hydrocarbons			
Crude Oil	37.50 MB	4,000-20,000 ft	Not a reserve
Natural Gas	490 BCF	4,000-20,000 ft	44.62 BCF at 14K ft
Distillate	5.72 MB	4,000-20,000 ft	0.12 MB at 14K ft

Figure 5. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing the conclusion of a resource study.

ESTIMATES OF UNDISCOVERED HYDROCARBON RESOURCES--PROVINCE 092 (Mast and others, 1989)

RESOURCE	Mean	F95	F5
Crude Oil			
recoverable	0.02 BB	Negl.	0.05 BB
economically recoverable	0.02 BB	Negl.	0.05 BB
Natural Gas			
recoverable	0.24 TCF	0.05 TCF	0.67 TCF
economically recoverable	0.24 TCF	0.05 TCF	0.67 TCF
Natural-Gas Liquids			
recoverable	0.00	0.00	0.00
economically recoverable	0.00	0.00	0.00

Figure 6. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing the conclusion of a second resource study.

GEOLOGICAL CHARACTERIZATION REPORT
(Powers and others, 1978)

POTENTIAL RESOURCES EXAMINED

- **Caliche**
- **Gypsum**
- **Salt**
- **Uranium**
- **Sulfur**
- **Lithium**
- **Potash**
- **Hydrocarbons (crude oil, natural gas)**

CONCLUDED

Only potash and natural gas have potential as significant exploitable deposits.

Figure 7. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing the conclusion of a third resource study.

CONCLUSIONS ABOUT THE POTENTIAL FOR ECONOMICALLY IMPORTANT NATURAL RESOURCES AT THE WIPP

1. **Crude oil will not be the target for exploration unless the price is drastically higher than at present.**

2. **Natural gas in the Morrow Formation is the only hydrocarbon of potential economic importance in the area.**

3. **All currently recognized potash resources are confined to a zone above the waste-filled rooms and drifts.**

4. **Only the lowest grade of potash ore overlies part of two waste panels.**

5. **Other resources are present, but because of abundance and greater accessibility elsewhere, these resources at the WIPP are of no economic interest.**

Figure 8. Reproduction of a viewgraph shown to the Future and Markers Panels by SNL, showing SNL's conclusion on oil resources near the WIPP.

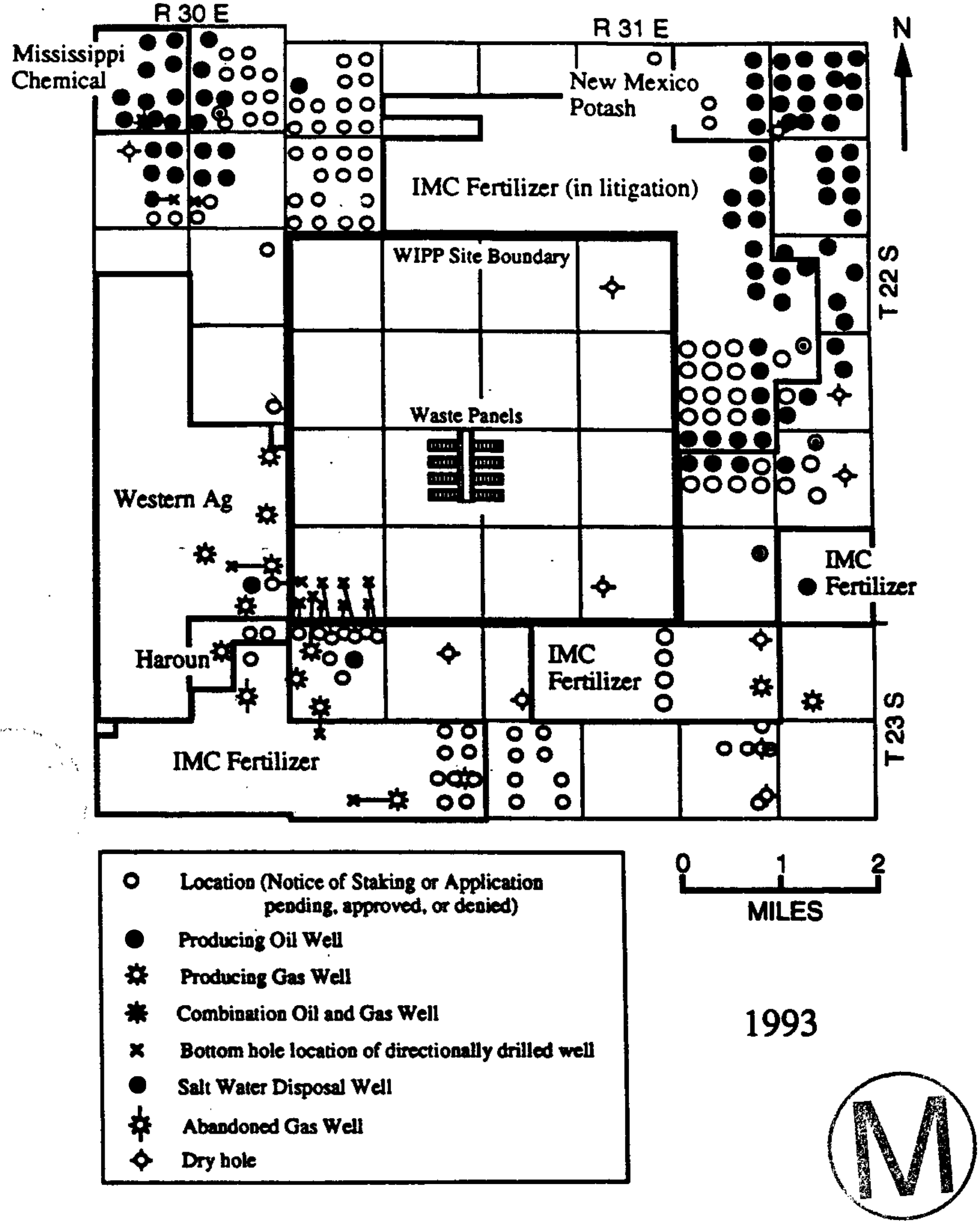

Figure 9. Oil and gas wells near the WIPP, October 1993.

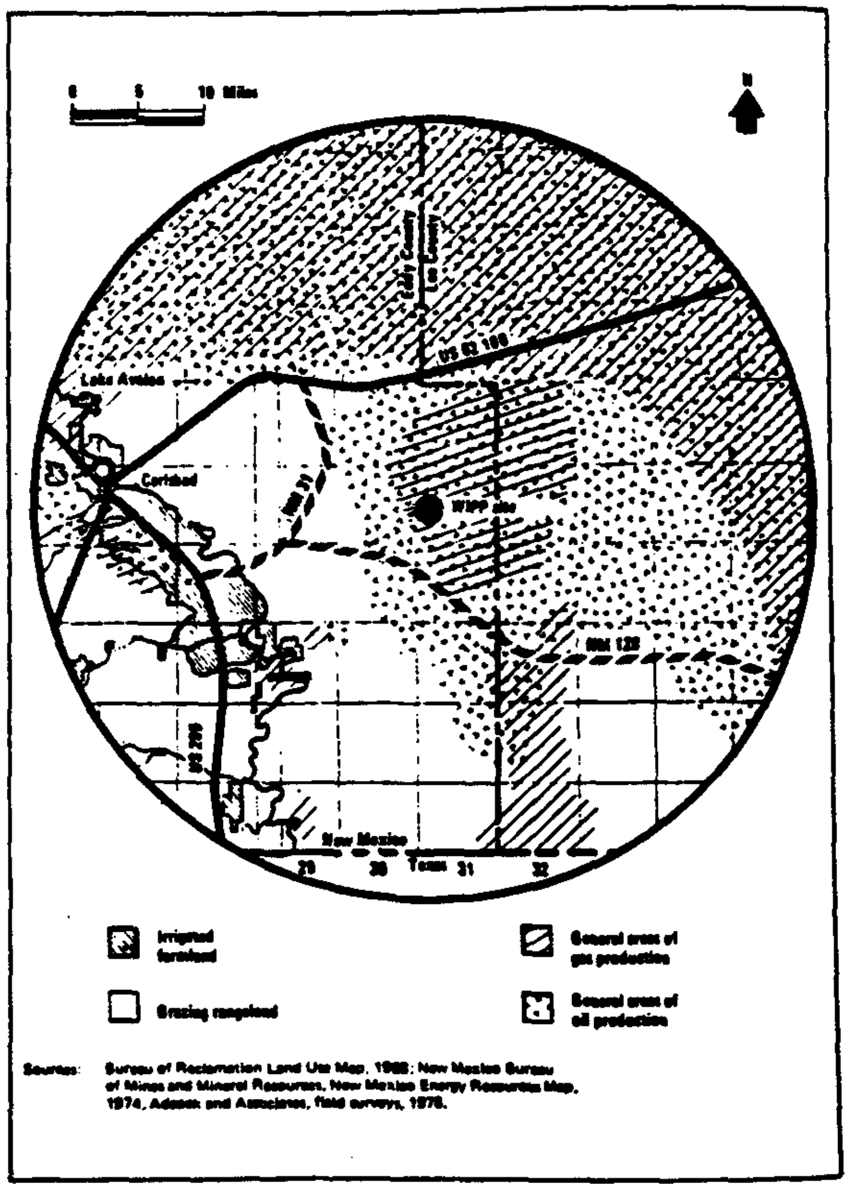

Figure 10. Reproduction of a map shown to the Future and Markers Panels by SNL, showing oil and gas resources near the WIPP.

Table II. Drilling rate for a 124 km^2 area immediately surrounding the WIPP*.

Year	Gas Wells	Oil Wells
1987	0	4
1988	0	2
1989	0	3
1990	0	13
1991	1	37
1992	1	23

*Source: Silva (1994)

SNL was successful in putting bias in the mind of the panelists.

To say that this elicitation puts rationale before numerical results belies the purpose of the effort. The emphasis on rationale may have prompted Prof. Hora to make arbitrary assumptions to obtain numerical results.

> The information for the drilling intensity from the Washington B team indicates that if minerals are extracted in the WIPP region, exploration will occur in the first 200 years or in the next 300 years, but not in both periods. **There does not seem to be adequate information from this team to model with dependence without making arbitrary assumptions**....[Sandia WIPP Performance Assessment Department 1992; vol. 3, p. A-87, emphasis supplied].

To object to elicitation for parameters without physical meaning is a surprise to us. One of the most frequently cited elicitation exercises is on perceived risk (Slovic, Fischhoff and Lichtenstein 1980), in which judges were asked to rank order risks from 40 technologies. The resulting ordinal ranking has no physical meaning. A greater surprise is that SNL would object to eliciting parameters on human intrusion when the entire Future and Markers Panels effort is attempting the same.

3.5 The Effect of Using Subjective Probabilities

We are now in a position to examine the consequences of using subjectively elicited probabilities. EEG has long maintained that a more reasonable conceptual model for intrusion would include a degrading plug, with the contaminated brine reaching the accessible environment at the ground surface, release Path b in Figure 11. Current oilfield practice in the Delaware Basin is to case the wells down to the top of the salt deposits, preventing contaminated brine from entering the water-bearing zones above the salt. Figure 12 shows CCDFs for the following conditions:

- Brine flow calculated for flow up the borehole, from the *1992 Performance Assessment*;
- Solubilities of all actinides set at 10^{-6} M;
- Intrusion probabilities from subjective elicitation, constant 30 boreholes/km^2/10000 years, or sampled between 0 and 30 boreholes/km^2/10000 years.

Figure 12 shows that if all actinide solubilities are 10^{-6} M, the mean CCDF of 70 would be very close to violating the containment requirement, unless subjective probabilities are used.

Recommendation 3.3. Discard the subjective probabilities for human intrusion used in the *1992 Performance Assessment* and adopt EEG's specific suggestion in Section 3.4.

4. Computer Code Documentation

4.1 The EEG has been concerned about the lack of documentation of computer codes used in the *1992 Performance Assessment*. Of the major codes used in the *1992 Performance Assessment*, as shown in vol. 1, Figure 4-4, only SANCHO and GENII-S have complete documentation. Ironically, no direct results from SANCHO and GENII are shown in the *1992 Performance Assessment*. In response to an EEG inquiry, USDOE provided the following schedule for complete documentation of computer codes shown in Figure 4-4 of vol. 1 (Arthur 1993):

Complete documentation is a requirement of Sandia's own software quality assurance program. For most of the codes shown in Figure 4-4, volume 1, only brief descriptions appear in the *1992 Performance Assessment*, and such descriptions do not present sufficient details for reviewers. As shown in our discussion of human intrusion, it is necessary to review the computational tools at that level of detail. In June 1994, EEG learned that complete documentation of all codes will be available by January 3, 1995.

Technical papers are no substitute for documentation, because technical papers and documentation have different purposes. Documentation is intended to communicate effectively

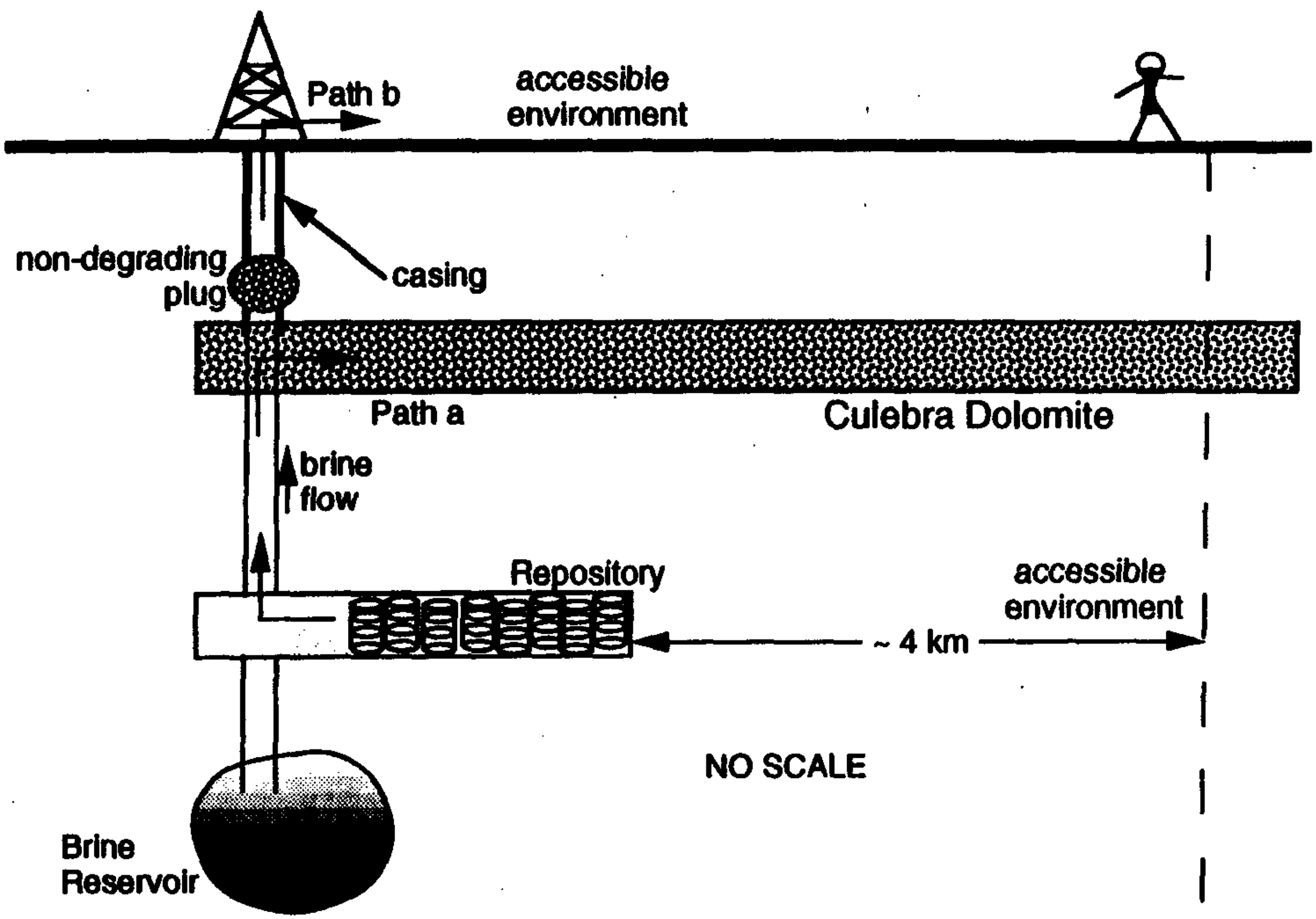

Figure 11. EEG scenario of direct discharge of contaminated brine to ground surface.

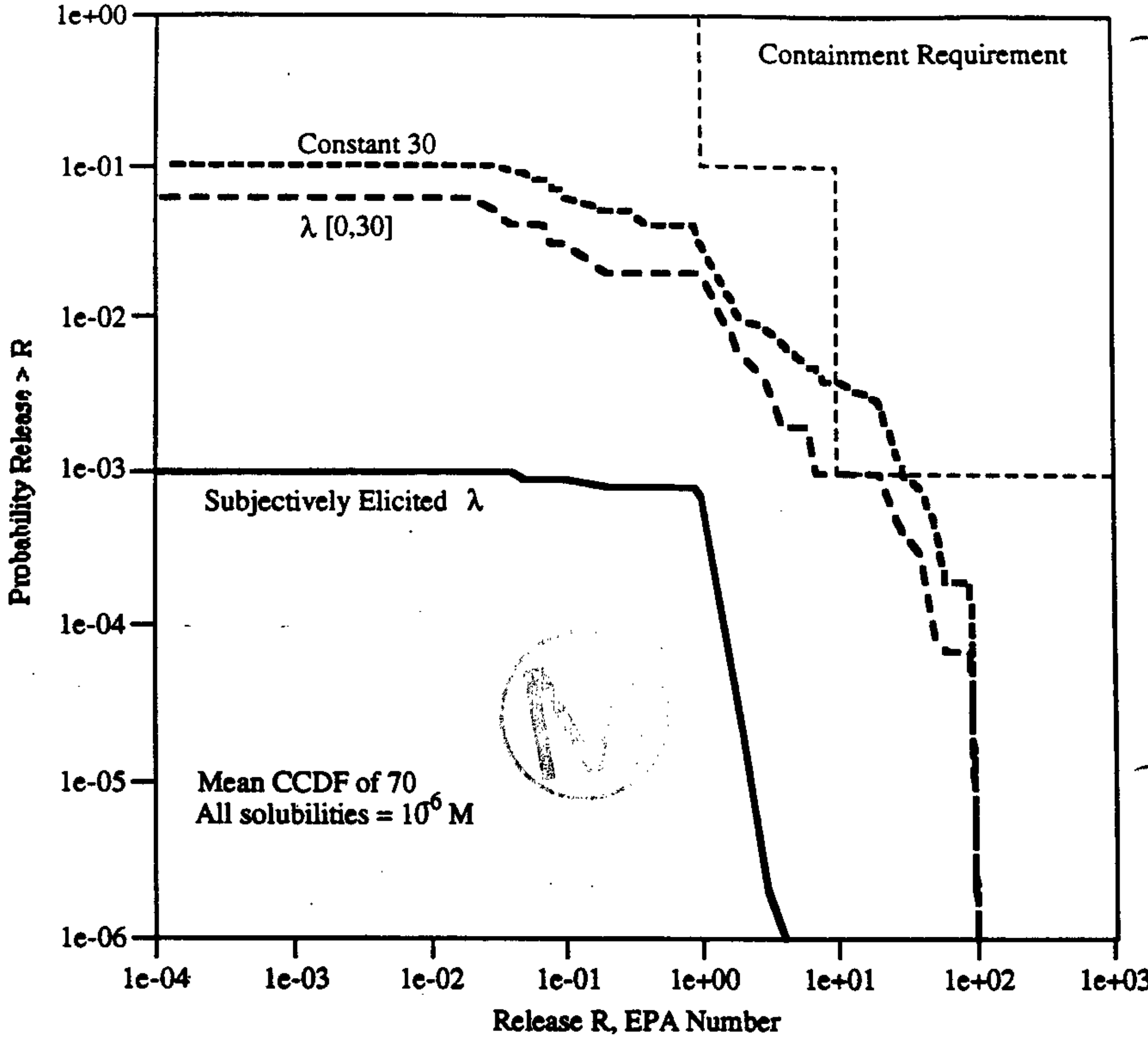

Figure 12. Mean CCDFs from the EEG scenario of direct ground discharge for all actinide solubilities set at 10^{-6} M, using 3 methods of deriving the rate of human intrusion, constant 30 boreholes/km²/10,000 years, uniform sampling between 0 and 30 boreholes/km² /10,000 years, and subjectively elicited probabilites.

Table III. Schedule for Performance Assessment Computer Code Documentation

Code	Aug 9, 93*	Jun 10, 94*
BRAGFLO	DEC 97	Sep 1, 94
CCDFPERM	DEC 94	Dec 1, 94
CUTTINGS	DEC 96	Oct 1, 94
GENII	DEC 96	Jul 1, 94
PANEL	DEC 97	Oct 1, 94
SECOFL2D	DEC 97	Jul 1, 94
SECOTP2D	DEC 97	Jul 1, 94

* Dates of USDOE promise by letter.

the details of the code design and operation so that people with different interests can be convinced of the usefulness and validity of the computer code. Documentation presents the code's logical structure, equations and methods, assumptions and limitations affecting the code's applicability, essential for an effective review.

The brief descriptions in the *1992 Performance Assessment* are inadequate as documentation for the following reasons.

4.2 According to SAND92-0700/3, p. 1-36, PANEL calculates

$$\dot{M}_i = -QC_{di} - \lambda_i M_i + \lambda_{i-1} M_{i-1} \tag{3}$$

where M_i is the mass of the ith nuclide in dissolved form,
Q is the brine flow rate, and
λ is the nuclide's decay constant.

The concentration is calculated

$$C_{di} = \frac{M_i}{\sum_j M_j} S_i, \tag{4}$$

where S_i is the concentration in saturated solution, and this equation calculates the isotopic fraction of solubility over j isotopes.

According to the February 22, 1994 USDOE presentation to USEPA, PANEL actually solves

$$C_{di}(t) = \begin{cases} S_i, & \text{if } I_i(t)/V(t) \geq S_i \\ I_i(t)/V(t), & \text{if } I_i(t)/V(t) < S_i \end{cases} \tag{4a}$$

where $I_i(t)$ is the inventory of element i at time t, and

$V(t)$ is the brine volume in the panel at t. Eq. (4a) incorporates a different concept than eq. (4). This kind of information is needed to fully understand the *1992 Performance Assessment.*

4.3 The transport code SECOTP2D offers the best examples of the need for full documentation. Roache (1993) does not explain how the following important items are handled.

- SECOTP2D is a two-dimensional code. How does it handle the conversion of the source term from zeroth dimension, the solubility, to two dimensions? The source is Qc, where Q is the well injection rate. How is Q determined? Is Qc spread uniformly vertically, uniformly laterally to infinity, making it an infinite line source?

- Two types of matrix diffusion are claimed for the Culebra, in the dolomite and in the clay layer. Is the classic Neretnieks equation for matrix diffusion used for calculating these effects?

- Over the years several codes have been used for the calculation of flow and transport in the Culebra, such as SWIFT, and STAFF2D. Are there benchmarking results?

c. To further demonstrate the inadequacies of technical papers as documentation, the following comments are offered on the Roache paper.

- The paper touts the TVD algorithm but failed to define TVD.

- The algorithm begins with a variable transformation. A key variable J in the transformation is not defined.

- No results are given for verification of the dual porosity option.

Finally, it is often claimed that because a computer code is undergoing continuous development, its documentation cannot be released. This is simply not the case. A calculation done with a computer code is made with a specific version. Subsequent calculations may use the next version. However, for the purpose of documentation, a calculation and the tool (computer code) are inextricably intertwined. For a meaningful review, the code version used and the extant documentation must be made available.

Recommendation 4. Establish a workable system to provide EEG with relevant documentation, so that EEG has reasonable access to perform its work.

5. The Culebra as a Natural Barrier

The *1992 Performance Assessment* elucidates the role of the Culebra as an isolation barrier. Figure 5-6 of vol. 1, claims that WIPP can meet the USEPA's containment requirement (USEPA 1993) without the Culebra as an isolation barrier. That is, if the USEPA containment limit is applied where brine is diverted into the Culebra, WIPP would still be in compliance. With matrix diffusion and sorption, the Culebra would contribute additional isolation.

Recommendation 5. Quantify the extent of matrix diffusion and sorption through accelerated experimentation.

6. Effects of Gas Generation

While the USDOE has analyzed the beneficial effects of gas generation, the EEG continues to be concerned that the deleterious effect of gas generation, particularly the opening of new discharge pathways, has not been analyzed.

Recommendation 6. In future analysis, the deleterious effect of gas generation should be included.

7. Correlation Among Variables

No correlation has been assumed between sampled variables using Latin Hypercube sampling. In real life, many of the variables are related. For example, there is an inverse correlation between VWOOD, the fraction of waste that is wood, and VMETAL, the fraction of waste that is metal.

Recommendation 7. The performance assessment should either give reasons why physical correlations have been ignored, or show results with correlations.

8. Natural Resources Near the WIPP

The *1992 Performance Assessment* is unclear on the extent of natural resources extraction near the WIPP site, and particularly the possible impact of human intrusion. In vol. 1, Section 2.2 an incorrect statement is made:

> About 56 productive oil and gas wells are located within a radius of 16 km (10 mi) from the WIPP; the wells generally tap Pennsylvanian strata, about 4,200 m (14,000 ft) deep (p.2-4).

This statement is incorrect because there are many more oil and gas wells. The estimate of 56 producing oil and gas wells is based on 1986 data. EEG showed (Silva and Channell, 1992) that some of the 1986 data were incorrect. Furthermore, if the USDOE wishes to take credit for current and accurate public records, then USDOE should have used current information and not obsolete information. Given the importance of drilling for oil and gas on the performance assessment calculations, future iterations should use a more accurate representation of the drilling activity near the WIPP facility. One method of so doing is to show up-to-date and accurate locations of oil and gas wells on a map. Most of the oil and gas wells drilled in the last four years do not tap the deeper Pennsylvanian Formation, but produce from various shallow (1200 to 2400 m) zones within the Delaware Mountain Group Formation.

The statement in the *1992 Performance Assessment* continues:

> The hydrocarbon well closest to the land withdrawal boundary is about 3 km (2 mi) to the south-southwest of the waste panels, and has produced natural gas since 1982 (Silva and Channell, 1992). The surface location of the well is outside the land-withdrawal boundary, but the borehole is slanted to withdraw gas from rocks below the WIPP horizon within the boundary. Except for this well, resource extraction is not allowed within the proposed land-withdrawal boundary (vol. 1, p.2-4).

The 1992 WIPP Land Withdrawal Act recognizes the validity of two specific oil and gas leases in section 31, within the WIPP Site Boundary. The owner of one of these leases has recently filed an application for permits to drill eight directionally drilled oil wells that would be completed within the WIPP Site Boundary but at depths greater than 2,000 m (6,000 ft) to produce oil from within the WIPP Site Boundary. While there was no restriction on drilling within the WIPP Site Boundary contained in the Consultation and Cooperation Agreement between the USDOE and the State of New Mexico, the second modification restricted slant drilling.

The following statement appears in vol. 1, section 3.3.3 (p. 3-10):

> ... the DOE agreed to prohibit further subsurface mining, drilling, slant drilling under the withdrawal area, or resource exploration unrelated to the WIPP Project from the land surface to 6,000 feet (1,830 m) in the subsurface for the 16 square miles under DOE control.

The second modification to the Cooperation & Consultation Agreement has been incorrectly interpreted. The Agreement is not limited to the first 6,000 feet (2,000 m) of depth. The Agreement states "The DOE will not permit subsurface mining, drilling, . . ."

Recommendation 8. Performance assessment reports should accurately reflect the status of resource development near the WIPP site.

9. Oil and Gas Production Near the WIPP

In vol. 1, section 5.3.5, the following statement is made regarding the Assurance Requirement (40 *CFR* 191.14) for natural resources:

> Future societies might attempt to exploit natural resources near the WIPP and thereby create the potential for a release of radionuclides into the accessible environment. These issues have been evaluated in several reports (USDOE, 1980, 1981b; USDOE and State of New Mexico, 1981, as modified; Brausch et al., 1982; Weart, 1983; USDOE, 1990a). A recent report summarizes these earlier reports (USDOE, 1991a), and the DOE will continue to document information about natural resources that was used in making the decision to proceed with the WIPP Project (I, p. 5-20).

A detailed reading of the references cited does not appear to support the text.

Silva and Channell (1992) showed that the *USDOE Implementation of the Resource Disincentive Plan in 40 CFR 191.14(e) at the Waste Isolation Pilot Plant* (USDOE, 1991a) is inconsistent in reporting the number of oil and gas leases within the WIPP Site Boundary and the production status of those leases.

The No-Migration Variance Petition (USDOE, 1990a) states:

> Oil and gas exploration has been and continues to occur around the WIPP site. The target horizons for this type of exploration are below the Castile. Oil and

gas exploratory drilling requires permits from the state, and it is unlikely that prospective future well drillers would not be informed about the existence of WIPP. As an additional protective measure, the DOE has purchased all oil and gas leases in the area of the WIPP site to prevent any exploration now and in the future (Section 6.3.2).

The last sentence above is incorrect. Weart (1983), Brausch *et al.* (1982) and Weart *et al.* (1991) failed to recognize the potential crude oil resources for this area. Crude oil is now being produced from the former control zone IV.

Recommendation 9. The performance assessment effort should use the latest and verifiable data on oil and gas production near the WIPP, because the extent of oil and gas resources in this area is likely to be an important determinant of inadvertent human intrusion, and oil and gas production can potentially affect the hydrogeology at and near the WIPP repository.

10. Gas Generation

10.1 BRAGFLO is one of the most important codes in the WIPP performance assessment. A brief summary of BRAGFLO is given in vol. 3, section 1.4.1. Equations 1.4.1-1 and 1.4.1-2 use rate constants and mole fractions (called "stoichiometry factors") to calculate the rate of gas generation. These factors, although not specifically referenced in this section, are referred to in the discussion on pp. 3-44 to 3-45. Median corrosion gas production rates are given as 6.3×10^{-9} moles H_2/m^2-s for inundated steel and 0.1 [-] for humid steel under aerobic conditions, and 0.5 [-] for inundated steel under anoxic conditions. An analogous set of rates are given for microbial gas generation, with units of moles of gas/kg cellulosics given only for inundated conditions. It should be noted that in the development of the equations on pp. 1-24 to 1-26, the rate constants and stoichiometric factors are given with acceptable units. Why aren't the dimensions the same for all these rates, if they are used for the same variable in BRAGFLO? How can a corrosion rate have the units of moles per unit area of exposed substrate in one case and no units in another? How can a dimensionless variable be used interchangeably with a variable with units?

10.2 A more serious question arises about the use of these results. The gas generation rates and stoichiometry factors cited are those calculated by a model and are thus th result of model inputs rather than experimental data. Table IV summarizes the results of the SNL scientific investigations into gas generation, and distinguishes model calculations from experimental measurements. Model results are only as good as model inputs. Some model inputs include unsupported assumptions, such as the failure to include methane. Experimental data exist - see Table IV- but have not been used in modeling. Moreover, as the Table IV shows, models give different gas generation rates when given different inputs and assumptions, and the median of such calculated rates has little validity.

Although the assumption that radiolysis will contribute only negligible hydrogen formation at WIPP appears to have found general acceptance, the data developed by Kosiewicz (1981) show this need not be the case. In fact, the gas generation problem was first noticed in stored drums of TRU waste in which hydrogen had been generated by radiolysis. Moreover, the microbial generation model does not recognize the dependence of the microbial gas generation rate on the initial and continued presence and availability of microbes. Radiolysis can be the principal source of gas from Pu-238 heat source waste.

Recommendation 10a. The gas generation calculations should include

(a) methane generation,

(b) radiolytically generated hydrogen.

Recommendation 10b. The relationships in the gas generation model should be validated before the gas generation model is incorporated into BRAGFLO.

11. Unanalyzed Scenarios

As Helton (1993) so aptly pointed out, the formulation of scenarios is an integral part of performance assessment. There are a number of assumptions used in the human intrusion scenarios to date that EEG believes need to be reconsidered and either changed or better justified. These have all been related to USDOE in previous written comments and discussed in meetings. For completeness of the record, all significant items are mentioned below.

Some scenarios not currently analyzed in performance assessment need to be considered. See especially the lower half of Figure 4-1 (vol. 2) in the *1992 Performance Assessment.*

Table IV. Gas Generation as Modeled and Tested

	Source	Gas From	Result moles/drum/a	Gas from 1050 drums in an alcove (moles/a)	Pressure P_0 (atm)	$P = nRT/V$ per annum (atm)	Gas Pressure at end of year one $P_1 = P_0 + P$
H_2	Brush *et al.*, (1993)	anoxic corrosion	2.0	2,100	1.0	0.0568	1.06
Total gas	Brush *et al.*, (1993)	microbio. deg.	1.0	1,050	1.0	0.0284	1.03
H_2 - 3 mos.	Brush *et al.*, (1993)	anoxic corrosion	1.97×10^{-6}	0.0	1.0	0.0	1.0
H_2 - 6 mos.	Brush *et al.*, (1993)	anoxic corrosion	1.72×10^{-6}	0.0	1.0	0.0	1.0
H_2 - 12 mos.	Brush *et al.*, (1993)	anoxic corrosion	1.23×10^{-6}	0.0	1.0	0.0	1.0
H_2 - 24 mos.	Brush *et al.*, (1993)	anoxic corrosion	9.9×10^{-7}	0.0	1.0	0.0	1.0
Total gas	Brush *et al.*, (1993)	aerobic microbes	0.5	525	1.0	0.0142	1.01
Total gas	Brush *et al.*, (1993)	anaerobic microbes	1.21	1271	1.0	0.0343	1.03
Total gas	Bixler (1989)		0.3	315	1.0	0.0085	1.01
Total gas	Molecke & Lappin (1990)	Calculated	0.05	52.5	1.0	0.0014	1.00
			0.5	525	1.0	0.06	1.06
			5.0	5,250	1.0	0.59	1.59
Total gas	Kosiewicz (1980)	radiolysis	0.3	315	1.0	0.04	1.04
			0.11	770	1.0	0.01	1.01
			0.016	115	1.0	0.0031	1.00

11.1 A Scenario Involving Nuclear Criticality

In 1984 S. Cohen, an EEG consultant, analyzed potential nuclear criticality in the Culebra Aquifer and concluded that this needed to be thoroughly evaluated by USDOE.

The potential nuclear criticality could occur if:

(1) sufficient quantities of a fissile radionuclide such as Pu-239 or U-233 are adsorbed on a large enough volume of aquifer matrix;

(2) there is sufficient hydrogen or other moderator available in the brine or matrix;

(3) the matrix or brine does not contain sufficient quantities of stable nuclides that can "poison" the reaction.

EEG's analysis indicated that, with the expected elemental composition of the brine and the Culebra aquifer matrix, nuclear criticality could occur in a block 7 m high x 0.5 m wide x 1 m long if the product of the distribution coefficient (K_d, mL/g) and plutonium solubility (S, moles/L) was greater than about 5.6×10^{-5} moles/g.

The possibility of a K_dS product of $> 5.6 \times 10^{-5}$ moles/g is credible. For example, the probability distributions for K_d and solubility from volume 3 of SAND 91-0893 (pages 2-104 and 3-64) have approximate probabilities of occurrence given in Table V.

Table V. Probabilities of Criticality From Sorbed Fissionable Species

Species	Probability $K_dS > 5.6 \times 10^{-5}$ moles/g
Pu^{5+}	0.025
Pu^{4+}	5×10^{-6}
U^{6+}	0.25
U^{4+}	0.11

In response to EEG's comments on the ***1990 Preliminary Comparison***, SNL responded that

> A performance assessment task has been initiated to examine the potential for nuclear criticality from post closure processes.

Two pages were devoted to discussing nuclear criticality in the ***1991 Preliminary Comparison*** (vol. 1, page 4-52). SNL recognized that sorption can also occur in the backfill and at certain components of the seal system as well as in the Culebra Aquifer. The very remote possibility of a high-yield nuclear explosion is also discussed. We find no analysis of nuclear criticality in the *1992 Performance Assessment*. No schedule has been given for performing additional criticality evaluations.

EEG also believes the possibility of a high-yield nuclear explosion is very remote. One concern is with an instantaneous criticality excursion in which there is a brief burst of energy, neutrons, and gamma radiation. Perhaps more likely in this situation, where fissile material is being added very slowly in a solution, is a delayed criticality where the system does not become promptly critical. Such a system would behave much like a nuclear reactor and could produce fissions, perhaps in bursts, for extended periods of time. This phenomenon has occurred in several process criticality accidents in the U.S., e.g. at Hanford in 1962 one system boiled for 37 hours (Thomas 1978). The Oklo "natural reactor" in Gabon is believed to have operated in a similar fashion.

It is not obvious that a criticality accident would have a significant effect on a repository waste disposal system, even if a criticality accident occurs. Considerable heat would be produced, some brine would be vaporized, and minor amounts of fission products would be formed. It takes 8×10^{20} fissions to produce one curie of Cs-137. Also, the relatively high K_d values that would be necessary to make criticality possible are otherwise a benefit because they retard radionuclide transport.

Recommendation 11.1 The criticality issue needs to be thoroughly evaluated before it can be concluded that its effects are negligible.

11.2 Subsidence

Subsidence could occur in the area overlying the WIPP some time after repository decommissioning. Subsidence can also occur from nearby potash mining. The *1992 Performance Assessment* identifies an event **TS** which is subsidence from mining of potash, but **TS** has not been analyzed.

SNL discussed the potential for subsidence in the *1990 Preliminary Comparison*. They recognized that "subsidence could in turn conceivably affect the disposal system in three ways: by increasing hydraulic conductivity of the Salado Formation, by creating fractures through the Salado Formation, or by disturbing the surface drainage and groundwater flow in overlying units." The incorporation of the effects of subsidence into the performance assessment is still planned. In the *1991 Preliminary Comparison* SNL presented an analysis of possible caving and subsidence over the waste storage areas from room closure.

SNL's analysis of subsidence concluded that no problems were likely to result for the waste disposal system. The maximum subsidence at the surface was calculated to be only 0.13 meter over an area of 1.54×10^6 m^2. The affected area at the surface was determined by assuming an angle of draw of 35°. It was further stated that if the Rustler-Salado contact residuum had (historically) lost about 400 meters due to dissolution without disrupting the confined water-producing Culebra and Magenta dolomite aquifers, subsidence should not be a problem.

No evaluation has yet been made of subsidence from potash mining. There are significant potash resources within the WIPP site boundary. However, the USEPA Standards requires analysis of only resource exploration drilling on site. However, it is appropriate to consider subsidence effects from potash mining offsite.

Offsite potash mining is highly probable. There are reserves on all sides of the site. Sections to the south of the site are already leased, sections to the north and east are under litigation for potash leases, and the entire western border is leased or expected to be leased. Because the areas leased or expected to be leased to the north and south include the flow path of the Culebra Aquifer across the waste storage area, a potential exists for both upstream and downstream effects on the Culebra. Catchment areas could be formed to the north from subsidence and shafts could provide access to the Culebra for recharge. To the south there could be increased transmissivity from subsidence effects. With the assumption that mining occurs up to the site boundary and the angle of draw is 35° the extent of influence at the Culebra Aquifer horizon would be about 200 meters onto the site. Another possibility is that mining activity near the South Boundary could result in vertical drainage (via shafts or boreholes) from the Culebra Aquifer into underlying mined out areas. This could significantly increase the hydraulic gradient between the injection point of contaminated brine and the site boundary.

Recommendation 11.2 Subsidence effects need to be evaluated in much more detail and incorporated, in some manner, into the human intrusion scenarios. Some scenarios currently analyzed in performance assessment should be re-formulated.

11.3 Contaminated Brine Flows to the Surface

The E1, E2 and E1E2 scenarios assume that the only material reaching the surface is drill-bit cuttings and some "cavings" from the annulus about the drill bit in the waste storage room. Brine flowing to the surface from an encounter with a pressurized Castile brine reservoir was not assumed. EEG believes that brine flows to the surface should be assumed and that the consequences could be significant for the E1E2 scenario.

Sandia and USDOE have described typical drilling practices elsewhere (Appendix C of SAND 89-0462 and in USDOE February 7, 1990 response to EEG's comments on the Draft Supplement EIS). These responses explain how it is possible to have very little flow to the surface by closing in blow-out preventers within a few minutes, determining the pressure, and then preparing drilling mud of sufficient density to stop the flow before resuming drilling. For example, USDOE stated in a February 7, 1990 letter that only 51 barrels flowed at WIPP-12 before shut in by a blow-out preventer.

The February 7, 1990 USDOE letter went on to say that at WIPP-12 an additional 49,224 barrels flowed during deepening, geophysical logging, and further deepening before it was finally shut in for subsequent hydrologic testing. This additional flow was described as resulting from a "conscious decision."

Virtually every time a pressurized Castile brine reservoir was encountered in the vicinity of WIPP, "conscious decisions" were made to allow varying amounts of brine to flow to the surface. Table VI, extracted from two WIPP reports (USDOE 1981a; 1983), describes the remedial measures taken. Although the available data are not as detailed or as quantitative as one would like, it is clear that drilling practice through 1982 included release of brine at the surface whenever pressurized Castile brine reservoirs were encountered. There has been considerable drilling activity around the WIPP Site in the last few years, and brine has been reported in seven wells. In two of these wells brine was reported to have flowed for three hours before being stopped, and in another, brine flowed for at least 12 hours. Records did not indicate how long the remaining wells flowed. It appears that, in most cases, significant amounts of brine flow to the surface before being controlled and performance assessment scenarios should assume that any intruding driller will face similar situations. Also, minor flows may not always be recorded in drilling logs, or perhaps even recognized. Furthermore, it is likely that not all Castile brine encounters have been reported.

Drilling mud return flow would be expected to increase the effective radius of the borehole and bring waste to the surface in suspension and in solution. In the E1E2 scenario brine discharged to the ground surface is expected to be saturated in actinides.

In a November 3, 1992 response to EEG's concern about contaminated brine flow to the surface, SNL stated:

> We will repeat these subsidiary simulations using BRAGFLO for both release during drilling and long-term releases through abandoned boreholes. As you suggested at our previous meeting, there are four cases: (1) E1 or E2 during drilling, (2) E1 while Castile brine is allowed to flow, (3) E1 followed by E2 after Castile brine has been allowed to flow into the panel and then is available to flow through E2 during drilling, and (4) E1E2 after both have been abandoned.

EEG, in a November 9, 1992, letter to SNL, agreed these 4 cases were the appropriate ones to consider and urged SNL to perform the analysis.

Recommendation 11.3 Provide results of the abovementioned analyses, and include contaminated brine flow to the ground surface in future versions of human intrusion scenarios.

11.4 A Brine-Slurry Release Scenario

A brine-slurry release scenario should be analyzed. A *brine slurry might result from brine* inflow from the Salado salt or intrusion into a Castile brine reservoir. Such a brine slurry could be under greater than hydrostatic pressure and thus have a force capable of driving some or all of the slurry to the ground surface. The potential quantities of ejected brine might be less than that from the E1 scenario but the consequences could still be significant. The *possible implications of a brine-slurry filled room were first raised* by SNL in 1987 and were also evaluated in 1988 by EEG (Chaturvedi, Channell and Chapman, 1988).

SNL has responded that all evidence indicates that the possibility of a brine slurry existing in a waste storage room is essentially zero and can be ignored (SAND91-0893, vol. 1, Appendix B). Lappin *et al.* (1989) and the Final Supplemental Environmental Impact Statement (USDOE, 1990b) are cited as support for this conclusion.

The brine-slurry release scenario is related to undisturbed performance and cuttings release. Actually a similar, though probably less serious, release is considered in undisturbed perfor-

Table VI. Castile brine reservoir interactions in the WIPP area

Name of Well	Drilled	Initial Flow (bbl/day)	Remedial Action
Mascho-1	1937	8,000	No action to stop flow.
Mascho-2	1938	3,000	No action to stop flow.
Culbertson-1	1945		3,000 barrels estimated to flow to surface. No record of flow rate or duration.
Tidewater	1962	?	12 pound/gallon drilling mud did not stop. Finally controled by casing and cementing.
Shell	1964	20,000	Allowed to flow until artesian flow ceased.
Belco	1974	12,000	Brine flowed to surface for 26 hours with 14 pound/gallon drilling mud.
Gulf	1975	5,000	No records on total volume or duration of artesian flow.
ERDA-6	1975	660	WIPP hole. Estimate 19,000 barrels could be produced by artesian flow.
Pogo	1979	1,440	Initial flow was after 14.6 pound per gallon drilling mud had been added. Stopped after 4 days with 15 pound per gallon mud.
WIPP-12	1981	12,000	WIPP borehole. Over 79,000 barrels produced. Estimate 350,000 bbls producible by artesian flow.

Table VI Sources

- U.S. Department of Energy, 1981a. ***Brine Pocket Occurrences in the Castile Formation, Southeastern New Mexico,*** TME-3080.
- U.S. Department of Energy, 1983. ***Brine Reservoirs in the Castile Formation, Southeastern New Mexico,*** TME-3153.
- R. H. Neill ***et al.***, 1983. ***Evaluation of the Suitability of the WIPP Site.*** EEG-23.

mance when the waste storage room became partially or fully saturated only in the lower portion of the room. An effect of partial saturation and incomplete consolidation of the waste could be to lower the shear strength and result in greater quantities of waste being brought to the surface than calculated with the current cuttings model (E2) assumptions.

Recommendation 11.4 Perform a complete analysis of the brine-slurry release scenario. In addition, variants of the brine-slurry scenario in undisturbed performance and in the E2 scenario need to be better understood.

11.5 Borehole Seals

The USEPA Standards requires human intrusion analysis that would create

> ... a ground water flow path with a permeability typical of a borehole filled by the soil or gravel that would normally settle into an open borehole over time... not the permeability of a carefully sealed borehole (40 *CFR* 191, Appendix C).

In the 1991 and 1992 *Performance Assessments* the resultant permeability of human intrusion boreholes was sampled lognormally between 10^{-11} m^2 and 10^{-14} m^2. This value was obtained from Table 2.2 of Freeze and Cherry (1979) for silty sand. The choice of silty sand is SNL's interpretation of USEPA guidance on borehole sealing cited above.

EEG has several problems with the SNL interpretation. Table 2.2 in Freeze and Cherry (1979) shows a permeability range for silty sand from about 8×10^{-11} m^2 to 8×10^{-15} m^2. The same table also shows ranges of 10^{-9} m^2 to 2×10^{-13} m^2 for clean sand and 10^{-7} m^2 to 10^{-10} m^2 for gravel. It appears that a strict following of the USEPA Guidance would require use of higher permeabilities, to include gravel in the borehole.

EEG believes that the assumption of borehole permeability described in the USEPA Standards is reasonable when considered along with the other assumptions in the guidance, but is not conservative in light of observed borehole sealing practices in the Delaware Basin. In 1989 the Bureau of Land Management found 6,527 shut-in and temporarily abandoned wells in New Mexico (USBLM, 1989). A temporarily abandoned well is simply abandoned, without plugging and sealing. The USBLM made the following statement about wells in the Carlsbad area:

> At Carlsbad, we reviewed the status of 2 shut-in and 11 temporarily abandoned

wells on a 15-well lease. These wells had been classified as shut-in or temporarily abandoned since the late 1960s without approval. There was no evidence these wells had been properly tested to ensure they were capable of producing oil or gas and properly classified. The operator of this lease stated that he did not perform well integrity tests because he estimated that it would cost about $2,000 per well. Additionally, he stated that he did not permanently plug wells because that would cost about $10,000 per well (USBLM, 1989).

Recommendation 11.5 Performance Assessment should not assume perfect plugging of abandoned oil and gas wells near the WIPP. For the human intrusion borehole, the range of degraded permeabilities should span sand and gravel.

12. Analysis of Direct Discharge to the Ground Surface

12.1 In the *1992 Performance Assessment*, the program CUTTINGS analyzes steady-state cuttings releases (Table VII) to the ground surface for the following processes

Table VII. Domain of the CUTTINGS program.

Laminar Flow		Turbulent Flow		Sediment-
Axial	Helical	Axial	Helical	Laden
Yes	Yes	Yes	No	No

EEG has examined the initial Reynolds numbers in the 70 vectors of CUTTINGS analysis for the *1992 Performance Assessment*. The distribution of these initial Reynolds numbers is shown in Figure 13. The mean of these initial Reynolds numbers is 7334 and the standard deviation is 87. These initial Reynolds numbers are well above the range for laminar flow. The analysis for erosion by laminar flow may be elegant, but it appears to be irrelevant. The exclusion of erosion by helical turbulent flow and the effect of sediment erosion is non-conservative.

12.2 In the *1992 Performance Assessment*, the program CUTTINGS analyzes only the E2 scenario. The E1E2 scenario was not analyzed. This was not stated in the *1992 Performance Assessment*.

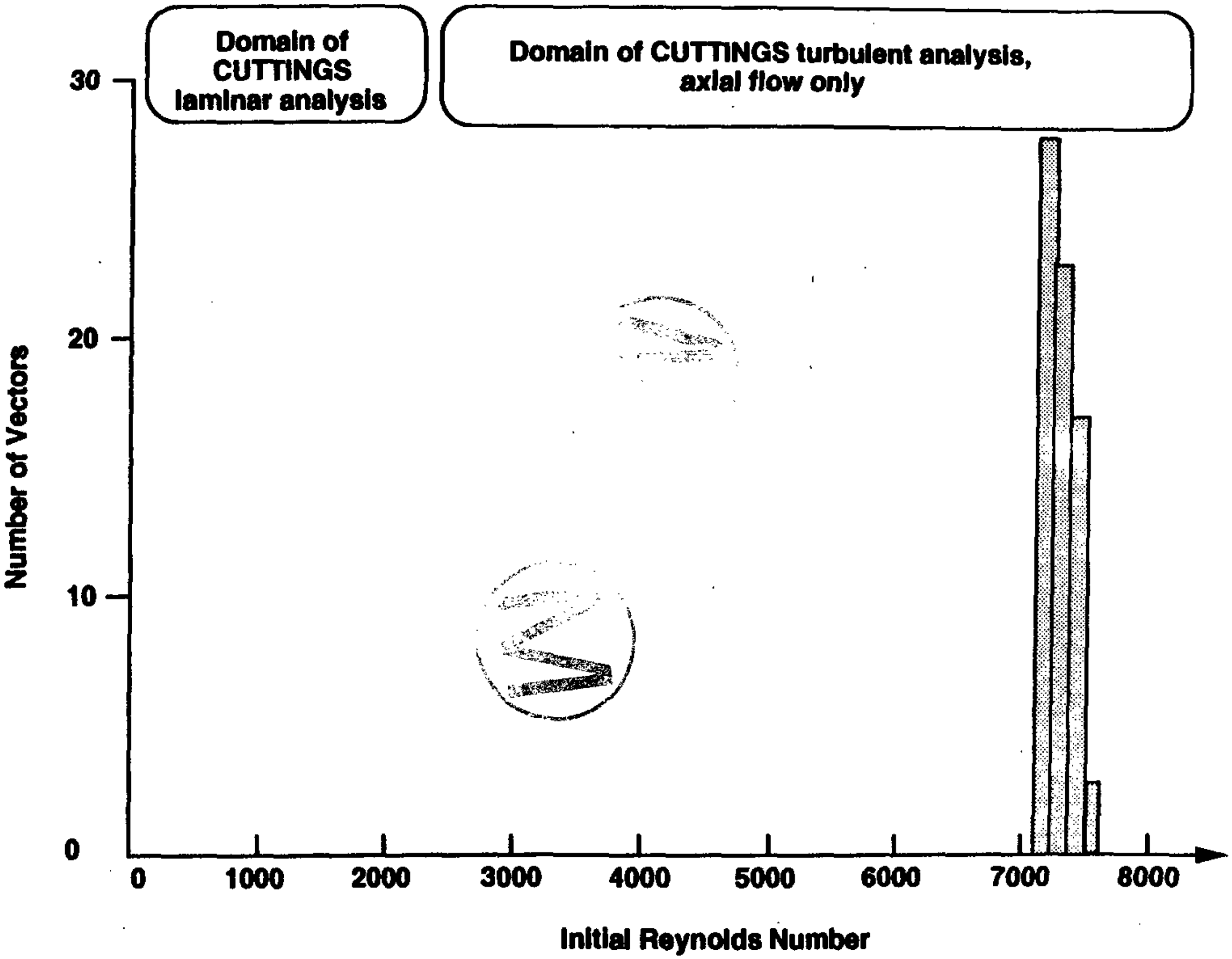

Figure 13. Distribution of initial Reynolds numbers in CUTTINGS vectors.

Recommendation 12. Future performance assessments need to include erosion of waste by helical turbulent flow and the effect of sediment erosion. Also needed is analysis of other relevant scenarios, such as E1E2 and brine slurry discharge to the surface.

13. Inventory

13.1 The radionuclides included in consequences analysis included only actinides plus ^{90}Sr, ^{137}Cs and ^{147}Pm. Missing notably are ^{135}Cs, ^{129}I and ^{99}Tc which are the most important nuclides in most other total system performance assessments. Inventories of these nuclides are available.

13.2 The *1992 Performance Assessment* used five activity levels for contact-handled TRU waste. The cited source is a SNL internal memo by Peterson [vol. 3, Appendix A, pp. A-135-140]. It is not possible to reproduce the results. Using data from input to the 1991 *Integrated Data Base*, (USDOE 1991b), we compare our results for categorizing contact-handled standard waste boxes against Peterson's in Figure 14. It is obvious the two do not match. SNL needs to explain how the results were obtained. The memo by Peterson was dated October 28, 1992, well after most of the computations for the *1992 Performance Assessment* had been completed. SNL should explain what inventory was actually used in calculations.

13.3 The inventory used in the *1992 Performance Assessment* is to be detailed in a report in preparation by Peterson. As of June 30, 1994, that report has not been published.

Recommendation 13.1 Include ^{135}Cs, ^{129}I and ^{99}Tc and other fission product nuclides as appropriate in future performance assessments.

Recommendation 13.2 Show the basis for inventories used.

14. Solubilities

Sandia calculates the flux of radionuclides from the waste by [vol. 3, p. 1-36]

$$\dot{M}_i = -QC_{di} - \gamma_i M_i + \gamma_{i-1} M_{i-1} \quad (3)$$

where M_i is the mass of the i^{th} nuclide in dissolved form,
C_{di} is the dissolved concentration of the i^{th} nuclide,

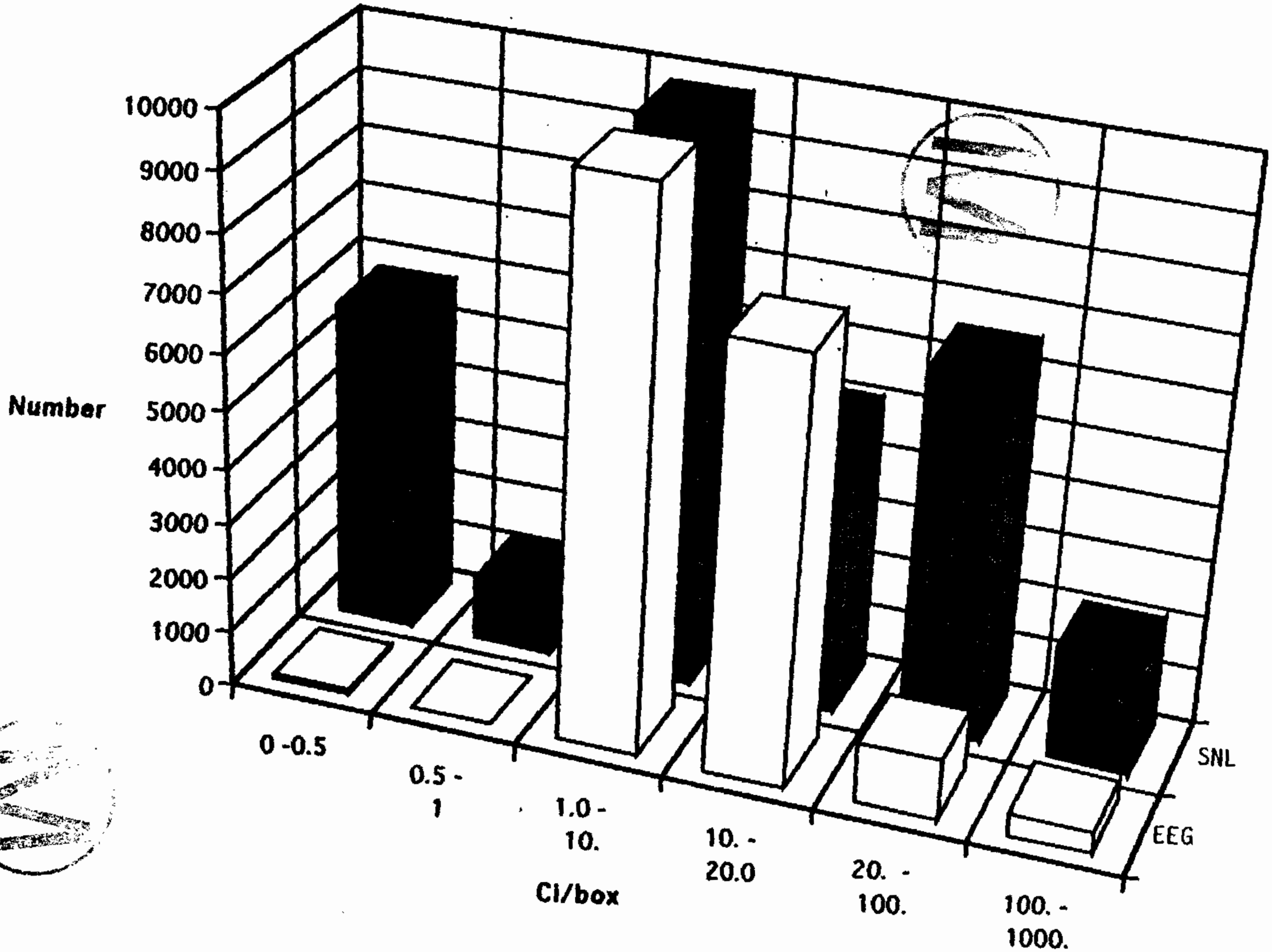

Figure 14. Radioactivity levels in standard waste boxes calculated by EEG and SNL.

Q is the brine flow rate, and

γ is the nuclide's decay constant.

The concentration is calculated as

$$C_{di} = \frac{M_i}{\sum_j M_j} S_i \qquad (4)$$

where S_i is the concentration in saturated solution, and this equation calculates the isotopic fraction of solubility over j isotopes.

From these equations, it is clear that solubility would be an important parameter in the calculation of consequences.

Experimentally measured solubility should be used in eq. (4), but few relevant measured actinide solubilities exists. Geochemical calculations, using either experimental or estimated stability constants, could be used. In the ***1992 Performance Assessment***, Sandia used neither of these approaches. Instead Sandia used subjective elicitation. A panel of outsider scientists was asked to make estimates. The resultant estimates span a wide range. For instance, the estimated plutonium solubility spans 12 orders of magnitude.

When these wide, subjective estimates are used in Latin Hypercube Sampling of input values, non-conservative solubilities in consequence calculations may result. We shall examine the case for plutonium. In the ***1992 Performance Assessment***, the sampling range for plutonium solubility was 5.5×10^{-4} mole/L to 2.5×10^{-17} M [vol. 3, p. 3-40], based on subjective elicitation, as shown in Figure 15. The black circle is the median and the open circle is the mean of the elicited distribution.

Solubility measurements are available at WIPP for Culebra water from the air intake shaft (Nitsche *et al.*, 1992), and for Brine A, a simulant of brine expected to inundate the repository (Nitsche *et al.*, 1993). Nitsche's solubility measurement experiments lasted several hundred days, and were started with various oxidation states of plutonium. Results are also shown in Figure 15. For the various initial oxidation states the steady-state concentration estimates are plotted, assuming the results are normally distributed, and the 25 and 75 percentiles are the edges of the boxes or ends of the arrows. The experimentally measured solubilities are generally greater than 10^{-7} M. However, when one examines the values of plutonium solubilities used in the 70 realizations in the Monte Carlo analysis [vol. 4, p. C-10], one find

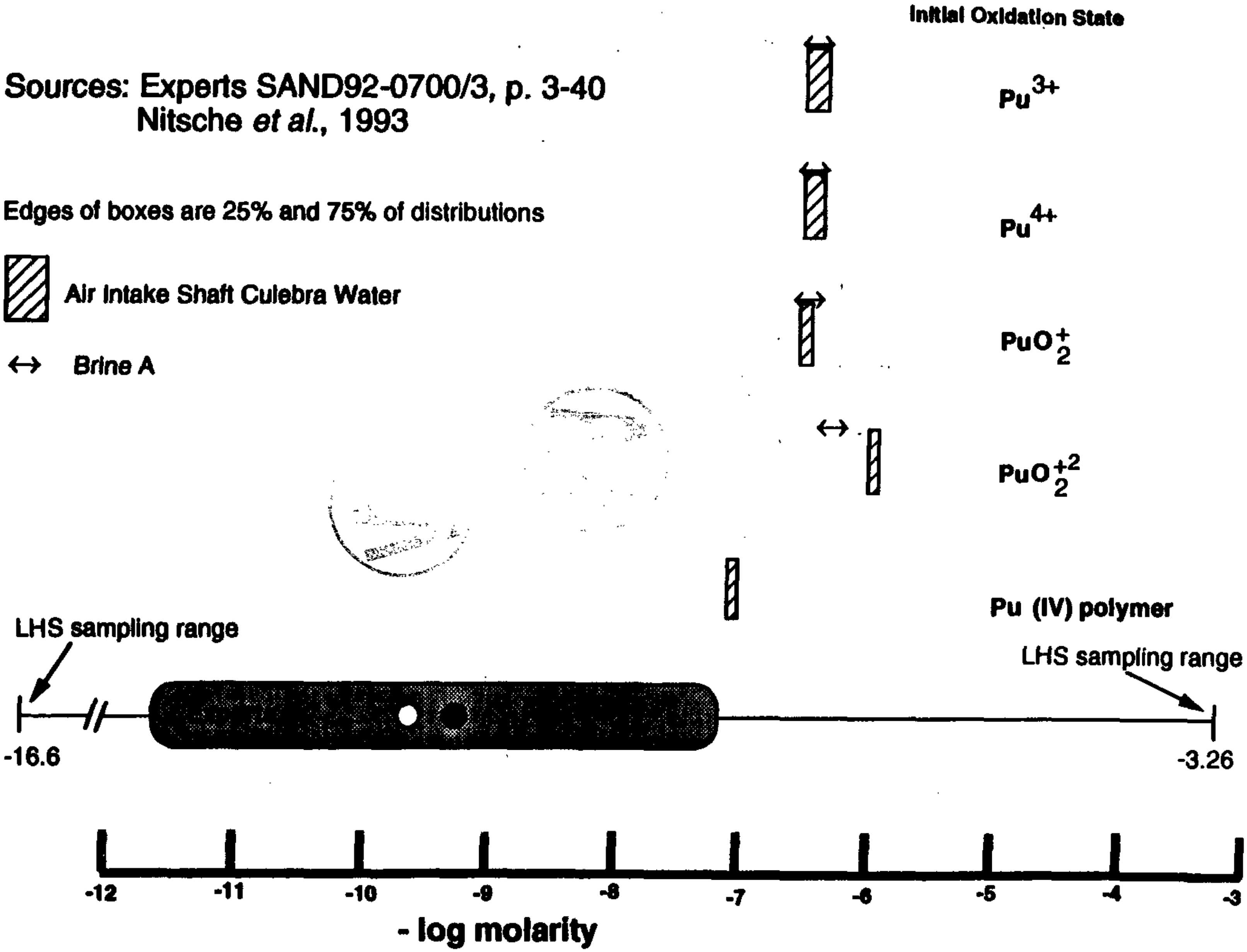

Figure 15. Comparison of subjectively elicited plutonium solubility and experimental solubility.

out that only 14 of the 70 realizations had a plutonium solubility of 10^{-7} M or higher, or 20%. The use of subjective elicitation apparently resulted in a downward bias in estimating plutonium solubility, leading to non-conservative consequences.

Recommendation 14. In future performance assessments, limit the sampling range to the error bands in experimental data.

15. Transport Modeling of Volatile Organics

In the analysis of compliance with 40 CFR 268, there has not been a transport analysis [vol.4, p. 4-38, line 25]. The conclusions in volume 5 are inferences using a flow model.

Recommendation 15. Two-phase transport of volatile organic compounds through gas-fractured interbeds should be analyzed in the future.

16. Corrensite Retardation in the Culebra

The *1992 Performance Assessment* identifies sorption on clay fracture-linings as one of three retardation mechanisms for radionuclide transport through the Culebra. Corrensite was addressed briefly in Recommendation 1.3. We elaborate here.

The concept of corrensite sorption is based on x-ray diffraction and analytical electron microscopy analysis of cores samples from clay-rich layers of the Rustler Formation, from wells drilled primarily in Nash Draw. This concept originates from the work of Sewards and others at the University of New Mexico under contract to the Sandia National Laboratories (Sewards 1991; Sewards, Glenn and Keil, 1991; Sewards, Williams and Keil, 1991; Siegel *et al.*, 1990).

16.1 Review of Corrensite Data

Sewards, Glenn and Keil (1991) presented mineralogical analysis of core samples from a single well, WIPP-19, and made no claim for clay-filled fracture linings in the Culebra.

Sewards (1991) gave data on "whole rock" as well as "fracture surface" compositions of core samples collected from six wells (WIPP-26, 27, 28, 29, 30, 32) in Nash Draw, one borehole (WIPP-33) between Nash Draw and the WIPP site, and three boreholes (WIPP-12,13, and 34) in the northern part of the WIPP site. Clays are expected to be present in the Nash Draw cores because of extensive dissolution, weathering, and erosion in that area. WIPP-3 is located in a sink hole and dissolution, weathering, and erosion are expected. Boreholes 12, 13 and 34 are located north of the WIPP repository and upstream from the expected direction of flow of water in the Culebra. Furthermore, cores are from these wells are in sections with known clay seams. For example, the only sample from WIPP-12 (CS-1) came from the zone 254.09 m (838.5 ft) to 254.15 m (838.7 ft) below the surface. The Basic Data Report for WIPP-12 (SNL and D'Appolonia, 1982) identifies mud seams at 253.85 m (837.7 ft) and 254.76 m (840.7 ft) depths.

Sewards, Williams and Keil (1991) presented mineralogy of 107 core samples from eight wells, three of which are located in the WIPP site. However, clay fraction separates (< 2 μm) were obtained for only three samples: WIPP-12 #3, a clay-poor dolomite; WIPP-12 #16, a clay-rich dolomite; and H6B #3, a shale. X-ray diffraction analysis was performed on the clay fractions from these three samples, and one sample (H6B #3) was analyzed under the electron microscope. The electron microscopy on this one sample casts doubt on the results of the x-ray diffraction

> There is, however, a discrepancy between the results of the quantitative XRD analysis and the results of the AEM investigation of sample H6B #3. In that sample, the XRD results show that the sample contains approximately 50% corrensite. When imaging was attempted on the AEM, it was extremely difficult to find any corrensite at all; the dominant phases appeared to be serpentine, illite, and chlorite (Sewards, Williams and Keil (1991); p. VII-19).

The conclusion of this report does not follow from the data analyzed:

> The fact that corrensite is the dominant phase in the Culebra samples is important. Corrensite has a high cation exchange capacity (CEC) and high surface area, thus it is able to sorb radionuclides very efficiently in the event of a low pressure breach in the WIPP facility. Although the clay minerals of only three samples were investigated, the results of Sewards, Glenn and Keil (1991) show that mixed-layer chlorite/smectite is the dominant clay phase throughout the Rustler Formation, so it is reasonable to suggest that the same is true in the Culebra unit (Sewards, Williams and Keil (1991); p. VII-19).

Sewards, Glenn and Keil (1991) made no claim for clays lining fractures in the Culebra. Corrensite was interpreted to be present in some of the samples, as one mineral among many, when powdered bulk samples were analyzed by x-ray diffraction.

Sewards *et al.*, (1992) presented mineralogical analysis from 47 samples. Of these, 17 samples were taken from the Culebra, and of these only nine are from the WIPP site: six from the Air Intake Shaft and three from WIPP-12. The report states:

> Only small amounts of clay can be sampled from the Culebra fracture coatings; therefore, initial technique and model development for adsorption studies on WIPP clays (Park *et al.*, in review) were carried out with material from a black shale layer in the unnamed member. This material, so-called CorWIPP, is 94% corrensite and is described as Sample AIS-15 in this report. Corrensite has a high cation exchange capacity and affinity for the uranyl ion in dilute solution (Park *et al.*, in review) and could provide significant radionuclide retardation in fractures in the Culebra (Sewards *et al.*, 1992).

The above quotation clearly identifies the problem with using Sewards' work to conclude that corrensite clay-lined fractures in the Culebra may provide retardation for radionuclide migration through the Culebra. The argument is based on a sample from a "black shale layer" obtained from the lower part of the Rustler Formation, below the Culebra, because not much clay could be sampled from Culebra fracture coatings. And yet, information from this sample is used to conjecture that "significant radionuclide retardation in fractures in the Culebra" could be present! This is the basis for continuing research on the adsorption properties of corrensite, model developement for retardation in the Culebra, and the assumptions of additional retardation.

16.2 Corrensite in the *1992 Performance Assessment*

Input to the *1992 Performance Assessment* has correctly evaluated the concept of corrensite retardation:

> Sewards (1991) measured and reported clay abundance for eighteen Culebra samples; thirteen from locations to the north and/or west of the WIPP site, and five from the north end of the WIPP site. None of these samples was from wells along fast transport paths. Because Sewards (1991) was focusing on clay abundance and compositional analyses, it is likely that samples were selected for analysis based on visual appearance of clays. Thus, these data may not be representative of clay abun-

dance on fracture surfaces in the area of interest for transport modeling (Novak, Gelbard and Papenguth, 1992).

Given the above analysis, why did SNL assume additional retardation from corrensite in the *1992 Performance Assessment*?

Recommendation 16. Abandon claiming credit for corrensite sorption as well as additional experiments with corrensite.

17. Ideal Gas Assumption in VOC Migration

In the *1992 Performance Assessment*, all gases are assumed to have the properties of hydrogen (vol. 5, p. 2-9) and behave like an ideal gas. While this assumption may be good for CO_2 and even for CH_4, it is not a good assumption for the volatile organic (VOC) gases regulated under 40 CFR 268. These gases have critical pressures well below lithostatic pressure, so that at lithostatic pressure they would not be expected to behave at all like ideal gases. In Table VIII, we show the ratio of the critical pressures of four prevalent VOC in TRU waste (Reid, Prausnitz and Poling, 1987) to lithostatic pressure of 15.2 MPa.

Table VIII. Ratio of Critical Pressures of Selected VOC
to Lithostatic Pressure at Repository Horizon

COMPOUND	P_c (MPa)	P_{lith}/P_c
Carbon Tetrachloride, CCl_4	4.56	3.3
Dichloromethane, CH_2Cl_2	6.30	2.4
1,1,1-trichloroethane, CCl_3CH_3	4.30	3.6
Trichloroethene, $Cl_2C{=}CHCl$	5.05	3.0

Table VIII shows that these four important VOC will not behave like ideal gases.

Recommendation 17. Unless there is experimental evidence that VOC vapors move as ideal gases and move with the low-molecular-weight gases generated by radiolysis, corrosion, or microbial action, movement of VOC vapors should not be modeled as ideal gas flow in showing compliance with 40 CFR 268.

III. DETAILED COMMENTS

Volume 1

Sec. 3.1 p. 3-3 This section says that USEPA expects the implementing Agency to use the same assumptions. But it does not say whether USDOE does or does not.

Table 3-1 p. 3-14, line 15 In this Table, techniques are given for assessing and reducing various kinds of uncertainties. For conceptual model uncertainty, an additional method of assessing its extent is to analyze alternate conceptual models. If alternate conceptual models can be rejected with confidence, then the favorite conceptual model has a better chance!

Table 3-1 p. 3-14 In Parameter Values and Variability, the use of expert judgment is said to be a method of assessing and reducing uncertainty. The fact is that the panel on solubilities greatly EXPANDED the uncertainty range.

Sec. 4.1.1, p. 4-2, line 28 The description of undisturbed performance should include a statement that the deleterious effects of gas fracturing have not been considered. The probability of gas fracturing is clearly above 10^{-4} in 10,000 years. Sandia's own experimental data suggest that without fracturing, the gas pressure is likely to reach and exceed lithostatic in hundreds of years.

Sec. 4.2, p. 4-8, line 38 Why is the maximum number of holes in the 70 simulations only 20 per km^2 when Latin Hypercube is used to sample uniformly (I presume) over interval [0,30]? Isn't the key advantage of Latin Hypercube to "ensures full coverage of the range of each sampled variable." (p. 4-14, line 10)?

Sec. 5.1.2.1.1, p. 5-3, line 27 Is λ really random in both space and time? As implemented it appears to be only a variable of time.

Sec. 5.1.2.1.2, p. 5-4 , line 35 It is not clear why the intrusion and subsurface release times are specified rather than random. If intrusion and release times are random, the source strength can be calculated in PANEL using eq. 1.4.4-11 in vol. 3. Are these six times of intrusion possible times of intrusion, or must the intrusions occur?

Sec. 5.1.2.2, p. 5-6, line 25 Given our comments on the subjective elicitation process in the preceding pages, we do not consider any of the results using λ_t to be valid.

Sec. 5.1.2.2, p. 5-6, line 27 When releases are calculated for six intrusions, is it six holes? Does this correspond to S(4,1,0,1,0,0) in Table 3-2 of SAND 91-0893/1?

Volume 2

Sec. 1.3.2, p. 1-4, line 26 CAMCON controls 75 codes for WIPP Performance Assessment. However, the key codes BRAGFLO, SECOTP2D and CUTTINGS are run outside of CAMCON, and also probably SANTOS-SANCHO. Does this make CAMCOM a general without troops?

Sec. 2.3.2.1, p. 2-47, line 2 The word should probably be "pyrophoric."

Sec. 2.3.2.1, p. 2-47, line 2 The second half of this sentence appears to be incorrect. The limit for pyrophoric ingredients is probably 1% of the weight of the waste, not 1% of the weight of an empty container.

Sec. 2.3.4.1, p. 2-54, line 20 To use ionic-strength corrected data from Well J-13 from Yucca Mountain as the median needs justification.

Sec. 2.3.4.2, p. 2-55, line 4 The laboratory measurements of plutonium solubilities and sorption coefficients in brines fall short for several reasons:

- solubilities and sorption coefficients in Culebra water are needed;
- for the spectrum of possible conditions, calculations are better.

Sec. 2.3.4.2, p. 2-55, line 6 It is not clear how the results of the Source Term Testing Program will be useful or used in performance assessment. The current performance assessment uses the actinide solubility. The LANL experiments give a release rate, rather than a solubility. The LANL release rate will be proportional to inventory. The performance assessment department should state how it intends to use the two different sets of data.

Sec. 2.3.5, p. 2-55, line 13 The statement is made that at decommissioning, free brine will not be present within the emplacement area. Experience over the history of WIPP indicates that brine *may* be present throughout the disposal phase.

Sec. 4.2.3.1, p. 4-11, line 11 Do these plastic containers meet the Waste Acceptance Criteria?

Sec. 4.2.3.2, p. 4-13, line 33 "All borehole plugs... degrade into material with properties similar to those of silty sand." Why not the plug above the Culebra?

Sec. 5.2, p. 5-2, line 22 Prof. Helton's method of calculating intrusion probabilities is not trivial. The full explanation is worthy of a journal paper. The brief explanation here raises more questions than answers. As a matter of fact, this summary is incomprehensible and confusing.

Sec. 5.2, p. 5-4, line 16 Hora's algorithm gives drilling rates in units of holes/mi^2/10000 years, not holes/km^2/10,000 years.

Sec. 7.2.3, p. 7-3, line 19 Should combustibles be organic?

Sec. 7.2.3, p. 7-3, line 21 Do you mean "biodegradation of organic materials only?" Non-combustible organics may still be biodegradable.

Sec. 7.6.1.2, p. 7-16, line 26 How is the scaling factor chosen? Who decides that it is reasonable? The same questions apply to the choice of A_R, θ, and ϕ in (7-14). Where are the results of climate change shown?

Sec. 7.6.2, p. 7-18, line 5 The numerical model for solute transport is 2-dimensional. The conceptual model shown in Figure 7-4 is 3-dimensional.

Volume 3

Sec. 1.2, p. 1-8, line 9 In the upper right plot in Figure 1.2-1, why is the median/mean of a standardized normal distribution 0.500001?

Sec. 1.4, p. 1-24, line 43 In eq.(1.4.1-9b) and eq.(1.4.1-11), the big dot used here for multiplication is confusing, and it is not needed. The dot is used on the previous two pages only for the dot product.

Sec. 1.4.4, p. 1-34 Instead of using two pages to explain what PANEL does not do, why not just present eq. (1.4.4-10) and explain that C_{di} is treated as a known constant.

Sec. 1.4.5, p. 1-38, line 11 Same comment on the big dot.

Sec. 2.3.3, p. 2-24 The data-source category of "engineering lore" is used here and in other places. "Engineering lore" is not defined on p. 1-13. In this case, the source is a refereed journal paper, which may well be "non-WIPP Literature Data."

Sec. 2.6, p. 2-78, line 14 The equation here does not make sense, and the definition of probability is not proper. For x as a random variate, try

$$P\left[\frac{b_c}{b}\right] = \begin{cases} 0, & 0 < x < 0.5 \\ x - 0.5, & 0.5 \le x \le 1.0 \end{cases}$$

Sec. 2.6, p. 2-83 Why is the median given here not equal to the median given on the previous page, line 13?

Sec. 2.6, p. 2-93, 94 These are curious tables. The range of partition coefficients extends to a region of no significance. One can calculate the lowest value of K_D which will give a positive retardation coefficient, using

$$R = \frac{\epsilon}{1-\epsilon}\rho K_D$$

where $\epsilon = 0.145$, from p. 2-82, $\rho = 2.82$, from p. 2-76, which gives $K_D > 2.09$, and $\log K_D > 0.32$. Examination of these tables says none of the nuclide's median partition coefficient will give a positive retardation. Why bother? Just forget retardation.

Sec. 3.3, p. 3-22, Table 3.1 A more correct term for "activity conversion" is "specific activity."

Sec. 4.2, p. 4-6. line 7 Certainly this refers to a regular borehole, However, Figure 4.2-2 refers to changes in permeability as a function of "time after intrusion." This legend cannot be correct. Should it be "time after sealing?"

Sec. 4.2, p. 4-6, line 11 Surely the concrete plugs do not have **initially** the permeability and porosity of silty sand. On p. 3-14, the permeability of concrete is given as $2.7\times10^{-19}\text{m}^2$, where the permeability of silty sand has a median value of $3.16\times10^{-12}\ \text{m}^2$.

Sec. 4.2.1, p. 4-4, line 38 Reference is made to the New Mexico Energy, Minerals, and Natural Resources Department, Oil Conservation Commission as the state agency responsible for negotiating plug and abandonment specifications and conducting inspections. The Oil Conservation Commission has not performed this function since 1978. On March 31, 1978, Division Order No. R-5709 established the Oil Conservation Division to take over the responsibilities of the Oil Conservation Commission and left the Oil Conservation Commission remaining in name as an appellate board. Many people in the industry still refer to OCD as OCC, but that is not technically correct.

Volume 4

p. 2-16, line 1 Assumption 1 states there are no synergistic effect between intrusions, except for the E1E2 scenario. However, on line 25, the statement is made that

> ...there is little reason to believe that the release taking place from one waste panel would affect the release taking place from another waste panel.

This presumes that brine entering one panel would not affect brine in another panel because of perfect panel seals which have not been designed or verified experimentally.

p. 2-16, line 6 The current assumption is that an E1E2-type scenario can only occur in the time interval $[t_{i-1},\ t_i]$. Indeed the *1992 Performance Assessment* only considered E1E2 at the same time. Should an E1E2 scenario occur at say 1995 and 2010 (years after closure), they would be analyzed as two E2, with quite different consequences.

p. 2-16, line 9 Assumption 3 is unsupportable. In the *1992 Performance Assessment* both BRAGFLO and PANEL considers one waste panel at a time. For an E1E2, BRAGFLO and PANEL would calculate Qc, the product of the brine flux Q, and the solubility c. If there are three intrusions, with two E2 holes hitting different panels, the resultant subsurface release is not the same as that of an E1E2 pair. It is likely to be $Q_1c + Q_2c$. Thus this is not an acceptable assumption.

Section 2.3 The current Poisson model assumes that the intrusions are independent, that is, one intrusion does not affect the probability of another. Does one intrusion increase or decrease the probability of additional intrusions? One does not drag a drill rig into an area and just drill one hole! Even the hydropads for WIPP have several wells on each. Exploration geophysicists operate on knowledge of geologic structures. If geologists tried a structure in 1997 AD, they are more likely to return in AD 2097 and try the same structure. Thus some built-in correlation is credible.

p. 2-18, eq. 2.4-14 This should probably read

$$cS^{+-}(l;t_{i-1},\ t_i) = \sum_{j=1}^{5} 2rC_{i,\ell(j)} + rGW2_i,$$

p. 2-18, line 47 A reason given for considering the consequence of only a single intrusion at 1,000 years is "increased radioactive decay." Many actinides have long half life:

Pu-239	24,000 years
Pu-242	376,300 years
Th-230	7,700 years
U-233	158,500 years
U-238	4.468×10^9 years.

Not much decay would have occurred in even 10,000 years!

p. 3-4, line 35 The range of LAMBDA is given as [0,1.0] while in Figure 3-1. p. 3-14, the range of LAMBDA is given as [0, 0.4].

Section 4.2.4 Here there are two possible representation between saturation and permeability and capillary pressure. They can be considered two different conceptual models, rather than mixing them 2/3 and 1/3.

p. 4-26, line 37 A reason given for using the van Genuchten equation is to simulate fingering. If fingers are at the scale of centimeters, and BRAGFLO's grid blocks are tens of meters, is this sufficient resolution to see this phenomenon?

p. 7-5, line 37 Should this be Figure 7.2-1?

p. 7-9, line 30 Solving eq. (7.2-5) analytically appears to be possible. Eq. (7.2-6) needs to be solved iteratively.

p. 7-7, Fig. 7.2-2 How is τ_{fail} determined?

p. 8-57, Figure 8.5-1; p. 8-58, Figure 8.5-2 What is the difference between a - and a blank in these tables.

p. 8-43, Figure 8.4-11 In the upper right frame, the mean CCDF is to the northeast of the 90% CCDF. This deserves more explanation. Please also explain why the mean CCDF starts at 8×10^{-3} on the probability scale, when there is a vector with probability of 0.5. According to p. 8-44, line 21, there are 21 vectors with releases, for the case of chemical retardation, matrix diffusion and no clay. Dividing 0.5 by 21, the minimum probability should be 2.38 $\times 10^{-2}$.

p. 8-60, line 31 This discussion of the effect of considering human intrusion for the full 10,000 years should be applied to Figure 9-1, especially Curve 1.

Volume 5

Is MBPERM gas or brine permeability?

p. 2-7, line 28 The word "scalcd" should probably be "sealed."

p. 2-8, line 10 The porosity of the damaged rock zone increases from that of intact salt to that of highly fractured rock at time zero. Shouldn't this increase begin when the damage to the salt occurs, at $t = -50$ years, the time of initial excavation?

p. 2-8, line 35 Sensitivity analyses show that BRSAT is the most important parameter in undisturbed performance, and the second most important parameter in 191B performance, yet the range that BRSAT is sampled from is "somewhat arbitrary?" Moreover, the reduction of the high end of the sampling range is because of computational concern! What would the results look like if this sampling is optimized?

p. 5-2, line 4 -A different set of permeabilities is used in the first 200 years. Is the first 200 years after closure, or after adminstrative control?

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ACRONYMS

AEM	analytic electron microscopy
BB	billion barrels
bbl	barrels
BCF	billion cubic feet
BT	billion tons
CCDF	complementary cumultive distribution function
CFR	*Code of Federal Regulations*
EEG	Environmental Evaluation Group
LANL	Los Alamos National Laboratory
M	mole/litre
MB	million barrels
MT	million tons
SNL	Sandia National Laboratories
TCF	trillion cubic feet
TRU	transuranic
USBLM	U. S. Bureau of Land Management
USDOE	U. S. Department of Energy
USEPA	U. S. Environmental Protection Agency
VOC	volatile organic compounds
WIPP	Waste Isolation Pilot Plant
XRD	x-ray diffraction

Computer Codes Mentioned

BRAGFLO
CUTTINGS
SANCHO
SECOTP2D
SWIFT

CAMCON
PANEL
SANTOS
STAFF2D

Variable Names

LAMBDA VMETAL VWOOD

ENVIRONMENTAL EVALUATION GROUP

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EEG-61

REVIEW OF THE WIPP DRAFT APPLICATION TO SHOW COMPLIANCE WITH EPA TRANSURANIC WASTE DISPOSAL STANDARDS

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FOREWORD

The purpose of the New Mexico Environmental Evaluation Group (EEG) is to conduct an independent technical evaluation of the Waste Isolation Pilot Plant (WIPP) Project to ensure the protection of the public health and safety and the environment. The WIPP Project, located in southeastern New Mexico, is being constructed as a repository for the disposal of transuranic (TRU) radioactive wastes generated by the national defense programs. The EEG was established in 1978 with funds provided by the U.S. Department of Energy (DOE) to the State of New Mexico. Public Law 100-456, the National Defense Authorization Act, Fiscal Year 1989, Section 1433, assigned EEG to the New Mexico Institute of Mining and Technology and continued the original contract DE-AC04-79AL10752 through DOE contract DE-ACO4-89AL58309. The National Defense Authorization Act for Fiscal Year 1994, Public Law 103-160, continues the authorization.

EEG performs independent technical analyses of the suitability of the proposed site; the design of the repository, its planned operation, and its long-term integrity; suitability and safety of the transportation systems; suitability of the Waste Acceptance Criteria and the generator sites' compliance with them; and related subjects. These analyses include assessments of reports issued by the DOE and its contractors, other federal agencies and organizations, as they relate to the potential health, safety and environmental impacts from WIPP. Another important function of EEG is the independent environmental monitoring of background radioactivity in air, water, and soil, both on-site and off-site.

Since 1978 EEG has been directly involved in quantifying the long-term consequences of radioactive waste releases from WIPP. We evaluated DOE's 1979 analyses contained in the Draft Environmental Impact Statement and published our analysis in 1979. The mission of WIPP at that time included high-level waste as well as transuranic waste.

Consequences were calculated via deterministic analyses in which an event was assumed to occur. EEG published nine reports calculating doses from the long term releases including consideration of brine reservoirs, drilling for mineral resources, sensitivity analysis for hydrological parameters in the Rustler, Breccia chimney and naturally occurring disruptive events. At about the same time that EEG was created in 1978, EPA began drafting standards for the safe disposal of high level and transuranic waste and the first briefing for EEG on this work by EPA occurred in 1979. EEG commented extensively on the multiple drafts and the standards were promulgated in September 1985.

Although not everyone was satisfied, the standards represented a consensus at that time. When the First Circuit Court vacated the standards in June of 1987, following a challenge by the Natural Resources Defense Council, Inc., the state of New Mexico entered into a formal agreement with DOE within a few days to continue to measure the expected performance against the vacated standards. It made sense since the standards were not expected to change much. Although it took 6.5 years for the agency to repromulgate the standards, DOE has been working since 1985 to show compliance and they currently plan to complete the task of the documentation of compliance for safe disposal by November 1, 1996.

The 1985 EPA standards required probabilistic analyses. The approach by DOE to show compliance has been an iterative one that we support. The last iteration of performance assessment was issued by Sandia National Laboratories in 1992.

Although the DOE draft application is substantially incomplete, we urged the Secretary of Energy in March 1995 to issue the draft report to enable oversight organizations to provide feedback to DOE and we commend DOE for issuing this interim application.

Robert H. Neill

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ACRONYMS

BHP	Borehole Plugging Program
BIR	Baseline Inventory Report
CSR	Compliance Status Report
CAM	Continuous Air Monitor
CAO	Carlsbad Area Office
CFR	Code of Federal Regulations
CH-TRU	Contract Handled Transuranic
DCCA	Draft Compliance Certification Application
DOT	U.S. Department of Transportation
DOE	U.S. Department of Energy
ESAAB	Energy Systems Acquisitions Advisory Board
EEG	Environmental Evaluation Group
EPA	U.S. Environmental Protection Agency
FEPs	Features, Events and Processes
FSAR	Final Safety Analysis Report
INEL	Idaho National Engineering Laboratory
GCR	Geologic Characterization Report
MDL	Minimum Detection Levels
NAS	National Academy of Sciences
NMVP	No Migration Variance Petition
NMBM&MR	New Mexico Bureau of Mines and Mineral Resources
NAS	National Academy of Sciences
NRC	Nuclear Regulatory Commission
ORNL	Oak Ridge National Laboratory
PBWAC	Performance Based Waste Acceptance Criteria
QA	Quality Assurance
QAPD	Quality Assurance Program Description
RCRA	Resource Conservation and Recovery Acts
RH-TRU	Remote Handled Transuranic
RTR	Real Time Radiography

ACRONYMS (CONT.)

SAR	Safety Analysis Report
SARP	Safety Analysis Report for Packaging
SNL	Sandia National Laboratories
TRU	Transuranic
USGS	U.S. Geological Survey
WAC	Waste Acceptance Criteria
WIPP	Waste Isolation Pilot Plant

EXECUTIVE SUMMARY

Overall Impression

The DOE Draft Compliance Certification Application (DCCA) cannot be considered to be an adequate draft document for demonstrating compliance with the EPA Standards for the Disposal of Transuranic Radioactive Waste (Title 40, Code of Federal Register, Part 191, Subpart B)[ES-1] requirements. It is more a framework for the application than a draft application, since it lacks a logical presentation of the proofs of compliance. A draft document should contain substantial features of the final document. The DCCA preface states that the draft does not provide "detailed information" on a number of topics and the submittal does not present the "complete picture" of long-term performance. In fact, the EEG finds that even the most basic information is lacking in this draft.

History of the Project

The historical sections of the DCCA omit several significant details concerning changes in the purpose and scope of the project, the history of site selection, the site selection criteria, the location of the repository, the design, and the waste acceptance criteria. Many apparent inconsistencies and contradictions in the project can be explained only through a full and accurate description of the history of the WIPP project,

Conceptual Models

The application is weak in describing alternative conceptual models for the projected conditions and processes in the repository and along the potential breach pathways, and in defending the ones selected. For some cases, the experimental data is not currently available to justify a particular model but additional data being collected may do so, as in the case of

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[ES-1] While the title of the DCCA or the text do not state it, the document only addresses compliance with Subpart B of the Standards (40 CFR 191) for disposal. Compliance with 40 CFR 191 Subpart A for the management of TRU waste is required by the Land Withdrawal Act, P.L. 102-579, Section 9 (a), and has to be documented.

radionuclide solubility. In other cases, potentially erroneous interpretations of the data have led to the concepts preferred by the DOE scientists. For example, although EEG clearly pointed out[ES-2] the error in using the limited stable isotope data from the Carlsbad Caverns pools in deciphering the past history of the Rustler aquifers, the DCCA presents only the conceptual model based on that data in estimating the age of the Rustler groundwater.

The EEG and DOE have debated many issues related to conceptual models since 1979, and in many instances additional boreholes or field experiments have led to a general consensus among the scientists; for example, whether pressurized brine exists in the Castile Formation underlying the repository, and whether "deep dissolution" is a threat to the integrity of the repository. However, there remain some instances where relatively inexpensive, but time-consuming, field experiments would provide the answers. The DOE conceptual model of radionuclide retardation in the Culebra aquifer remains a long-standing issue that would require such time-consuming field experiments to resolve; EEG first suggested such field work in 1979. Until the support for the conceptual models is on a solid basis, the WIPP cannot be said to comply with 40 CFR 191.

Hydrology

A basic understanding of the hydrology of the site is yet to be attained. The location of the water table at the WIPP site has not yet been identified; this would require an investigation of the hydrology of the shallow zone overlying the Rustler Formation, including the Dewey Lake Redbeds. The Culebra dolomite plays an important part in the postulated breach scenarios yet knowledge of its recharge and discharge locations and the mechanics of flow and transport in this most important aquifer are currently inadequate. The postulated direction of flow as indicated by the potentiometric heads differs from that obtained from water chemistry--such differences do not lead to confidence in the DOE conceptual models. Several Culebra wells have shown an as yet unexplained rise in water levels in recent years; this, too, should be explained in a compliance application. The DCCA does not adequately address these topics.

[ES-2]Chapman, Jenny B. 1986. *Stable Isotopes in Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP Area.* Albuquerque, NM: Environmental Evaluation Group, EEG-35.

Containment Requirements

The Sandia National Laboratories (SNL) published three iterations of performance assessment (PA) calculations in 1990, 1991, and 1992 to demonstrate compliance with the containment requirements listed in 40 CFR 191.13. These iterations demonstrated that incorporation of improvements in the methodology--better prediction of drilling probabilities, superior addressing of fracturing due to gas pressure, recognition that borehole plugs can degrade, improved methods of breach scenario calculation--were possible, and important. However, the DCCA offers no further improvement in WIPP performance assessment over the 1992 PA calculations.

Containment requirement calculations should be the heart of the application but only rudimentary information on the topic is supplied in the DCCA. The draft application is seriously deficient in not analyzing several potentially disruptive scenarios, in not adequately establishing the probabilities for a number of potential breach scenarios, and in not providing the basis for calculation of consequences. The exclusion of features, events, and processes eliminated on regulatory or low consequence potential has not been adequately justified; 23 of the 53 parameters listed in appendix PAR lack specific information; no sensitivity analysis is included; the number of consequence calculations has been reduced from 70 in the 1992 performance assessment to 20 in the DCCA; no evidence of computer model validation is included, nor quality assurance of data demonstrated; only a single Complementary Cumulative Distribution Function (CCDF) is shown. These lapses make it impractical to make any judgement about the WIPP's compliance with the EPA's disposal standards on the basis of this draft application.

Waste Inventory and Characterization

Various DOE documents present seriously conflicting pictures of the volume and radioactivity of the TRU waste available and expected to be generated. In the DCCA, performance-based waste acceptance criteria are mentioned, but never identified, perhaps because the DCCA also fails to identify the specific waste parameters important to compliance. Reliance on process knowledge for waste characteristics continues to be insufficiently justified. These conflicts and omissions provide little confidence in the DOE's inventory assessments.

Assurance Requirements

The purpose of the assurance requirements (40 CFR 191.14) is to provide confidence for long-term isolation of the waste that cannot be achieved solely by the numerical containment requirements (40 CFR 191.13). The EPA explained the need for the assurance requirements as follows:

> "There are too many uncertainties in projecting the behavior of natural and engineered components for many thousands of years--and too many opportunities for mistakes or poor judgements in such calculations--for the numerical requirements on overall system performance in subpart B to be the sole basis to determine the acceptability of disposal systems for these very hazardous wastes. These uncertainties and potential errors in quantitative analysis could ultimately prevent the degree of protection sought by the Agency from being achieved."[ES-3]

The assurance requirements should not therefore be confused with the containment requirements. The DOE attitude toward demonstrating compliance with the assurance requirements, however, continues to reflect a lack of commitment, and none of the six elements of 40 CFR 191.14 can be said to have been adequately addressed in the DCCA, as explained below.

Institutional Controls and Monitoring: 40 CFR 191.14(a) and (c) concern active and passive institutional controls; the plans for these are not scheduled to be prepared until October 30, 1997. 40 CFR 191.14(b) requires developing a plan for monitoring of the repository after disposal is completed; there is only a commitment to develop such a plan, with no completion date given, in the DCCA.

Engineered Barriers: 40 CFR 191.14(d) requires engineered barriers to be included in the repository. The EPA definition of engineered barriers (*barrier* in 40 CFR 121.12) includes only three examples: a canister, a waste form, and a material placed over and around the waste (backfill). In various sections of the DCCA, however, the DOE has used the repository

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[ES-3]Preamble to 40 CFR 191, Federal Register, Vol. 50, No. 182, p. 38079.

itself, and the shaft and panel seals as examples of engineered barriers--clearly not the intent of this requirement. The DOE also interprets the 1992 Land Withdrawal Act statement that DOE " ...shall use both engineered and natural barriers, and waste form modifications at WIPP to isolate transuranic waste after disposal to the extent necessary to comply with the final disposal regulations"[ES-4] as requiring no engineered barriers if not required to show compliance with the containment requirement (40 CFR 191.13). The assurance requirement (40 CFR 191.13 d) requires engineered barriers whether or not they are needed to show compliance with the containment requirement. Thus, it is necessary to include engineered barriers at WIPP to comply with the EPA Standards and the Land Withdrawal Act. The DOE position on this issue is indefensible.

Natural Resources: 40 CFR 191.14(e) requires that areas with natural resources be avoided in selecting the sites for nuclear waste repositories, "...unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future". The WIPP site was selected in a resource-rich area in 1974, and the WIPP Final Environmental Impact Statement of 1980[ES-5] estimated the crude oil reserves at the WIPP site as "nil" even though information to the contrary was available[ES-6]. Oil and gas wells and potash mines now surround the WIPP site leaving no doubt about the existence of natural resources in the area. The DCCA uses the time of site selection as an excuse to "grandfather" the site into existence, as the provisions of 40 CFR 191 were not published until 1985. There is no "grandfather" provision in 40 CFR 191; and there has been no formal acceptance of WIPP as a waste repository, nor any waste emplaced. To be constructive, EEG has recommended that instead of debating the favorable characteristics of the site and the degree to which they compensate for the existence of resources, the performance assessment should recognize the characteristics of the site as they are, and consider all plausible scenarios for breach. EEG also notes that siting in a resource-rich area provides another reason for the inclusion of robust engineered barriers in the repository design.

[ES-4]Public Law 102-579, Sec. 8(g).

[ES-5]DOE/EIS-026, 1980, Vol. 1, Table 9-14.

[ES-6]Silva, M.K. 1994. *Implications of the Presence of Petroleum Resources on the Integrity of the WIPP site*. Albuquerque, NM: Environmental Evaluation Group, EEG-55, p. 18.

Retrievability: The final assurance requirement, 40 CFR 191.14(f), requires that the removal of the waste be a viable option for a reasonable period of time after disposal. The DCCA offers no plans or data to demonstrate compliance with this requirement.

DOE has failed to adequately address all of the assurance requirements of 40 CFR 191.14 in the DCCA, and no determination of compliance is possible until this important area is adequately assessed.

Individual Protection and Ground Water Protection Requirements

The DCCA has only three pages to show compliance with the requirements of 40 CFR 191.15 and 40 CFR 191.16. The work simply has not been done, and the WIPP's compliance with these requirements cannot be assessed until it is.

DOE Self-Regulation

While the DOE self-regulates several aspects of the WIPP project, and the DOE Orders are applicable to it, the DCCA does not list the DOE in the list of regulatory agencies. The Biennial Environmental Compliance Report (Appendix BECR) provides detailed information on the status of compliance with laws, regulations, and standards by a number of regulatory agencies, but omits any information on the status of compliance with regulations issued by the DOE. An analysis of the DOE Orders, and reviews and approvals by the Office of Environment Safety and Health (ES&H) and the Defense Nuclear Facilities Safety Board (DNFSB) should be included in the BECR. Public accountability of compliance with the DOE requirements is essential.

COMMENTS ON THE DCCA EXECUTIVE SUMMARY

The Purpose of WIPP
Page ES-1

The description of the purpose of the WIPP project continues to remain confused in the DOE documents. "Research and development facility to demonstrate the safe disposal of radioactive waste ..." has never adequately described the purpose of WIPP, even though it is the language in the 1979 Act authorizing WIPP. The second sentence in the Executive Summary of the DCCA, "The facility was constructed in southeastern New Mexico in a manner intended to meet criteria established by the scientific and regulatory community ...", is also convoluted. The following straightforward statement is suggested to describe the purpose of the WIPP project for use in all the WIPP project documents: "The Waste Isolation Pilot Plant is planned to be a permanent geologic repository for transuranic waste generated by the defense activities of the United States."

As appropriate, additional statements about the DOE being the manager of the waste and the repository, the EPA being the certifier of compliance with the environmental regulations, etc., can be added.

Waste Quantity and Radioactivity Limitations
Page ES-2, lines 21 to 25

The paragraph should be changed to correspond with the limitations in the waste amount and radioactivity listed in Sec. 7 of the Land Withdrawal Act.

Assumed Characteristics
Page ES-2, line 28

"Assessments of the repository performance are based in part on <u>assumed</u> characteristics of the waste including factors such as the levels of radioactivity present in the waste, the amount of moisture in the waste, and the quantities of other materials that might have some effect on the potential for the waste to migrate toward the accessible environment." Emphasis added.

The characteristics of the waste should not have to be assumed; they should be known.

The Results of Analyses

Page ES-3, lines 22-27

In addition to the limitations listed, many plausible scenarios were not considered in developing the CCDFs shown in Figures ES-1 and 6-18. Also, the values of many important parameters used for developing these CCDFs were simply guesses by the scientific investigators, and not the values obtained from experiments. Thus, the results presented in this document are no more than a generic demonstration of the performance assessment procedures. They make no contribution towards assessing the WIPP's compliance with 40 CFR 191.13. Compliance with 40 CFR 191.14, 191.15 and 191.24 has also not been demonstrated.

Authorized Wastes

Page ES-2, line 36

It is stated that the DOE may only emplace the radioactive waste at WIPP that meets the definition of TRU waste in the Land Withdrawal Act (LWA) and the DOE waste acceptance criteria.

The waste must also meet the NRC standards for transportation and the EPA standards for long-term disposal.

CHAPTER 1. INTRODUCTION

Total Projected Quantity of Waste in the Repository
Page 1-1, lines 12-17

The Executive Summary states that the WIPP facility is designed to receive up to 6.2 million cubic feet (175,600 m^3) of contact-handled and 250,000 cubic feet (7,080 m^3) of remote-handled transuranic waste. Chapter 1 states that approximately 2.8 million cubic feet (79,300 m^3) of TRU waste is currently in storage and an additional 2.0 million cubic feet (56,640 m^3) is expected to be generated, although this projection may increase. The estimate of 2.8 million cubic feet (79,300 m^3) of retrievably stored TRU waste is much lower than other estimates by the DOE, and the 4.8 (2.8+2.0) million cubic feet (135,940 m^3) estimate is much lower than the 6.2 million cubic feet (175,600 m^3) capacity of the WIPP repository.

Since the allowable release limits in the EPA Standards 40 CFR 191 are based on the inventory (radionuclides and curie content) to be disposed in the repository, it is important to make an accurate projection of the curie content of each radionuclide to be emplaced. If the actual amount placed is lower than the assumption made to calculate the release limits, then the calculations would not be conservative, i.e. would project higher allowable releases than should be allowed, and vice-versa.

Project Overview
Pages 1-2, 1-3

Only through a full description of the checkered history of the WIPP project can the inconsistencies and contradictions in the project be fully explained. For example, The WIPP facility has not been constructed to "determine the efficacy of an underground repository for disposal of TRU waste and TRU mixed waste" (p. 1-2, lines 11,12). Study of the in situ geomechanical and geohydrological behavior of the repository did not require excavation of the full-fledged repository and waste handling facilities, or the heated room experiments. The facility was constructed prior to the decision to apply EPA standards for the mixed (TRU and chemically hazardous) waste. The WIPP facility was constructed in the 1980s because the

DOE had planned to emplace underground all the then retrievably stored (200,000 drums) transuranic contact-handled (CH-TRU) waste, and limited quantities of high level waste for experiments, before assessing the WIPP's suitability as a permanent repository. Similarly, for those who may not be familiar with the DOE desire to conduct a "test phase" involving emplacement of waste in the Panel 1 rooms and in the alcoves, the provisions of the Land Withdrawal Act are hard to explain. This section should describe the plans prior to October 1993, the reasons for the DOE decision to abandon the idea of testing with the waste at WIPP, and the effect of that decision on the requirements of the Land Withdrawal Act.

An illustration of the difficulty caused by the omission of discussion of the "Test Phase" is provided by the following sentence in the Project Overview section (Sec. 1.2).

> The DOE's decision was reached after all prerequisites for ending construction were met and documented (page 1-3, lines 7 and 8).

The *decision* in this sentence refers to the decision by the DOE Energy Systems Acquisition Advisory Board (ESAAB) in 1991 to start the "Test Phase" by shipping one bin of waste to WIPP. Without identifying what the *decision* was for, this sentence is meaningless. The fact is that the site characterization work is still continuing at the WIPP site, and since only one out of the planned eight waste panels has been excavated, the construction has also not ended. This factor also caused delay in initiating several necessary field and laboratory tests for site and waste characterization. Some of these tests are being conducted now under a tight schedule and others have been abandoned or postponed because they do not fit in this tight schedule. This also explains the sentence, "Additional scientific studies may continue during the disposal phase." (p. 1-3, line 15).

The project is finally on the right track. Only an awareness of the past mistakes and disassociation with the past short-sighted approaches will keep it there.

Page 1-2, line 15

"The LWA requirements relevant to this application focus on the criteria for certification of compliance with the radioactive waste disposal regulations issued by the EPA."

The application focuses on the regulations for disposal. The criteria only clarify those regulations.

Page 1-2, line 30

The text fails to note that the site was moved 1.25 miles south after the publication of the 1980 FEIS.

Page 1-3, line 9

What are the documents?

Page 1-3, line 11

Change "Once the DOE demonstrates compliance..." to "Once the EPA certifies compliance..."

Page 1-3, line 14

While the text states that the disposal phase will last 25 years, the DOE/CAO announced in October 1995 that the disposal will take 35 years.

Page 1-3, line 16

"The disposal phase will end when the design capacity is reached."

Since the current estimate of transuranic waste for emplacement at WIPP is only 2/3 of the design capacity, this would mean the disposal phase would not have an end date.

Page 1-3, line 26

The text states that the purpose of the active and institutional controls is to reduce the likelihood of human intrusion to the extent practicable. While this is a laudable goal, the standard states that the purpose is "to indicate the dangers of the wastes and their location" (40 CFR 191.14.d).

Site Selection Process

The discussion of the site selection process should include the following facts:

- One of the most restrictive site selection criteria, primarily because of the Lyons (Kansas) experience, was avoidance of drill holes penetrating through the salt within two miles of the repository border (p. 2-5)[1-1].

- The two-mile criterion caused the potential site to be shifted twice as new oil or gas wells were drilled nearby. The separation distance criterion was changed to one mile after the site at the ERDA-6 borehole was found to be unacceptable (p. 2-10[1-2] p. 2-6, 2-7, 2-12[1-1]), (pp. 6-7)[1-3].

- One of the three locations in New Mexico examined in detail to be the WIPP site was the Mescalero Plains area. The salt depth was adequate in that area but it was rejected because of extensive oil-field development (1980, p. 2-10)[1-2].

[1-1]Powers, D. W., S. J. Lambert and S. E. Shaffer. 1978. *Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico.* Albuquerque, NM: Sandia National Laboratories. SAND 78-1596/2 vols.

[1-2]United States Department of Energy. 1980. *Final Environmental Impact Statement Waste Isolation Pilot Plant.* DOE/EIS-0026/2 vols.

[1-3]Environmental Evaluation Group. 1979. *Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U.S. Department of Energy.* Santa Fe, NM: Environmental Evaluation Group. EEG-3 (EEG-2 Appendix III).

- Extensive oil-field development has occurred in the area surrounding the WIPP site with more than 100 producing oil and gas wells in the two mile zone surrounding the 4 mile x 4 mile WIPP Land Withdrawal area (p. 42)[1-4].

- The original location of the WIPP repository was in the north-central part of the 4 mile x 4 mile WIPP site. After the borehole WIPP-12, located one mile north of the center of the WIPP site, encountered pressurized brine in the Castile Formation in November 1981, the repository was relocated to its present site in the south-central part of the WIPP site. A geophysical electromagnetic survey conducted over the present repository in 1987 indicated the presence of brine in the Castile Formation below the repository.

- Selection of the specific horizon, at 2150 ft (655 meters) below the surface, was a compromise. Salt of highest purity is found in the lower Salado Formation but that is too close to the Castile Formation with its brine reservoirs. A marker bed (MB 139) is only 4-5 ft (1-4 m) below the repository and the Marker Bed 138 is located 39 ft (12 m) above the repository roof. There are several anhydrite and clay layers within the repository horizon.

Page 1-3, line 29

The NAS 1957 report also recommended completion of the site characterization work before making a decision to use the site for a repository and before authorizing construction. The DOE did not follow this advice, causing many difficulties for the WIPP project. Also, "1955" on line 29 should be "1957".

[1-4] Silva, M. K. 1994. *Implications of the Presence of Petroleum Resources on the Integrity of the WIPP*. Albuquerque, NM: Environmental Evaluation Group. EEG-55.

Page 1-4, line 16

The text indicates that the site was shifted twice to keep it two miles away from the then existing deep boreholes. It fails to mention that the criterion was changed to one mile, since the two mile limit could not be met.

Page 1-5, line 10

The text states that the WIPP site was selected but does not point out that it was moved twice.

Page 1-5, line 10

There were two horizons selected; not one.

Page 1-5, line 13

"The facility has been constructed at a horizon such that operational and rock-support problems are minimized." This statement underestimates the extent of problems associated with rock stability at the WIPP repository horizon. The lower purer salt horizon, not selected for the repository due to its proximity to the Castile brine reservoir horizon, would most likely have been better with respect to the rock-support problems.

Regulatory Framework

This section should describe the EPA's and the New Mexico Environment Department's regulatory authorities over WIPP.

Page 1-5, line 23

Add the 1992 WIPP LWA as an additional authority to establish and implement regulatory standards.

Page 1-6, line 4

The description of the history of 40 CFR 191 fails to mention that within four days after the standard was vacated in June 1987, New Mexico entered into a formal Consultation and Cooperation Agreement with DOE within four days to act as though the standards were fully in effect. Hence there has been no lost time in the applicability of the 1985 standards through the present.

Evaluating Long-Term Performance

Page 1-9, line 3

The text states that the results of sensitivity analyses will be provided in the final application. Since such analyses were provided in the 1992 iteration, why aren't they available now?

Page 1-11, Figure 1-2

Nothing is shown for backfill nor on the current work on waste form modifications at INEL, ORNL or other sites.

Bibliography

Page 1-15

There are more recent iterations of the SAR than the 1990 version.

CHAPTER 2. SITE CHARACTERIZATION

The EEG provided detailed comments on the site characterization issues discussed in the "Compliance Status Report for the WIPP"[2-1] to the DOE on November 21, 1994. The DOE response of August 23, 1995, essentially reiterated the DOE position on these issues and therefore the issues remain unresolved. The EEG comments on the Compliance Status Report (CSR), which are included as Supplement 1 to this report (pages S1-1 through S1-28), should therefore be viewed as a part of the EEG comments on the DCCA[2-2]. The following comments address additional issues that were not covered in our comments on the CSR.

The Culebra Dolomite Member

Sec. 2.1.3.5.2, Page 2-37

The Culebra Dolomite Member of the Rustler Formation was discussed in Lowenstein (1987)[2-3], and not in Lowenstein (1988)[2-4]. The post-burial alteration of the Rustler Formation should be discussed in this chapter (in Sections 2.1.3.5.2, 2.1.6.2.2, 2.1.6.2.3) as a different interpretation based on the detailed sedimentological study by Lowenstein[2-2]. This interpretation is different from the one presented by Holt and Powers (1984)[2-5] and Holt and Powers (1988)[2-6].

[2-1]U.S. Department of Energy. 1994. *Compliance Status Report for the Waste Isolation Pilot Plant.* DOE/WIPP-94-019 Rev. 0).

[2-2]U.S. Department of Energy. 1995. *Draft Title 40 CFR 191 Compliance Certification Application for the Waste Isolation Pilot Plant.* Draft-DOE/CAO-2056.

[2-3]Lowenstein, T.K. 1987. *Post Burial Alteration of the Permian Rustler Formation Evaporites, WIPP Site, New Mexico.* Santa Fe, NM: Environmental Evaluation Group. EEG-36.

[2-4]Lowenstein, T.K. 1988. Origin of Depositional Cycles in a Permian "Saline Giant": The Salado (McNutt Zone) Evaporites of New Mexico and Texas. *Geological Society of America Bulletin* 100 (4): 592-608.

[2-5]Holt, R.M., and Powers, D.W. 1984. *Geotechnical Activities in the Waste Handling Shaft Waste Isolation Pilot Plant (WIPP) Project Southeastern New Mexico.* Carlsbad, NM: U.S. Department of Energy. WTSD-TME-038.

[2-6]Holt, R.M., and Powers, D.W. 1988. *Facies Variability and Post-Depositional Alteration Within the Rustler Formation in the Vicinity of the Waste Isolation Pilot Plant, Southeastern New Mexico.* Carlsbad, NM: U.S. Department of Energy. DOE/WIPP 88-004.

The statement, "After dolomite, Sewards et al. (1991, p. IX-1) report that clay is the second, most abundant mineral of the Culebr[illegible] lay minerals include corrensite, illite, serpentine, and chlorite. Clay occurs in bulk rock [illegible] acture surfaces." (DCCA, p. 2-37, lines 33-35)[2-2] is not entirely correct. The actual [illegible] nt is, "[illegible] the Culebra and Magenta units are primarily dolomite with some quartz and clay ..." (p. IX-1)[2-7]. This is very different than clay being the second most abundant mineral in the Culebra. Of course, some clay signatures were seen in the x-ray diffraction tests [illegible] he Culebra rock samples, and some might even be found in fractures. The key question th[illegible] mpacts the performance assessment and the application for compliance, however, is, "how much credit may be taken for chemical retardation due to the presence of clay in the fractures and in the rock matrix?" The EEG does not believe that a case has been made to take any credit for retardation due to the presence of clay. This issue was discussed at length in our comments on the Compliance Status Report (pages S1-1 through S1-28 of this report).

Incidentally, the reference for Sewards et al. (1991)[2-7], should be "SAND 87-7036" and not "SAND 97-7036" (p. 2-181, line 2).

Castile Hydrology

Sec. 2.2.1.3.2, Page 2-94

The following facts should be added in this section.

- Brine from the borehole WIPP-12 did flow to the surface at a rate of approximately 350 gallons per minute (22 liters per second). More than 1.14 million gallons (4.3 million liters) of brine "unavoidably" flowed to the surface and was collected in a large pond on the surface before the well was brought under control[2-8].

[2-7]Sewards, T., Glenn, R., and Keil, K. 1991. *Mineralogy of the Rustler Formation in the WIPP-19 Core*. Albuquerque, NM: Sandia National Laboratories. SAND87-7036.

[2-8]Popielak, R.S., Beauheim, R.L., Black, S.A., Coons, W.E., Ellingson, C.T., and Olsen, R.L. 1983. *Brine Reservoirs in the Castile Formation [Waste Isolation Pilot Plant] Project Southeastern New Mexico*. Albuquerque, NM: Sandia National Laboratories. 2 Vols. SAND78-1596, p. H-9.

- Steve Lambert of Sandia National Laboratories disagreed with the Popielak et al.[2-8] conclusion that "these fluids originated from ancient seawater and that there is no evidence for fluid contribution from present meteoric waters." Using the uranium-isotope disequilibrium method of determining the age of entrapment of groundwater, Lambert (in Appendix A of Popielak et al.)[2-8] presented calculated ages of the WIPP-12 Castile brine to be between 45,000 years to 2,000,000 years, for different assumptions of leaching and rate of injection.

- The electromagnetic survey conducted in 1987 indicated the presence of brine in the Castile Formation below the present WIPP repository[2-9].

Hydrology of the Rustler-Salado Contact Zone

Sec. 2.2.1.4, Page 2-95

The discussion in this section is unsatisfactory because it does not make full use of the available facts from WIPP studies. It should be revised.

Chaturvedi and Channell (1985, p. 34)[2-10] pointed out that the data from hydrologic testing at the WIPP site shows that the "brine aquifer" of the pre-WIPP investigators[2-11] extends east of Nash Draw to the WIPP site. Most of the WIPP boreholes have found brine in the Rustler/Salado contact zone and, in fact, the water-level recovery rate after pumping from this

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[2-9]Earth Technology Corporation. 1987. *Time Domain Electromagnetic (TDEM) Surveys at the WIPP Site, Final Report.* Albuquerque, NM: Sandia National Laboratories. SAND87-7144.

[2-10]Chaturvedi, L. and J.K. Channell. 1985. *The Rustler Formation as a Transport Medium for Contaminated Groundwater.* Santa Fe, NM: Environmental Evaluation Group. EEG-32.

[2-11]Robinson, T.W., and Lang, W.B. 1938. *Geology and Ground-Water Conditions of the Pecos River Valley in the Vicinity of Laguna Grande de la Sal, New Mexico, with Special Reference to the Salt Content of the River Water.* Twelfth and Thirteenth Biennial Reports of the State Engineer of New Mexico for the 23rd, 24th, 25th, and 26th Fiscal Years, July 1, 1934 to July 30, 1938. Santa Fe, NM: State Engineer.

zone was much faster than the Culebra recovery rate in borehole P-18, east of the WIPP site[2-12].

Mercer (1983, p. 53)[2-13] proposed the possibility of leakage from the overlying Culebra as the source of water in the Rustler/Salado contact zone at the WIPP site. With respect to the rate of movement of brine in the Rustler/Salado contact zone, Mercer (1983, p. 20)[2-13] had this to say:

> The rate of movement in the Rustler-Salado contact residuum at the WIPP site has not been determined because the hydraulic properties are extremely variable and because of the lack of a valid value for the effective porosity.

Since 1983, the focus of the WIPP subsurface hydrology program has been almost exclusively on the Culebra member as the most permeable zone in the Rustler. The Rustler/Salado contact zone should also be considered as a pathway of migration of radionuclides from the WIPP site to the Pecos River.

The Culebra Member of the Rustler Formation

Sec. 2.2.1.5.2, Page 2-99

The subject of the remaining uncertainties in the characterization of fluid flow and transport mechanisms in the Culebra should be addressed in this section.

The postulated groundwater travel time in the Culebra from the WIPP repository area to the accessible environment is between 100 and 1000 years. Current projections of transport showing compliance with 40 CFR 191.13 rely on dilution of concentration by diffusion into the static fluid volume of the rock matrix, and additional chemical retardation along the flow

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[2-12]Mercer, J.W., and Orr, B.R. 1979. *Interim Data Report on Geohydrology of Proposed Waste Isolation Pilot Plant Site, Southeast New Mexico.* Albuquerque, NM: U.S. Geological Survey. Water Resources Investigations 79-98, p. 120.

[2-13]Mercer, J.W. 1983. *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medanos Area, Southeastern New Mexico.* Washington, D.C.: U.S. Geological Survey. Water Resources Investigations 83-4016.

path. Furthermore, if channeling, instead of the presently assumed dual porosity, is the dominant mechanism of flow and transport, the retardation will be considerably reduced. Thus, the mechanism of flow and the degree of physical and chemical retardation of radionuclides as they are transported through such flow, are critical issues affecting the outcome of the performance assessment. These issues, along with the description of the seven well field tracer tests and the laboratory tests and how they are expected to resolve the issues, should have been discussed in this section.

The issue of the Culebra water chemistry remains unresolved. A full discussion with respect to the flow directions, vertical seepage, karst, present day recharge and paleo-recharge is needed. Chapman's[2-14] criticism of the basis of dating the Culebra water to be "tens of thousands of years" old (DCCA, p. 2-100, line 24)[2-2] should be included. The EEG has never accepted the concept of the Culebra being "a relict of a flow regime of a wetter climate" (p. 2-100. lines 28-29). Chapman[2-14] clearly argued against accepting that concept. Chapman, Ingraham and Hess[2-15] provide additional support for the Chapman[2-14] arguments against using the enrichment in heavy isotopes in the Carlsbad Caverns pools to date the Rustler water.

Finally, this section should also provide an account of the anomalous rise in the water-levels in the Culebra at and south of the WIPP site and discuss possible mechanisms for this phenomenon. The possible causes mentioned in the WIPP Annual Site Environmental Report for C.Y. 1993 (DCCA[2-2] Vol. IX, App. SER, Sec.7.2, page 7-5) are insufficient to explain the anomalous water level rises.

[2-14]Chapman, J.B. 1986. *Stable Isotopes in the Southeastern New Mexico Groundwater: Implications for Dating Recharge in the WIPP area.* Santa Fe, NM: Environmental Evaluation Group. EEG-35.

[2-15]Chapman, J.B., N.L. Ingraham and J.W. Hess. 1992. Isotopic Investigations of Infiltration and Unsaturated Zone Flow Processes at Carlsbad Caverns, New Mexico." *Journal of Hydrology* 133: 343-363.

The Dewey Lake Redbeds
Sec. 2.2.1.6.1, Page 2-104

Much more information about the occurrence of groundwater in the Dewey Lake Redbeds (DLR) Formation, at and surrounding the WIPP site, is available compared to that presented in this section of the report. The water table at the WIPP site is believed to be in the Dewey Lake Redbeds. Water was observed in the DLR in wells H-1, H-2 and H-3, and in the Air Intake Shaft in the center part of the WIPP site. The well P-9 (H-11 hydropad) produced 25 gallons per minute from the DLR. Wells H-14, P-15, P-17, the Barn well and the Ranch well produce water from DLR. The latest WIPP well to produce water from the DLR is the well WQSP-6A, located between H-1 and H-14. It produced 28 gallons per minute in late 1994/early 1995. The statement, "in the vicinity of the WIPP shafts, the Dewey Lake has not produced water" (DCCA, page 2-104, lines 14-15)[2-2] is incorrect.

The statement, "Hydrologic properties of the Dewey Lake are characterized based on only a few measurements compared to the more extensive data set available for member of the Rustler. As a result, the position of the water table is not well known." (DCCA, p. 2-104, lines 7-9)[2-2] is inexcusable for an important document such as this.

The EEG position is that without an understanding of the basic regional hydrologic parameters of an area, such as the water table and the recharge and discharge areas and amounts, the knowledge about the site is incomplete. The EEG has long advocated studies to obtain knowledge of the basic hydrologic framework of the site. This should be done without further delay.

Groundwater Elevation Measurements in 1991
Sec. 2.2.1.7, Page 2-107

Why does the discussion in this section utilize data only until 1991, when observations on the water levels have continued until now, and the application was prepared in 1995?

The water-level rise at and surrounding the WIPP site is a major issue because it potentially implicates the activities in the oil and gas fields in that area. Much information exists in a number of Sandia National Laboratories (SNL) Memoranda, and it should be used to rewrite this section.

Surface-Water Hydrology

Sec. 2.2.2, Page 2-108

This section should describe the karst topography and hydrology of the WIPP site and vicinity. See, e.g., Chaturvedi and Channell (1985)[2-10].

Groundwater Discharge and Recharge

Sec. 2.2.3, Page 2-110

The recharge area for the Rustler Formation water at the WIPP site has never been identified. On the basis of potentiometric surfaces, Mercer[2-13] suggested Bear Grass Draw (T.18S, R.30E) and the Clayton Basin as possible areas of recharge. After a detailed study, Hunter[2-16] however, concluded, "Existing data are inadequate to determine evaporation from and recharge to the groundwater system in the vicinity of the WIPP site." Several studies suggested by Hunter[2-16] and endorsed by EEG (Chaturvedi and Channell, 1985, p. 71-74)[2-10] have never been carried out.

Similarly, the discharge area has never been identified. We agree with the general concept (DCCA[2-2] p. 2-113, lines 7-11) that the Culebra probably discharges into the Pecos River and some water may flow into the Balmorhea-Loving trough alluvium. As shown by Chaturvedi and Channell (p. 40-42)[2-10], the hydraulic distinction between the water-bearing zones of the Rustler Formation is obliterated at least 2 miles east of the Livingston Ridge and thus the water flowing into Laguna Grande de La Sal and the Pecos River at Malaga Bend may not be identified as belonging to a particular zone of the Rustler Formation.

[2-16]Hunter, R.L. 1985. *A Regional Water Balance for the Waste Isolation Pilot Plant (WIPP) Site and Surrounding Area.* Albuquerque, NM: Sandia National Laboratories. SAND84-2233.

Detailed arguments against the use of isotopic data to conclude the slow rate of recharge or the age of the Rustler groundwater (DCCA[2-2], p. 2-113, lines 18-25), have been provided by the EEG in commenting on the WIPP Compliance Status Report[2-1]. Those comments are provided at the end of this chapter.

Resources

Sec. 2.3, Page 2-113, line 34

The opening sentence incorrectly states that the section refers only to resources beneath the WIPP Site. The section also refers to resources adjacent to the WIPP Site.

Page 2-113, lines 35 through 37

The definitions for the terms *resources* and *reserves* are given without reference. On the next page the DCCA then ignores its own convention and randomly interchanges the words *reserves* and *resources*.

Page 2-114, lines 1 through 6

The definitions for the terms *proven reserves, probable reserves* and *possible reserves* are incorrect. The correct terms are proved reserves, probable resources, and possible resources (See Figure 1).

The DCCA definitions are given without reference and are inconsistent with the definitions used in Broadhead et al.[2-17], as discussed below.

[2-17]Broadhead, R.F, Luo, F. and Speer, S.W. 1995. Oil & Gas Resource Estimates, Chapter XI, <u>in</u> *Evaluation of Mineral Resources at the Waste Isolation Pilot Plant Site, New Mexico Bureau of Mines and Mineral Resources*. Carlsbad, NM: Westinghouse Electric Corporation.

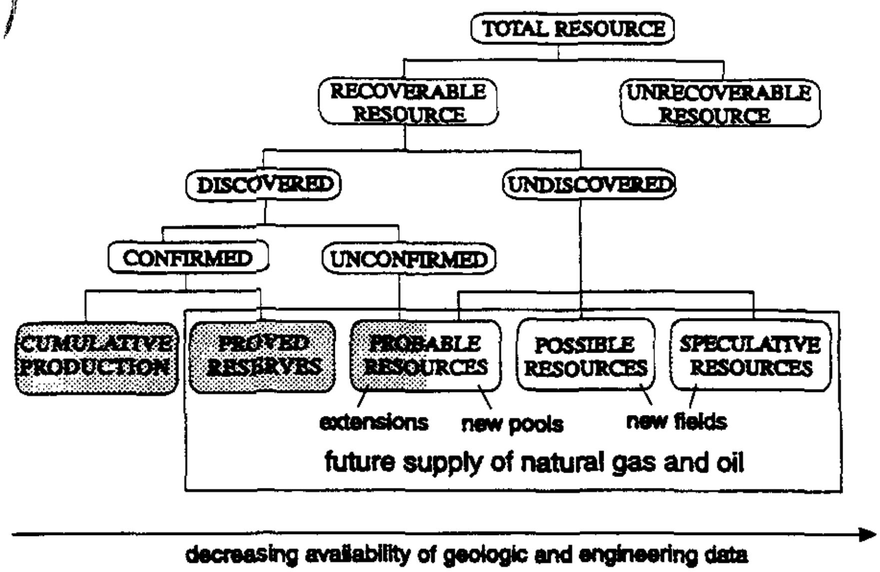

Figure 1. Oil and natural gas resource categories. After Broadhead et al., 1995.[2-17]

Proved Reserves

DCCA definition: For hydrocarbons, *proven reserves* can be expected to be recovered from new wells on undrilled acreage or from existing wells where a relatively major expenditure is required to establish production.

NMBM&MR definition: *Proved reserves* are an estimated quantity of crude oil, natural gas condensate, or natural gas that analyses of geologic and engineering data demonstrate with reasonable certainty to be recoverable in the future form discovered oil and gas pools. Pools are considered proved that have demonstrated the ability to produce by either actual production or by conclusive formation tests[2-17], that is by drilling. This report restricts the definition proved reserves to those producible resources identified as producible by existing wells (whether currently producing or abandoned).

Probable Resources

DCCA definition: *Probable reserves* refer to reserves of hydrocarbons suspected of existing in certain locations based on favorable engineering and/or geologic data.

NMBM&MR definition: *Probable resources (extensions)* consist of oil and gas in pools that have been discovered but have not yet been developed by drilling; their presences and distribution can generally be surmised with a high degree of confidence. *Probable resource (new pools)* consist of oil and gas that are surmised to exist in undiscovered pools within existing fields.

Possible Resources

DCCA definition: *Possible reserves* are based on condition where limited engineering and/or geologic data support recoverable potential.

NMBM&MR definition: *Possible resources* are less assured; they are postulated to exist outside known fields but within productive stratigraphic units in a productive basin or geologic province.

Extractable Resources

Sec. 2.3.1, Page 2-117, line 22

Rather than refer to the United States Geological Survey (USGS) for established grades of potash, it might be better to refer to the U.S. Bureau of Land Management (BLM).

Page 2-117, lines 23 through 26.

The DCCA appears to be making a policy statement that has already been challenged by the BLM. The DCCA maintains that the USGS assumes that the "lease" and "high" grades comprise reserves because some lease-grade ore is mined in the Carlsbad Potash District. Most of the potash that is mined, however, is better typified as the high grade. Even the high-grade resources may not be reserves, however, if their properties make processing uneconomic. The BLM policy with respect to leasing criteria was recently reiterated in the October 12, 1995, letter from the BLM District Manager[2-18]. The BLM currently uses a leasing criteria of a minimum thickness of 4 feet and an ore grade of 4% K_2O for Langbeinite and 10% for Sylvite as a measure of the quality of potash ore. In use since they were established in 1969 by the USGS, these standards are still effective today. Our records show that during the last five years a significant amount of sylvite ore has been mined at or below the 10% minimum standard. This is also true for langbeinite, meaning the ore is being mined at or below the 4% minimum standard.

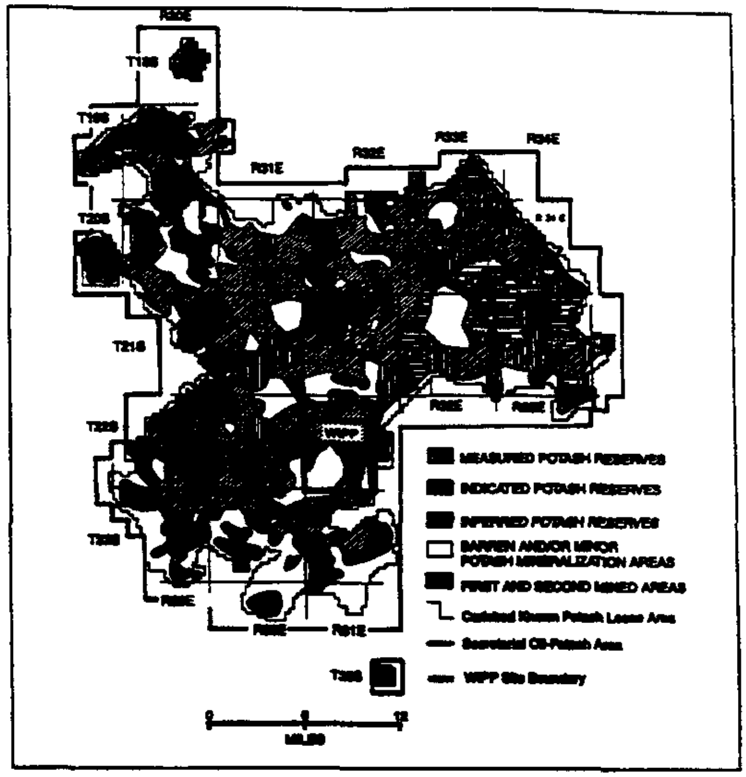

Figure 2. Potash resources. Adapted by M.K. Silva, EEG, from J.A. Olsen, 1993, Federal Management of the Potash Area in Southeastern New Mexico, in *New Mexico Geological Society Forty-Fourth Annual Field Conference, October 6-9, 1993: Carlsbad Region, New Mexico and West Texas*, pp. 39-41. Socorro, NM: New Mexico Geological Society.

Page 2-117, line 34 and Table 2-5.

It appears that the quantities of potash summarized by this table are incorrect and do not reflect the higher quantities considered by the BLM to be reserves as a matter of official policy. The discussion would benefit from maps of the potash resources such as that prepared by Griswold and Broadhead et al.[2-17], and those prepared by Silva for the June 13, 1995, EEG Workshop on waterflooding as shown in Figures 2 and 3.

[2-18] Cone, L.M., Roswell District Manager, BLM. 1995. October 12 letter to G. Griswold.

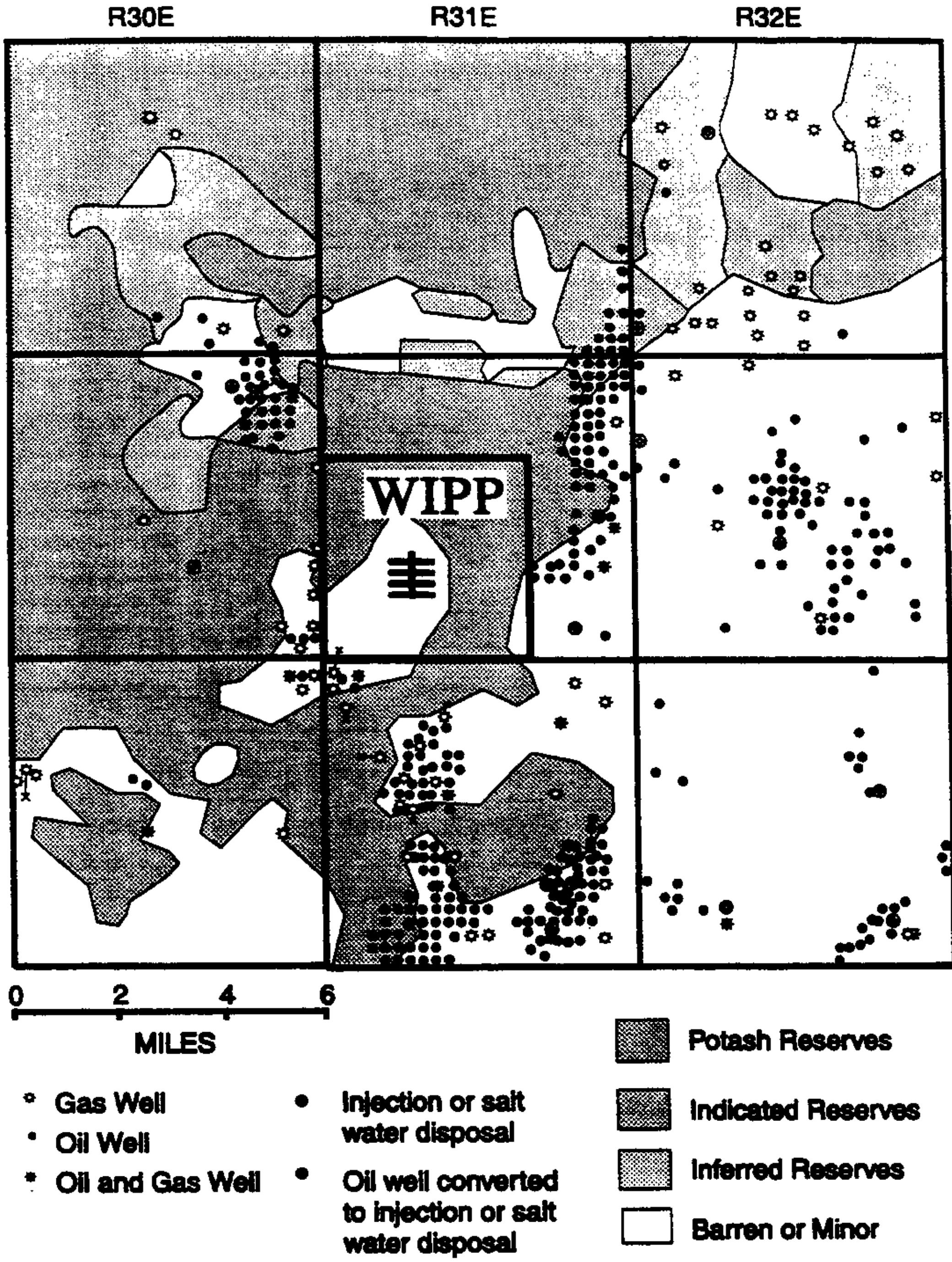

Figure 3. Oil and gas wells restricted from drilling through potash resources. Prepared by M.K. Silva (EEG).

Hydrocarbon Resources at the WIPP Site
Section 2.3.1.2, Page 2-118

The section on hydrocarbon resources would benefit from a presentation of a map of current well locations and a map of existing oil and gas wells and applications for permit to drill as indicative of the interest of the oil and gas industry (Figures 4 and 5). The 1995 summary of previous evaluations by Broadhead et al.[2-17] is mentioned in this section but the 1994 summary and analysis by Silva[2-19] is not mentioned. Proper citation procedure dictates citing Silva[2-19]. It would also be worthwhile to provide a map of proven and probable reserves for the various formations such as those contained in Broadhead et al.[2-17].

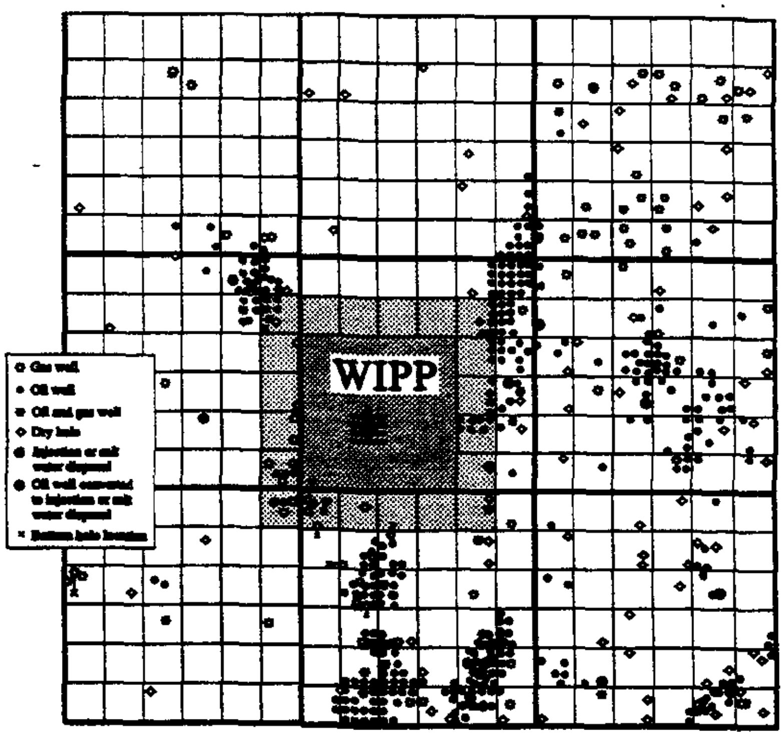

Figure 4. Oil, gas, and injection wells in nine-township project study area. Adapted from Broadhead et al.[2-17] by Matthew Silva (EEG).

[2-19]Silva, M.K., 1994. *Implications of the Presence of Petroleum Resources on the Integrity of the WIPP*. Albuquerque, NM: Environmental Evaluation Group. EEG-55.

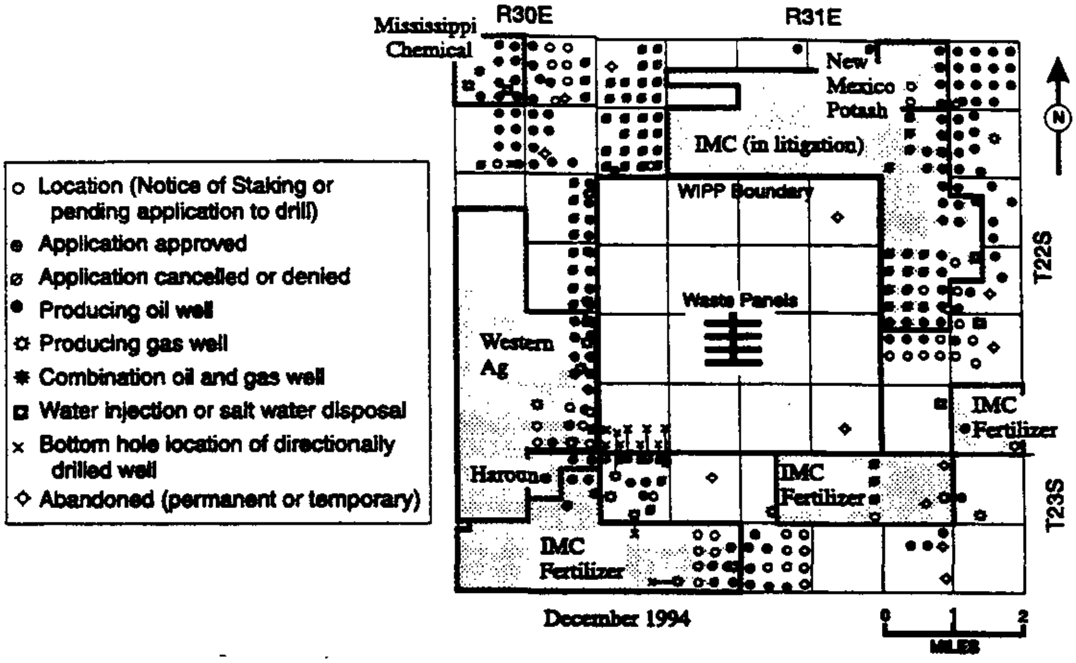

Figure 5. Resource activity and interest in the immediate vicinity of WIPP. Prepared by M.K. Silva (EEG).

Environmental Monitoring

Page 2-133, lines 2-8

The DCCA[2-2] states that WIPP has conducted a radiological monitoring program to "...determine the widespread impacts of nuclear tests at the Nevada Test Site and to evaluate the effects of Project Gnome." The WIPP environmental monitoring program has not included soil, water, biota or air particulates collected from the Gnome site. The only DOE work in the vicinity of the Gnome site was an April 1988 aerial gamma survey. Although the survey detected elevated gamma activity from ^{137}Cs, the presence of other radionuclides such as ^{241}Am, ^{238}Pu and ^{239,240}Pu was not detected. The EEG has measured these actinides at the Gnome site and published a report[2-20] in 1995.

[2-20]Kenney, Jim W., Paula S. Downes, Donald H. Gray, and Sally C. Ballard. 1995. *Radionuclide Baseline in Soil Near Project Gnome and the Waste Isolation Pilot Plant.* Albuquerque, NM: Environmental Evaluation Group. EEG-58.

Incorrect Measured Concentrations of Radionuclides

Page 2-137, Table 2-9

The reported concentration of 7.2×10^{-4} Bq/g (19.4 pCi/l) of ^{137}Cs in the water samples from water wells around the WIPP site exceeds levels measured elsewhere in the U.S. Similarly, the reported concentration of 12×10^{-4} Bq/g (32.4 pCi/l) for ^{60}Co appears to be incorrect. In addition, all the reported minimum detection levels (MDL) appear needlessly high. For example, the MDL for ^{90}Sr is considerably lower than the reported value of 7.4×10^{-4} Bq/g (20 pCi/l). EEG has an MDL for ^{90}Sr of 0.5×10^{-4} Bq/g water.

Historic Climate Conditions

Sec. 2.5.1, Page 2-137

There appear to be significant recent scientific advances in the area of reconstruction of the past climatic changes that have not been reported in this section. The EEG is conducting a review of the most current scientific literature in this area and will provide the results of that review in due course.

Seismology

Sec. 2.6, Page 2-143

It appears that the seismicity concerns are mainly for the short-term during the operational period, rather than the long-term (10,000 years). We have provided comments on this subject in our January 17, 1996 review of the Safety Analysis Report. If long-term safety concerns due to postulated earthquakes at the site are identified during our continued review of this topic, we will comment on it later.

Rock Geochemistry

Sec. 2.7, Page 2-151

The last paragraph of this section should be updated to reflect much additional experimental and modeling work on the occurrence of brine in the Salado salt, that has been performed since the publication of the Geologic Characterization Report (GCR)[2-21] in 1979. The baseline position paper by Howarth et al.[2-22] provides a summary of the WIPP project position on this subject and should be used to update this section.

[2-21]Powers, D.W., S.J. Lambert, and S.E. Shaffer. 1978. *Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico.* Albuquerque, NM: Sandia National Laboratories. SAND-78-1596/2 vols.

[2-22]Howarth, S. et al. 1994. *Salado Formation Fluid Flow and Transport Containment Group-White Paper for Systems Prioritization and Technical Baseline*, Rev. 1. Carlsbad, NM: U.S. Department of Energy.

CHAPTER 3. FACILITY DESCRIPTION

Need for more information

The DOE should document the process of demonstrating compliance with the EPA regulations for the management and storage of transuranic waste, contained in Subpart A of 40 CFR 191.

This chapter should describe the important features of the WIPP facility and the operational safety issues, at least those that relate to radiological safety. We realize that the Safety Analysis Report is the primary publication dealing with such issues, but at least a brief description in this chapter would be very beneficial. Such a description should cover at least the following topics:

- A description of the various components of the surface and underground facilities that play a role in the safe handling of the waste from unloading to emplacement in the repository. This discussion should include, for example, the safety features of the waste handling building and either why any accidents involving radioactive material are not likely to happen or what provisions have been made for a quick cleanup if such an event occurs. A discussion of the probability of waste hoist accidents should also form a part of this description.

- A description of the waste handling procedures, from unloading the TRUPACT-II to emplacement underground.

- A description of the underground facilities, including the mining and radiological safety issues. This should include a discussion of the safety of the Panel 1 and approach drifts, operation of continuous air monitors, maintenance operations for mining safety, and measures expected to be taken to keep the operations safe for 35 year operational life of the facility starting in 1998.

- Plans for waste emplacement. This discussion should include the expected rate of waste arrival, initially and later for 35 years; expected time to fill the 7 rooms of Panel 1; plans for emplacement of backfill; plans for closing the entry to each room and the panel; ventilation provisions at various stages; plans for carrying out the maintenance operations such as rockbolt detensioning during the emplacement operation; plans for emplacing the remote-handled TRU (RH-TRU) waste, including the date of first arrival and expected rate; description of the "panel closure system" (previously called the panel seals) as shown in Fig. 3-1 of DCCA[3-1], etc.

- The DCCA does not discuss the continuous air monitoring (CAM) systems currently in use at the WIPP. These CAM systems are an important part of the defense in depth philosophy at WIPP. The FSAR[3-2] classifies the repository CAMs as class IIIA and the Station A CAM as class II. Such important systems should be included in the DCCA repository configuration.

  DOE and the "Energy Systems Laboratory" at Texas A&M University have developed the use of a shrouded probe for single point aerosol sampling. This EPA approved shrouded probe is used in the repository and in the exhaust duct systems to deliver a representative particulate sample to the CAM system at WIPP. The shrouded probes should be identified as a part of the repository configuration in the DCCA.

- This chapter should include a discussion of the impact of abandoning the experimental area north of the shafts, without backfill and without sealing the boreholes that were drilled up to 50 ft above and below the excavated area.

[3-1]United States Department of Energy. 1995. *Draft Title 40 CFR 191 Compliance Certification Application for the Waste Isolation Pilot Plant. Draft-DOE/CAO-2056.*

[3-2]U.S. Department of Energy. 1990. *Final Safety Analysis Report, Waste Isolation Pilot Plant.* WP 02-9.

Waste emplacement requirements

Page 3-1, line 20

In addition to meeting the requirements of the definition of TRU and those that can be certified to the WAC, the TRU waste must also meet the NRC shipping criteria, the RCRA requirements, and approval by EPA.

Time to emplace waste

Page 3-1, line 32

The 25 year waste emplacement period was revised by the DOE in October 1995 to 35 years. The impact of this change does not appear to have been addressed.

WIPP design criteria

Page 3-5, line 6

Although the design criteria in DOE Order 6430.1, General Design Criteria, were applied to the WIPP, DOE is reevaluating the facility in the context of DOE Order 5480.23, April 1992; new DOE safety analysis report guidelines; and 10 CFR 835. The DOE Implementation Plan[3-3], calls for the rewriting and approval of a new disposal phase safety analysis report (SAR), and the disposal phase SAR is not complete. Particular concerns are the DOE regulations and the New Mexico Consultation and Cooperation Agreement, requiring worker and public dose assessments. The dose assessments are a necessary prerequisite to facility risk classification. Before final classification of facilities and structures, the disposal phase SAR must be completed and approved.

[3-3]U.S. Department of Energy. 1994. *Implementation Plan for the FY-95 Annual Update of the WIPP Safety Analysis Report for the Disposal-Phase Operations.* Revision 1.

Self-regulation

Page 3-5, lines 5-36

The approval of the design, the construction and documentation of safety of the DOE WIPP facility is by the DOE Carlsbad Area Office. The system should require approval by another DOE organization such as the Office of Environment Safety and Health.

Engineered barriers

Page 3-9, Sec.3.3

The text states that the design includes engineered barriers that significantly delay the migration of waste. The barriers are not identified nor are calculations presented quantifying the significant delay. The EEG does not consider the panel and shaft seals to be engineered barriers because they represent, at best, an imperfect attempt to undo the damage done to the natural environment by excavation and will not "prevent or substantially delay movement of water or radionuclides toward the accessible environment" any more than the natural environment would have. The definition of *barrier* in 40 CFR 191.12 includes, as examples, "a geologic structure, a canister, a waste form with physical and chemical characteristics that significantly decrease the mobility of radionuclides, or a material placed over and around waste, provided that the material or structure substantially delays movement of water or radionuclides." This definition does not include panel and shaft seals. This point was clarified by the EPA in 1987, as follows:

> It is EPA's intention that a barrier is a material or structure that prevents or substantially delays the movement of water in all directions emanating from the radionuclides in the waste. This would include at least the waste form, the canister overpack, and the geologic formation. While we encourage any added protection, even if not meeting these requirements completely, *it would not include items such as room and shaft seals*[3-4]. (Italics added).

[3-4]Meyers, S. 1987. May 22 letter from S. Meyers, Director, Office of Radiation Protection, EPA, to G.A. Smithwick, Principal Deputy Assistant Secretary, DOE/ES&H.

The DOE should use proper engineered barriers at WIPP, such as stabilizing waste in a low-solubility waste-form, robust containers, and engineered backfill. All references to the shaft seals as engineered barriers should be deleted from the DCCA and other documents.

Seals and Plugs
Page 3-9, Sec. 3.3.1

This section should be renumbered so that it is not a subsection of the Engineered Barriers section.

The DOE will have to demonstrate, through use of experimental data, that the postulated lowest value of the permeability of the seal system used in the performance assessment for assessing compliance with 40 CFR 191 as well as the No Migration Variance Petition, will be met. To the extent that the DCCA has not demonstrated it, this section is incomplete.

Upper salt column
Page 3-16, line 14

What is the basis for concluding that the upper salt column has no compliance related requirements?

Recompaction of salt
Page 3-16, lines 17, 21, and 34

A number of statements predict the performance of the salt column (80% of density produces intact salt permeability, 85% density results in permeability nearly equivalent to intact WIPP host rock salt), but no supporting evidence is provided.

Lower salt column

Page 3-21, lines 16-19

"Because of uncertainty regarding the marker beds and clay seams in the vicinity of the shaft station, efficient sealing functions are not currently modeled in the performance assessment for either the lower shaft salt component or the shaft station concrete monolith."

When and how will this be done?

Plugging of Boreholes

Page 3-21 to 3-25, Table 3-2

The DOE had planned to develop special borehole plugging procedures for boreholes at the WIPP site. It now appears that conventional plugging procedures for commercial wells will be followed.

The reference to the Christensen and Peterson paper[3-5] (page 3-21, line 35) is made in a wrong context. They do not provide "an evaluation of all vertical penetrations". Christensen and Peterson[3-5] and several other reports and papers by them and their colleagues at Sandia National Laboratories provide the results of research conducted under the Sandia Borehole Plugging Program (BHP), a program "specifically designed to support plugging activities for the proposed Waste Isolation Pilot Plant"[3-5] (Foreword).

This section (3.3.3 Borehole Plugs) should describe the results and recommendations of the BHP and should describe the plans and schedule of plugging the boreholes in the WIPP site area.

[3-5]Christensen, C.L. and E.W. Peterson. 1981. Field-Test Programs of Borehole Plugs in Southeastern New Mexico. In *The Technology of High-Level Nuclear Waste Disposal Advantages in the Science and Engineering of the Management of High-Level Nuclear Wastes*, edited by P.L. Hofman and J.J. Breslin. Oak Ridge, TN: U.S. Department of Energy. DOE/TIC-4621, vol. 1: 354-369 and SAND79-1634C.

M

The statement, "Only ERDA-9 is drilled to the repository horizon, near the WIPP underground" (page 3-21, lines 26-27) is incorrect. First, the borehole ERDA-9 was drilled to a total depth of 2887 ft, 51 ft into the Castile Formation and 737 ft below the repository horizon. Secondly, there are six boreholes within the WIPP site (ERDA-9, WIPP-12, WIPP-13, DOE-1, Badger Federal, and Cotton Baby), and at least ten just outside the WIPP site boundary, that are deeper than the repository horizon.

CHAPTER 4. WASTE DESCRIPTION

The material in this chapter does not indicate that there are problems in describing the physical, chemical and radiological characteristics of the waste to be emplaced in the repository. DOE states that the chapter documents the characteristics of the waste and provides the bases for the compliance assessments. However, the statement appears on page 4-1, line 9, "Assessments of the performance of the repository are based on <u>assumed</u> characteristics of the waste to be emplaced in the WIPP." [underline added]. The project has yet to identify which waste parameters are significant to compliance (page 4-8, line 21) and specific characterization techniques to determine these parameters have not yet been developed (page 4-8, lines 25-26). Furthermore, the estimated quantities of waste shown in this Chapter do not match values listed in the Baseline Inventory Report (Volume III, App. BIR).

Conflicting Information on the Purpose of the Baseline Inventory Report

The DOE's September 14, 1995, (pages 14 and 15) comments to EPA on the proposed 40 CFR 194 argue for general waste characterization requirements rather than specific waste characterization requirements, citing the Transuranic Waste Baseline Inventory Report as an example of general waste characterization. But the DCCA specifically states that the WIPP Baseline Inventory Report is not a waste characterization document (page 4-2, line 22). Which document specifies the waste characterization requirements of the WIPP?

RH-TRU Waste

Page 4-3, line 16

The DCCA suggests that the amount of RH-TRU is a small percentage of the WIPP TRU inventory. While this is true by volume, the RH-TRU waste is 37% of the total radioactive inventory according to the B.I.R. (Vol. III, page 4-11), and 33% of the total according to Volume I, page 4-15.

The inventory shown in Table 4-1 (page 4-4) does not agree with the inventory shown in Table 4-1 (page 4-5) of the Baseline Inventory Report published in Volume III, the supporting appendix (BIR). The RH-TRU projected inventory has varied widely over the years, as shown at the right[4-1] (Figure 6). DOE should make an effort to explain why the latest values are correct. Rev. 1 of the BIR increased the RH-TRU inventory by a factor of 3 to 4 and Rev. 2, December 1995 (received 2/9/96) increases the RH-TRU inventory by a factor of 5.6 over Rev. 1 to 27.000 m^3, considerably larger than the existing design capacity of 7080 m^3 for the RH-TRU.

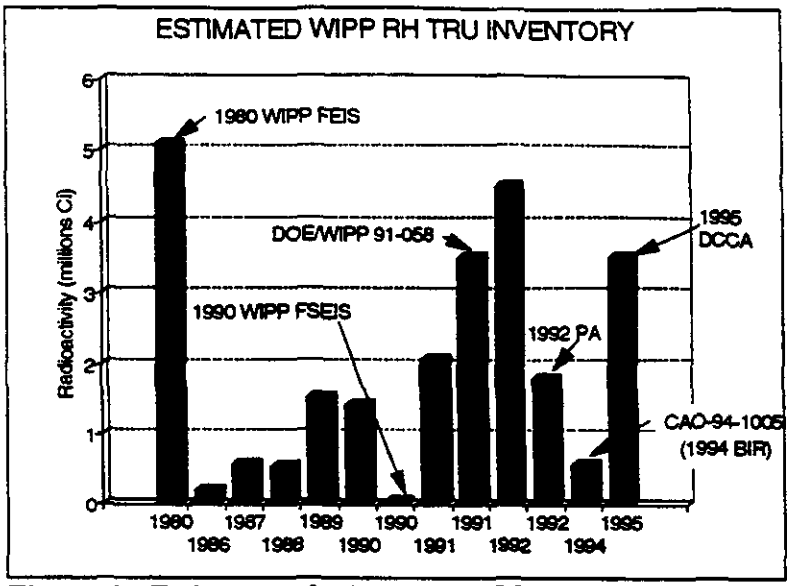

Figure 6. Estimates of WIPP RH-TRU Inventory from 1980 to 1995.

The term "Newly Generated Waste" in Table 4-1, (page 4-4) implies that the waste exists. Since it does not exist, the term "yet to be generated" would be more appropriate.

Actinide Inventory
Page 4-5, line 16

While the list of radionuclides identifies all of them as actinides, ^{90}Sr and ^{137}Cs are not actinides.

[4-1]Silva, M.K and R.H. Neill. 1994. *Unresolved Issues for the Disposal of Remote Handled Transuranic Waste in the Waste Isolation Pilot Plant*, figure 1. Albuquerque, NM: Environmental Evaluation Group, EEG-56.

Waste Acceptance Criteria

Page 4-6, line 22

This section states the objectives of the WAC.

> The primary objectives of the WAC are: (1) to ensure that all TRU wastes are packaged so that handling and subsequent disposal can be performed safely, and (2) to maintain the repository's ability to isolate the waste. Emphasis added.

But in two instances (page 4-6, lines 16 and page 4-7 line 11) DOE states that the existing and current WAC does not include the second objective listed above.

> The current WAC are based on transportation requirements and safe handling and storage criteria. If required, long-term performance-based WAC will be applied to the WIPP inventory baseline when the overall assessment of the disposal system's performance is complete.

The final Waste Acceptance Criteria have not yet been published. Further, the transportation criteria for RH-TRU have not been submitted to NRC for review and approval. The most recent WIPP Disposal Decision Plan, dated October 6, 1995[4-2], indicates that due to delays at DOE Headquarters, the transportation Safety Analysis Report for Packaging (SARP) will be sent to NRC in September 1996 rather January 1996. Current waste acceptance criteria can not be based on RH-TRU transportation criteria because there are none. Further, the waste acceptance criteria are based in part on transportation requirements and cannot be completed until the NRC completes its review of the SARP, which will not even be provided to the NRC by the DOE until September 1996. DOE notified EEG in November 1995 that the WAC were being revised.

[4-2]Dials, G.E., Manager, DOE Carlsbad Area Office. 1995. October 12 letter of transmittal with *WIPP Disposal Decision Plan*, Rev. 2, October 6, 1995, to R.H. Neill, Director, Environmental Evaluation Group.

Performance Based Waste Acceptance Criteria
Page 4-7, line 15

While the text states that the performance based waste acceptance criteria (PBWAC) identify the bounding characteristics of waste for repository performance, there are no published performance based WAC and this program has not yet been developed. It appears that for this draft application, the DOE has not done the calculations to determine the impact of various waste parameters. As part of the draft application, the DOE appears to be relying on a yet to be specified PBWAC to assure compliance. Without the calculations and a detailed PBWAC program, it is not possible to assess the contributions and limitations of these yet to be determined criteria. PBWAC is not even defined in the Glossary, Chapter 8, Vol. III.

Waste Characterization Program
Page 4-8, line 10

The discussion in this section indicates that the project has not yet identified which specific waste parameters are important to compliance, and if found to be important, they will be developed. This section also mentions a yet to be published load management alternative "to ensure the proper mix of waste forms on both panel and room scales." (line 27). If such a load management plan exists, please reference it. The paragraph suggests there may be problems with some waste characteristics. If so, what are they?

Accountability of Radioactivity
Page 4-8, line 19

The sentence, "The DOE must account for more than 1% of the total activity in the container, prior to shipment to WIPP." appears incomplete.

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Waste Streams

Page 4-8, line 30

This section describing waste streams should either provide the details or a reference for specific information. It does note that categorizing wastes in specific streams is based on the availability of information.

There are questions on the availability of information, particularly RH-TRU waste. As observed by previous studies at generator/storage sites, records on RH-TRU waste are scarce (Jensen and Wilkinson, 1983, p. 91) and actual data on stored RH-TRU waste are minimal (Stewart et al., 1989).

Recent reports from the generator/storage sites strongly suggest that reliable information is not available for many waste streams. For example, a recent report on the feasibility of treating TRU waste at Oak Ridge National Laboratory states:

> Uncertainties in the characterization—isotopic, physical, and chemical—of TRU waste affect operation and maintenance costs, the retrieval method, processing options, and disposal locations. TRU waste streams at ORNL are not as yet fully characterized. Moreover, there are uncertainties in the characterization data available for TRU waste sludge. Isotopic data are based on best available sample obtained in single-point sampling of only 8 of the 13 BVESTs and MVSTs.[4-3] Detailed physical data such as particle size, hardness, viscosity, and particle distribution are unknown. Chemical data on tank contents are not completely known. To a lesser extent, uncertainties also exist in available characterization data on TRU waste solids. Generally data are available on the physical and radiological content of remotely and contact-

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[4-3]Three types of TRU waste stored at ORNL were included in the study: (1) 225,000 gallons of RH-TRU waste stored in eight 50,000 gallon Melton Valley Storage Tanks (MVSTs) and five 50,000 gallon Bethel Valley Evaporator Storage Tanks (BVESTs); RH-TRU waste stored in approximately 300 concrete casks, 2 steel drums, and 13 wooden boxes, and; (3) CH-TRU waste stored in 2600 drums and 60 boxes.

handled TRU waste solids, but there are numerical disparities within this documentation.[4-4]

The DOE has access to this site information and should provide it as part of the application, rather than settle for a statement in the WIPP Baseline Inventory Report, such as:

> The number and types of documents can very greatly from site-to-site so it is impractical to list them as references in this document[4-5].

It is unclear why the "completeness of documentation" (page 4-9, line 11) determines the uncertainty assigned to process knowledge. The Baseline Inventory Report was developed from "best available information and process knowledge."[4-6] According to the DOE Glossary, Vol. III, process knowledge is a qualitative evaluation of the contents of a waste container through study of existing records of production history of the waste. Best available information includes on-site documents and records. In considering the limits of reliability, it is important to remember that documents and records are derived from sources including "...interviews with existing and former workers...".[4-7]

It seems that the statistical analyses of measured waste characteristics rather than the completeness of documentation would be a more scientific and defensible approach to quantifying the reliability and uncertainty in process knowledge. In general, a statistical

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[4-4]Parallax, Inc. 1995. *Feasibility Study for Processing ORNL Transuranic Waste in Existing and Modified Facilities, Management Summary.* Oak Ridge, TN: Lockheed Martin Energy Systems, Inc.

[4-5]U.S. Department of Energy. 1995. *Draft Title 40 CFR 191 Compliance Certification Application for the Waste Isolation Pilot Plant*, vol. III, Appendix BIR vol. 1, section 2.2.1, DRAFT-DOE/CAO-2056.

[4-6]U.S. Department of Energy. 1995. *Draft Title 40 CFR 191 Compliance Certification Application for the Waste Isolation Pilot Plant*, vol. III, Appendix BIR vol. 1, section 1.2, DRAFT-DOE/CAO-2056.

[4-7]U.S. Department of Energy. 1995. *Draft Title 40 CFR 191 Compliance Certification Application for the Waste Isolation Pilot Plant*, vol. III, Appendix BIR vol. 1, section 2.2.1, DRAFT-DOE/CAO-2056.

analysis should first determine the number of samples needed from each waste stream population. The waste inventory and the characteristics for a waste stream should be determined by process knowledge and be recorded prior to sampling. Then the selected waste containers from each stream would be characterized by a physical sampling program to determine the contents of each container. From the measurements of the physical contents, the statistics for that waste stream, including uncertainty (variance or standard deviation), could be calculated. The inventory, as determined by process knowledge, could be compared with the statistics to determine if process knowledge represents the same population.

RH-TRU waste forms

Page 4-12, line 7

The DCCA incorrectly states: "Free liquid or particulate wastes are not associated with processes that generate RH-TRU waste."

For example, in a report on unresolved issues with RH-TRU waste, the EEG notes there are 1900 cubic meters (500,000 gallons) of TRU contaminated liquids and sludges in underground tanks.[4-8,4-9] There are 225,000 gallons of RH-TRU waste stored in eight 50,000 gallon Melton Valley Storage Tanks and five 50,000 gallon Bethel Valley Evaporator Storage Tanks[4-10].

[4-8]Silva, M.K. and R.H. Neill. 1994. *Unresolved Issues for the Disposal of Remote Handled Transuranic Waste in the Waste Isolation Pilot Plant.* Section 3.1. Albuquerque, NM: Environmental Evaluation Group, EEG-56.

[4-9]U.S. Department of Energy. 1991. *Recommended Strategy for the Remote-Handled Transuranic Waste Program.* DOE/WIPP 90-058, Rev. 1, p. 4-2.

[4-10]Parallax, Inc. 1995. *Feasibility Study for Processing ORNL Transuranic Waste in Existing and Modified Facilities, Management Summary.* Oak Ridge, TN: Lockheed Martin Energy Systems, Inc.

Free Liquid Content

Page 4-12, line 14

The project relies on real time radiography to determine the presence of free liquids, which are prohibited by the Waste Acceptance Criteria. While the DCCA notes that drums have been excluded from the WIPP program due to non-conformance with the criteria of no free liquids, the DCCA fails to mention that real time radiography is limited. It is well documented that real time radiography can not detect all free liquids. For example, the visual examination of WAC certified drums for the bin test turned up a drum that contained a full can of free liquid, which was a flammable volatile organic compound[4-11]. The DOE response stated:

> The second concern expressed in your letter was that real time radiography (RTR) did not detect the "flammable organic compounds which were in liquid form." I am sure you are clearly aware the RTR is essentially an x-ray and cannot be used to assess the flammability of any compounds, liquid or solid. The fact that the RTR cannot distinguish between a completely full can or completely empty can is an acknowledged limitation. All measurement technologies have limitations. In the case of RTR, these limitations are known and understood. RTR error is anticipated and is accepted in the same way that all measurement technologies occasionally produce a result outside the accepted confidence interval. We continue to evaluate RTR at the sites where it is used and, through the Interface Working Group on Non-Destructive Evaluation, we will continue to make appropriate enhancements to this and other measurement systems[4-12].

[4-11]Neill, Robert H., Director, Environmental Evaluation Group. 1992. Letter of July 29 to W. J. Arthur III, WIPP Project Integration Office.

[4-12]Arthur, W.J., WIPP Project Director, WIPP Integration Office. 1992. Letter of October 29 to R.H. Neill, Director, Environmental Evaluation Group.

The DCCA should discuss these RTR limitations and provide the references to published reports reflecting the commitment to the continued evaluation of RTR at the sites subsequent to 1992.

Analytical Methods

Page 4-15, line 10

The limitations of each analytical method, radioassay, non-destructive examinations such as real time radiography, and, visual examinations should be discussed in detail with supporting references. For example, there is no system in place to radioassay RH-TRU waste.

Visual Examinations

Page 4-16, line 14

This section cites a miscertification rate of only 2 percent at the INEL. Further, the DCCA claims that this miscertification includes all WAC and Transuranic Package Transporter (TRUPACT)-II Authorized Methods for Payload Control (TRAMPAC) criteria, not just the presence of free liquids. This claim doesn't match data provided in the DOE's annual reports to the EPA on the TRU waste characterization efforts for the now abandoned bin tests. Out of 80 drums selected from a WAC certified population at INEL, 46 failed to meet the WAC and/or the TRAMPAC for a miscertification rate of 58%. The list of excluded drums from the annual report[4-13] to the EPA is shown below (Table 1). The observation tends to support the notion of requiring a thorough characterization as the EPA did for the No-Migration Determination for the Bin Test Program.

[4-13]U.S. Department of Energy. 1993. *No Migration Determination Annual Report for the Period September 1992 through August 1993.* DOE/WIPP 93-062.

TABLE 1. MISCERTIFIED DRUMS EXCLUDED FROM USE IN BINS

Drum Number	Bin Number	Nonconformance	Reason for Exclusion
RF004500559	IDRFBN9100001	Contained U-235[1]	Not applicable
RF002800598	IDRFBN9100001	Contained free liquid	WIPP WAC
RF001902106	IDRFBN9100004	Possible pressurized container	WIPP WAC
RF003101490	IDRFBN9100004	Possible pressurized container	WIPP WAC
RF005400341	IDRFBN9200005	Contained free liquid	WIPP WAC
RF005500375	IDRFBN9200005	Excessive decay heat	TRUPACT-II C of C
RF002800659	IDRFBN9200005	Excessive decay heat	TRUPACT-II C of C
RF000241353	IDRFBN9200005	Excessive decay heat	TRUPACT-II C of C
RF002201038	IDRFBN9200005	Excessive decay heat	TRUPACT-II C of C
RF002800703	IDRFBN9200005	Excessive decay heat	TRUPACT-II C of C
RF002301549	IDRFBN9200005	Less than 100 nCi/g	WIPP WAC
RF003100946	IDRFBN9200005	Less than 100 nCi/g	WIPP WAC
RF001901607	IDRFBN9200005	Possible pressurized container	WIPP WAC
RF001901991	IDRFBN9200005	Excessive decay heat	TRUPACT-II C of C
RF000239134	IDRFBN9200005	Excessive decay heat	TRUPACT-II C of C
RF000108833	IDRFBN9200006	Contained free liquid	WIPP WAC
RF074403825	IDRFBN9200006	Drum flammable VOC[2] >500 ppm	TRUPACT-II C of C
RF000237798	IDRFBN9200006	Excessive decay heat	TRUPACT-II C of C
RF002302673	IDRFBN9200006	Excessive decay heat	TRUPACT-II C of C
RF002202850	IDRFBN9200006	Excessive carbon tetrachloride	NMD
RF001908888	IDRFBN9200006	Excessive decay heat	TRUPACT-II C of C
RF001905358	IDRFBN9200006	Excessive decay heat	TRUPACT-II C of C
RF002203352	IDRFBN9200006	Excessive decay heat	TRUPACT-II C of C
RF001905574	IDRFBN9200006	Excessive decay heat	TRUPACT-II C of C
RF001215294	IDRFBN9200006	Excessive decay heat	TRUPACT-II C of C
RF002500316	IDRFBN9200006	Excessive decay heat	TRUPACT-II C of C
RF074403768	IDRFBN9300007	Contained free liquid/ Excessive decay heat	WIPP WAC TRUPACT-II C of C
RF005500406	IDRFBN9300007	Less than 100 nCi/g	WIPP WAC
RF074403890	IDRFBN9300007	Contained free liquid	WIPP WAC
RF000108844	IDRFBN9300007	Less than 100 nCi/g	WIPP WAC
RF074403907	IDRFBN9300007	Contained free liquid	WIPP WAC
RF074403900	IDRFBN9300007	Contained free liquid	WIPP WAC
RF074403740	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C

RF001901846	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF002500319	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF000210253	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF002500321	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF001901850	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF001901849	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF001904355	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF001904149	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF001905199	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF000210256	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF000108870	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF001905261	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C
RF001905674	IDRFBN9300007	Excessive decay heat	TRUPACT-II C of C

[1]At present, INEL is not capable of certifying drums suspected of containing, or determined to contain, U-235.

[2]Usage of the TRUPACT-II prohibits the transportation of containers exceeding the 500 ppmv limit. For this reason, Drum RF074403825 was excluded from Bin IDRFBN9200006.

CHAPTER 5. QUALITY ASSURANCE

Overview

While a compliance application should show evidence that specified requirements have been met, the material in this chapter does not address the requirements of 40 CFR 191, and specifically states that it does not address the proposed 40 CFR 194 QA requirements.

This chapter is mostly a description of the conceptual framework of the current CAO QA program. Many of the sentences seem to be simply lifted from NQA-1 or other such documents, with the verb "shall be" replaced by "is" or "are".

Model Validation

There is no discussion of model validation, which is vital to demonstrating compliance with the containment requirement through performance assessment. A detailed QA process is needed for performance assessments with a complete discussion of plans for model validation.

This chapter does not mention quality assurance for analysis. The Sandia procedures for analysis, choice of parameter values, performing calculations, and software quality control are only peripherically mentioned on the last page of Chapter 5.

Comparison of Chapter 5 (QA) and 40 CFR 191

There are no direct requirements in 40 CFR 191 concerning QA.

A description of the QA/QC performed on the data used to show compliance with the 40 CFR 191 requirements should be included. The requirements in 40 CFR 191 concern containment (191.13), institutional controls, post-closure monitoring, permanent markers, engineered and natural barriers, and waste removal (191.14), individual protection (191.15) and groundwater protection (191.16). Chapter 5 does not address QA for any of these areas.

Comparison of Chapter 5 (QA) and the Proposed 40 CFR 194

The proposed EPA criteria, 40 CFR 194, contain a list of specific QA requirements. However, Chapter 5 lumps QA (194.22) with expert judgment (194.26) and peer review (194.27), and states: "These requirements are not addressed in this document" (page 5.1 lines 15-17).

The draft compliance application should address them. DOE and EPA should develop a common understanding before a final compliance application is written. An examination of DOE WIPP QA documents and 40 CFR 194 requirements shows a gap that needs to be bridged.

The proposed 40 CFR 194.22(a)(1) states that DOE "...shall implement a quality assurance program that meets the requirements of ASME NQA-1-1989 edition, NQA-2a-1990 addenda (part 2.7) to ASME NQA-2-1989 edition, and NQA-3-1989 edition (excluding 2.1 (b) and (c))". DOE is not currently fulfilling this requirement.

DOT Shipping Container Requirements
Page 5-2, line 9

Various federal requirements codified in the Code of Federal Regulations are identified including 10 CFR 71 for Type B shipping containers. Since all CH-TRU waste will be placed in Type A containers, the list should also include 49 CFR 173, the DOT requirements for Type A shipping containers including tests.

QA Program Requirements
Page 5-2, lines 9-14

The NQAs are listed as sources for the QA program. These, and other "sources", are "...directed through the DOE Environmental Management (EM) QA Requirements and Description to the DOE CAO". In the CAO QAPD Revision 0, an appendix to the draft DCCA, only NQA-2 part 2.7 is specifically required (for software). The CAO QAPD Revision 0 is only partly based on NQA-1, and NQA-3 is not mentioned at all.

Revision 1 to the CAO QAPD is currently being developed; the draft also does not specifically require full implementation of the NQA requirements.

The Revision 0 software portion requires NQA-2 part 2.7 but the proposed Revision 1 does not, though it implements many (but not all) of its provisions. It is worthy of note that the proposed 40 CFR 194.23(b) also requires NQA-2 part 2.7 compliance.

The proposed 40 CFR 194.22 (b)(1) also specifies that the NQA-1, 2, and 3 requirements must be met for environmental monitoring, geological measurements, computations, codes, and models used to demonstrate compliance, expert judgements, disposal system design, all other data used to support compliance applications, and anything else "...important to the containment of waste in the disposal system." Documentation of most parts of all of these precede the only evidence provided in the July 15, 1994, CAO QAPD Revision 0 (Appendix QAPD), effective July 15, 1994.

Chapter 5 of the DCCA presents no evidence that full compliance with the NQAs occurred in the past.

WIPP Site Monitoring Programs
Page 5-7

This section describes the system used to assure the validity of the measurements of the environmental surveillance at WIPP. Unfortunately the data for radioactivity in water samples as well as the minimum level of detectability reported in water wells at WIPP on page 2-137 of the DCCA are incorrect. It might be helpful for DOE to reference the data obtained by EEG in our monitoring program for the past eight years.

Program Assessment
Page 5-8, line 10

The text states "Managers at all levels periodically assess the performance of their organization". This is an ideal; at INEL, Argonne West, the September 1995 CAO DOE audit discovered that no assessment of the waste characterization program at the Argonne

West facility had been performed since the previous WIPP-level audit in September 1993. If the statement was "Managers at all levels *are required to* periodically assess the performance of their organization" it would reflect the real QA program as it exists now, which may not necessarily have been true at the time data was gathered.

Qualifications of Existing Data
Page 5-9, line 1

Most of the activities cited in other sections of the DCCA were performed before the conceptual framework shown in Chapter 5 was in place. There are no specific descriptions of QA during the gathering of data for these earlier activities.

Page 5-9, lines 1-17 briefly describe Sandia's "Qualification of Existing Data" program, but provide no information as to which data are involved, what the status is, or when the information will be available.

Evolving requirements
Page 5-9, lines 19-31

This section briefly describes the evolution of the WIPP QA program requirements. Reference is made to NQA-1 as a "standard" for the program over the last 15 years. The proposed 40 CFR 194 requires compliance with NQA-1, NQA-2 part 2.7 (software), and NQA-3 (site characterization). Currently, the CAO QA program still does not require full implementation of ASME NQA-1, NQA-2, and NQA-3. It should be required.

Description Postdates Other Compliance Activities

Most of the activities cited in other sections of the DCCA were performed before the QA system described here was in place. There are no specific descriptions of QA for data obtained during these earlier activities. The work in Chapter 2 on site characterization, in Chapter 3 on the design and building of the WIPP facility, and in Chapter 6 on PA were mostly completed before the CAO QAPD (which became effective on July 15, 1994) was in place. The CAO QAPD (included as the appendix QAPD) is the only objective evidence presented in this document concerning QA activities.

CHAPTER 6. CONTAINMENT REQUIREMENTS

Basis of Review

The performance assessment in the DCCA has been reviewed by state-of-the-art terms in performance assessment. Because the compliance criteria for the standards were not finalized during our review, the DCCA has not been judged against the requirements of 40 CFR 194. It should be noted, that even with all the disclaimers, the DCCA is in the form of an application. It is no longer a demonstration of the methodology or a dry run. The DCCA must meet a higher expectation and after several iterations of performance assessment, the work is finally ready for a review to assess compliance with the EPA disposal standards for transuranic waste. In particular, the EEG evaluation is focused upon these questions:

Have all relevant scenarios been analyzed?
Are probabilities of scenarios adequately established?
Have consequences been properly stated?

Have All Relevant Scenarios Been Analyzed?

Not all potentially disruptive scenarios have been analyzed. Previous performance assessments for the WIPP analyzed only the effect of human intrusion by inadvertent drilling. In the DCCA, other possible disruptive events and processes have not been considered. Justification has not been provided for Features, Events and Processes (FEPs) not considered for regulatory reasons, or eliminated for low consequence.

What scenarios need to be considered? The EPA Standards stipulate that performance assessments need not consider events or processes that are estimated to have less than one chance in 10,000 of occurring over 10,000 years. In terms of analyzing human intrusion, the EPA suggests inadvertent and intermittent intrusion by exploratory drilling for resources (other than any provided by the disposal system itself) may be the most severe intrusion scenario assumed.

The EPA standards further state:

> Furthermore, the performance assessments need not evaluate in detail the releases from all events and processes estimated to have a greater likelihood of occurrence. Some of these events and processes may be omitted from the performance assessments if there is a reasonable expectation that the remaining probability distribution of cumulative releases would not be significantly changed by such omissions. (40 CFR 191, Appendix C).

Examination of the EPA's guidance for implementation of 40 CFR 191, subpart B, reveals the following:

- The lower limit for events and scenarios to be considered is 10^{-8} per year. That means, events and processes with a probability of occurrence of between 1 and 10^{-8} per year must be analyzed.

- The most severe human intrusion scenario that requires analysis is drilling into the repository. Less severe scenarios should be analyzed in accordance with the rule above.

- To omit the analysis of a particular event or process because of the lack of impact, first the lack of impact must be demonstrated by an analysis, not an assumption.

Certain human-initiated events and processes are known to be on-going in the vicinity of the WIPP (p. 6-36)[6-1] and have been retained for further analysis. However, these same on-going events and processes have been screened out from further analysis in the postclosure phase, presumably because of EPA's regulatory guidance.

Water injection for secondary recovery of oil and brine reinjection remains to be analyzed. Consider the impact of a specific case of water injection for secondary recovery. In 1991,

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[6-1] U.S. Department of Energy. 1995. *Draft Title 40 CFR 191 Compliance Certification Application for the Waste Isolation Pilot Plant*, Draft-DOE/CAO-2056.

Hartman, a small oil and gas operator, purchased a worked-out lease in the extreme southeast corner of New Mexico and started drilling. While drilling through the Salado Formation, Hartman encountered a massive salt-water blowout. Brine flowed from the well for five days before being controlled. A total of 5.7 x 10^6 L of brine was trucked away before a pipeline was installed. A New Mexico court determined that a major oil company's water flooding project 3.5 km away was responsible. This incident occurred at the southeastern corner of New Mexico, in the same Salado Formation that overlies the WIPP and is of relevance to the WIPP because within 3.2 km (2 mi) of the WIPP perimeter, there are over 120 producing oil and gas wells. Furthermore, secondary recovery by water flooding and brine re-injection has begun in these recently discovered fields.

Unexpected water flows are not rare events. Between 1978 and 1993, 189 unexpected water flows were reported to the New Mexico Oil Conservation Division for Region One, which encompasses approximately 6000 km^2 in the southeast corner of the state.

One example of a yet to be addressed scenario is as follows. Water or brine is injected into Marker Bed 138 or 139, introducing massive amounts of water into the repository, which carry dissolved radionuclides to the accessible environment.

Other potentially disruptive events that should be analyzed include the impact of potash mining. Over 80% of the potash in the United States is produced within 100 km of the WIPP. From the WIPP site one can see the surface works of three major potash mines. The potash is midway between the Culebra aquifer and the repository horizon. Potash mining has an extraction ratio well above 80%, and potash miners do not usually backfill mined out volumes. Thus massive underground cavities may exist in the future, and may be an additional pathway for radionuclide transport. Subsidence remains a concern that could affect the hydraulic properties of the overlying aquifers.

Are Probabilities of Scenarios Adequately Established?

Because the scenarios of water flooding and potash mining were not considered in the DCCA, no probabilities for these disruptive events have been estimated. The implication is that there is insufficient specification of probabilities.

Have Consequences Been Properly Stated?

The results of the performance assessment described in the DCCA are questionable because "place-holders" are substituted for the most important data.

During 1994 and 1995, the WIPP project undertook a Systems Prioritization study to focus resources on the key variables that control compliance demonstration. The study identified eight groups of variables which needed additional work for the final compliance certification application. For the DCCA, the values used for the eight variables are only estimates made by Sandia National Laboratories staff conducting the experiments. The data from these experiments are expected sometime in 1996 and later. Difficulties caused by using the predictions of the results of the experiments, rather than the experimentallly obtained values, are discussed below.

Solubility

Upon human intrusion by drilling, the release rate of radionuclides is the product of actinide solubilities and brine flux. In the DCCA, generic actinide solubilities are used. For example, the solubilities of Pu(III) and Np(III) are assumed to be equal. If this were true, then there would not be any need for solubility experiments in progress now.

For actinides with multiple oxidation states, they are partitioned according to the following scheme. Let n_1, n_2, n_3, n_4 be random numbers.

$$
\begin{aligned}
VI &= n_1/5, \\
V &= n_2\,(1.0 - VI)/(n_2 + n_3 + n_4), \\
IV &= n_3\,(1.0 - VI)/(n_2 + n_3 + n_4), \\
III &= n_4\,(1.0 - VI)/(n_2 + n_3 + n_4),
\end{aligned}
$$

This partitioning scheme implies that various oxidation states might exist jointly. At a specific pH and Eh, there is likely to be a unique dominant species and attendant oxidation state. (See WIPP P.A. Dept., 1992, p. 3-43).[6-2] One does not have a 10%, 30%, 30%, 30% mixture of oxidation states.

The solubility of actinides in oxidation state *y* is then sampled from 1 to 10^{-10} molar. In EEG-57[6-3] we commented on the futility of sampling from a wide range of solubility, and the lack of confidence such a procedure conveyed.

The partitioning of actinides into oxidation states is inconsistent with experimental evidence. In WIPP-commissioned Pu solubility measurements, no matter what the initial oxidation states were at the start of the experiments, 70% to 95% of the final oxidation state at steady state was Pu(VI) (Nitsche, et al., 1994 in Novak.[6-4] Yet in the above partitioning by oxidation states, only 20% or less of the total inventory is allowed to be in VI. The experimentalists could not explain the move to VI, and conjectured that it might be due to α-radiolysis. In the DCCA, it is reasoned that the repository would be reducing. However, the solubility experiments were carried out in contact with the atmosphere, resulting in the final oxidation state being VI. If the conditions in the repository are expected to be reducing, then the oxidation state will not be VI in the repository and the results of the experiments in contact with the atmosphere would not be applicable to the expected repository conditions. All of the aqueous separation processes for plutonium utilize the fact that Pu has a variety of oxidation states, each with widely varying chemical properties. Hence the interconversion of Pu among

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[6-2]WIPP PA (Performance Assessment) Department. 1992. *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992 — Volume 1: Third Comparison with 40 CFR 191, Subpart B.* Albuquerque, NM: Sandia National Laboratories, SAND92-0700/1.

[6-3]Lee, W. W-L., L. Chaturvedi, M. K. Silva, R. Weiner, and R. H. Neill. 1994. *An Appraisal of the 1992 Preliminary Performance Assessment for the Waste Isolation Pilot Plant.* Albuquerque, NM: Environmental Evaluation Group. EEG-57.

[6-4] Novak, C.F. 1995. *Actinide Chemistry Research Supporting the Waste Isolation Pilot Plant: FY 94 Results.* Albuquerque, NM: Sandia National Laboratories, SAND94-2274.

its various oxidation states has been the topic of much study.[6-5] Literature on the effect of radiation on the oxidation state of Pu in solution suggests that radiolysis and exposure to oxygen would actually decrease the average oxidation number. In HCl, the medium of the solubility experiments, the average oxidation number did not decrease, consistent with the experimental results. Thus the discrepancy between the experimental results and the partitioning rule needs to be explained.

Perhaps the most important note about the solubilities used in the DCCA is that DOE assumed a distribution of aqueous solubilities with large uncertainty (Appendix PAR, p. 250, 253, 256, 259, DCCA, vol. 1).[6-1]

No attempt has been made to justify the probability distribution used.

Conceptual Model for Flow in the Culebra

The DOE has identified intrusion scenarios that result in contaminated brine discharging into the Culebra Dolomite member of the Rustler Formation. However, for the calculation of direct discharge to the ground surface through borehole cuttings, the contaminated fluid is discharged to the ground surface bypassing entry into the Culebra. Thus, the two scenarios are inconsistent. How can brine enter the Culebra if a well-casing is present? Or, if the well is uncased, why shouldn't the brine enter the Culebra instead of flowing to the surface? The following quotation from the Disposal Room Model Position Paper summarizes current technology in drilling in the Delaware Basin.

> Within the Delaware Basin near the WIPP site, gas and oil wells are started by clearing the site and drilling a shallow hole (40') to house a conductor pipe. The conductor pipe is set in cement and serves to prevent surface sands from sloughing into the wellbore during later drilling. Drilling is continued below

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[6-5]Rabideau, S. W., M. J. Bradley and H. D. Cowan. 1959. *Alpha-Particle Oxidation and Reduction in Aqueous Plutonium Solutions*. Los Alamos, NM: Los Alamos National Laboratory, LA-MS-2236.

> the conductor pipe, to 300-600 feet to top of the salt section using a large diameter (17-26 inches diameter) drill bit and another steel casing is set.[6-6]

A similar statement appears in the DCCA.

> . . . oil wells normally have a standard 0.413 m drilled hole to the top salt to accommodate 0.340 m steel casing, and gas wells normally have a standard 0.445 m drilled hole to accommodate 0.356 m casing. (Appendix PAR, P. 223, DCCA, vol. 1).[6-1]

Thus, in order for radionuclide contaminated brine to flow into the Culebra, the fluid must flow through the pipe casing. In the 1992 performance assessment there was a nondegraded plug that forced discharge into the Culebra. Now the DOE assumes 100% failure of the casing!

The contaminated brine would not naturally flow into the Culebra and that is reinforced by the fact that the DOE set the permeability of other hydrostratigraphic units to zero to prevent brine from entering those units and to maximize the flow to the Culebra. The Unnamed Lower Member (p. 6-78), the Tamarisk (p. 6-85), and the Forty-Niner (p. 6-86) are all assigned zero permeability, and the Magenta (p. 6-85) and the Dewey Lake Redbeds (p. 6-86) are assigned low permeabilities.

There is a clear need to analyze two different scenarios: One with casing and the other without, and assign appropriate probabilities of occurrence for the two.

Retardation Mechanisms

In the postulated transport of radionuclides in the Culebra, three retardation mechanisms are used (DCCA, p. 6-80).[6-1]

[6-6]Butcher, B. M. et al. 1995. Disposal Room and Cuttings Models, Position Paper.

- Equilibrium Sorption;
- Matrix Diffusion;
- Corrensite Clay Sorption.

Our review raises questions about postulating each of these retardation mechanisms.

Equilibrium Sorption: During the advective-diffusive transport of contaminants, dissolved solute can adsorb onto solid surfaces or precipitate. The suite of processes that lead to contaminants traveling slower than the average pore velocity of ground-water flow is generally referred to as sorption. For many contaminants, many ground-water compositions, and many rock types, a linear isotherm results with

$$\frac{dS}{dC}=K_d \tag{1}$$

where S is the mass of solute adsorbed or precipitated per unit dry bulk mass of rock, C is the solute concentration, and K_d is known as the distribution coefficient. Using the distribution coefficient, one can compute the velocity v_i at which the particular contaminant will travel

$$\frac{v_i}{v}=\frac{1}{1+\rho_b K_d\left(\frac{1-\epsilon}{\epsilon}\right)} \tag{2}$$

where v is the average ground-water velocity, ρ_b is the bulk density of the rock, and ε is the matrix porosity.

Over the years there have been attempts to measure distribution coefficients relevant to the WIPP. However, these distribution coefficients do not represent anticipated conditions in the Culebra. First, because the chemistry of the water has a significant influence on sorption behavior. The isotherm experiments used unrepresentative chemistry for Culebra water, making the resultant distribution coefficients values invalid. Secondly, the distribution coefficients are from single measurements on powdered samples. Powdered samples have a different surface area to volume ratio and experiments with powdered samples are likely to overstate sorption in the field. As can be seen in eq. (1), it is difficult to obtain a proper K_d from a single measurement. Thirdly, review of the experimental conditions did not provide assurances that equilibrium conditions were reached in the isotherm experiments. Thus we conclude that experimental data valid for use in performance assessments of the WIPP are not currently available on partitioning coefficients for the Culebra Dolomite.

The problem is compounded because performance assessment did not use the flawed experimental data, but subjectively elicited probability distributions of distribution coefficients from Sandia National Laboratories employees. Clearly, additional data are needed.

The DOE is currently conducting a multi-well tracer test at the WIPP site. This test is designed to provide information on flow mechanism, as well as partition coefficients for actinides. In April 1995 the DOE dropped plans for a sorbing tracer test, while keeping the non-sorbing tracer test. Can one use a non-sorbing tracer test to obtain K_d for sorbing species?

For a nonsorbing species, the residence time t_n in a fracture of half-aperture δf is

$$t_n = (\phi_f + \phi_m)\ V_r/Q$$

where V_r is the volume of pores in the rock, Q is the water-flow rate, and ϕ_f and ϕ_m are the fracture and matrix porosities respectively.

For a sorbing species, the residence time in the same system is

$$t_s = (\delta_f + K_s) S_s V_r / Q$$

where K_d is a surface distribution coefficient, and S_s is the specific surface area.

It is apparent that the two residence times are different, and a non-sorbing tracer test cannot be used to obtain K_d for actinides.

Matrix Diffusion: Matrix diffusion has been shown to be an important mechanism in radionuclide retardation.[6-7] Water and contaminants in fracture flow result in transport of the contaminants from the fracture into the microfissures of the rock by diffusion. This diffusion of contaminants into the rock matrix and subsequent sorption onto the surfaces of the microfissures and dead-end pores is a significant retardation mechanism. This diffusive flux of contaminants from the fracture to the rock matrix (z direction) can be represented by

$$q = -\epsilon\tau\left(D'\frac{\partial C'_l}{\partial_z}\right)_{z=0} \tag{3}$$

where D' is the free-water molecular diffusion coefficient in the matrix (L^2/t),

ε is the rock porosity,

C'_l is the concentration of the lth solute in the matrix (M/L^3),

τ is the tortuosity correction (-).

Note the predominance of diffusive parameters.

The WIPP performance assessment takes credit for matrix diffusion, but offers no direct experimental evidence for its extent. The only related experiment was a diffusion test with a non-reactive tracer.[6-8] A series of multi-well, field scale, tracer tests has been planned but it is unclear how the results of these tests would provide unequivocal evidence for matrix

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[6-7]Neretnieks, I. 1980. Diffusion in the Rock Matrix: An Important Factor in Radionuclide Retardation? *J. Geophy. Res.* 85B:4379.

[6-8]Dykhuizen, R. C. and W. H. Casey. 1989. An Analysis of Solute Diffusion in Rocks. *Geochim. et Cosmo. Acta* 53:2797.

diffusion. Lee and Chaturvedi[6-9] have suggested some laboratory experiments to give direct evidence of matrix diffusion.

Corrensite Clay: The DOE identifies sorption on clay fracture-linings as one of three retardation mechanisms for radionuclide transport through the Culebra. The EEG was verbally informed that the assumption of corrensite clay as asorptive clay lining was dropped from future performance assessments. However, the definition sketch for SECOTP2D still shows corrensite clay lining (p. SECOTP2D-3).[6-1] The DOE is also funding basic studies on corrensite sorption mechanism. We will repeat the following comments on the lack of corrensite clay evidence in the Culebra fractures.

The concept of corrensite sorption is based on x-ray diffraction and analytical electron microscopy analysis of cores samples from clay-rich layers of the Rustler Formation, from wells drilled primarily in the Nash Draw, a topographic depression several miles west of the WIPP site and in a known Karst region. This concept originates from the work of Sewards and others.

Sewards, Glenn and Keil[6-10] presented mineralogical analysis of core samples from a single well, WIPP-19, and made no claim for clay-filled fracture linings in the Culebra.

Sewards[6-11] gave data on "whole rock" as well as "fracture surface" compositions of core samples collected from six wells in the Nash Draw, one borehole (WIPP-33) just outside the WIPP site, and three boreholes in the northern part of the WIPP site. Clays are expected to

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[6-9]Lee, W. W-L. and L. Chaturvedi. 1995. Radionuclide Retardation Mechanisms in the Culebra Aquifer at the Waste Isolation Pilot Plant. In *Proceedings of the Conference on Radioactive Waste Management and Environmental Remediation, ICEM "95, held in Berlin, Germany, September 3-7, 1995,* edited by S. Slate, F. Feizollahi, and J. Creer. New York, NY: American Society of Mechanical Engineers, 877-881.

[6-10]Sewards, T.R., R. Glenn and K. Keil. 1991. *Mineralogy of the Rustler Formation in the WIPP-19 Core.* Albuquerque, NM: Sandia National Laboratories, SAND87-7036.

[6-11]Sewards, T. 1991. *Characterization of Fracture Surfaces in Dolomite Rock, Culebra Dolomite Member, Rustler Formation.* Albuquerque, NM: Sandia National Laboratories, SAND90-7019.

be present in the Nash Draw cores because of extensive dissolution, weathering, and erosion in that area. WIPP-33 is located in a sink hole and dissolution, weathering, and erosion are expected. The other boreholes are located north of the WIPP repository and upstream from the expected direction of flow of water in the Culebra. Furthermore, cores from these wells are from sections with known clay seams.

Sewards, Williams and Keil[6-12] presented mineralogy of 107 core samples from eight wells, three of which are located in the WIPP site. X-ray diffraction analysis and an electron microscope were used to identify clays. However, electron microscopy raised doubt about the results of the x-ray diffraction results. When imaging was attempted on the electron microscope, it was extremely difficult to find any corrensite at all. However, Sewards, Williams and Keil[6-12] proceeded to conclude "that corrensite is the dominant phase in the Culebra."

Sewards *et al.*,[6-13] presented mineralogical analysis from 47 samples. Of these, 17 samples were taken from the Culebra, and of these only nine are from the WIPP site: six from the Air Intake Shaft and three from WIPP-12. The report (p. 28) states:

> Only small amounts of clay can be sampled from the Culebra fracture coatings; therefore, initial technique and model development for adsorption studies on WIPP clays (Park, et al., in review) were carried out with material from a black shale layer in the unnamed member. This material, so-called CorWIPP, is 94% corrensite and is described as Sample AIS-15 in this report. Corrensite has a high cation exchange capacity and affinity for the uranyl ion in dilute solution (Park, et al., in review) and could provide significant radionuclide retardation in fractures in the Culebra.[6-13]

[6-12]Sewards, T., M. L. Williams, and K. Keil. 1991. *Mineralogy of the Culebra Dolomite Member of the Rustler Formation.* Albuquerque, NM: Sandia National Laboratories, SAND90-7008.

[6-13]Sewards et al. 1992. *Nature and Genesis of Clay Minerals of the Rustler Formation in the Vicinity of the Waste Isolation Pilot Plant in Southeastern New Mexico.* Albuquerque, NM: Sandia National Laboratories, SAND90-2569.

The suggestion that corrensite clay-lined fractures in the Culebra may provide retardation for radionuclide migration is based on a single sample from a "black shale layer" obtained from the lower part of the Rustler Formation, below the Culebra, because not much clay could be sampled from Culebra fracture coatings. And yet, information from this sample is used to conjecture that "significant radionuclide retardation in fractures in the Culebra" could be present! Moreover, clay in fractures can act either as an additional sorption agent, or serve to block mass transfer between the fracture and the matrix. The *1992 Performance Assessment*[6-14] has eliminated the latter role. This is double counting for a mechanism which may not exist. Credit for corrensite sorption should not be taken in WIPP performance assessment unless demonstrated by additional evidence.

Colloids

Colloidal transport, a newly identified concern for the WIPP, has two components. The first concern is hydrodynamic chromatography, where colloidal particles might travel at the maximum velocity in a fracture rather than the average or retarded velocity. The second concern is that actinides might attach themselves to natural colloid particles, resulting in the same acceleration process. In the DCCA, colloids are not allowed to travel faster than the solute. This misses the essence of the concern for colloids in transport. The formation rate of colloids can be measured or calculated, but in the DCCA the initial colloid concentration is arbitrarily set by analysts.

Additional work is underway to delineate the role of colloids as a concern. We await the results.

[6-14]WIPP PA (Performance Assessment) Department. 1992. *Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992*, 3 vols. Albuquerque, NM: Sandia National Laboratories, SAND922-0700.

Conceptualization of Risk

Section 6.1.1, Page 6-3

Kaplan and Garrick[6-15] are cited as the basis for the ordered triple form of representing risk. Kaplan and Garrick recognize that it is impossible to identify all possible scenarios. In section 3.5 of the cited paper, they recommend the use of an N+1 scenario to represent all unidentified scenarios. Equation 2 is thus a deviation from Kaplan and Garrick that at least needs to be explained. A much better solution is to accommodate the N+1 scenario in the definition of risk and incorporate it as a modifier to the CCDF.

FEP Cutoff of 10^4 Years

Page 6-22, line 20

The 10,000 year cutoff may eliminate scenarios with significant impact. The DOE[6-16] noted that the time of maximum risk occurred at 1.6 x 10^6 years. The new NAS guidance to EPA for HLW disposal urges the calculation of risks for periods up to 1 million years. It is recognized that the EPA standard only requires 10,000 years in calculations but DOE should extend the time for their assessment.

Criteria for Screening of FEPs

Page 6-20, line 22; Section 6.2; Appendix SCR

By introducing an intermediate step, the draft application departs very sharply from the procedure proposed by Cranwell[6-17] and inappropriately eliminates viable features, events, and processes. A new elimination criteria is inserted as the second "sieve" (Regulations — DOE

[6-15]Kaplan, S. and B. J. Garrick. 1981. On the Quantitative Definition of Risk. *Risk Analysis* 1(1):11-27.

[6-16]U. S. Department of Energy. 1980. *Final Environmental Impact Statement, Waste Isolation Pilot Plant*, 2 vols. DOE/EIS-0026.

[6-17]Cranwell, R. M., R. V. Guzowski, J. E. Campbell, and N. R. Ortiz. 1990. *Risk Methodology for Geologic Disposal of Radioactive Waste: Scenario Selection Procedure.* NUREG/CR-1667. Sandia National Laboratories, Albuquerque, NM, SAND80-1429.

Interpretation) as shown in the figure below. Further, the procedure is such that the DOE determines which scenarios can be eliminated based on the DOE interpretation of the EPA regulations.

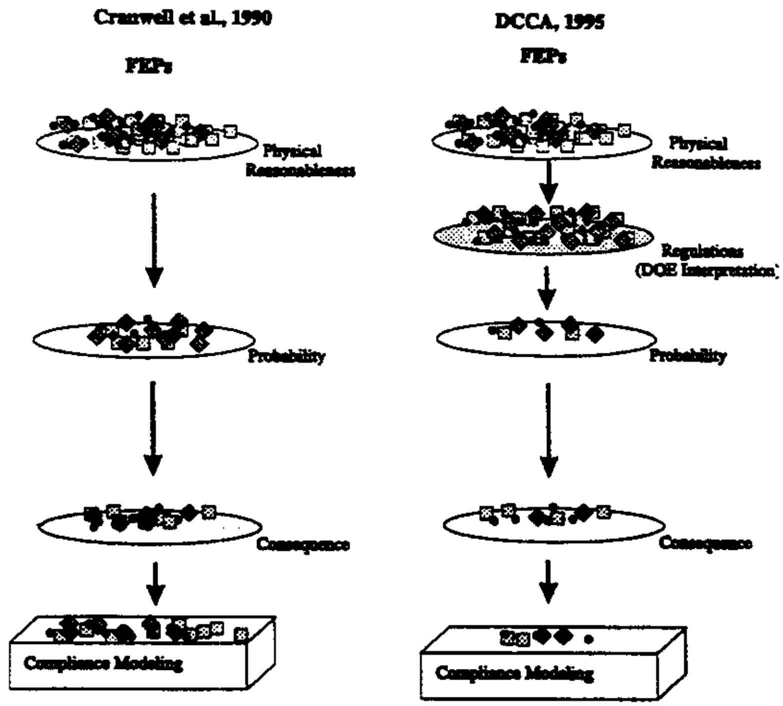

Figure 7. Comparison of Cranwell and DCCA Elimination Criteria.

Page 6-22, lines 18 through 21

Delete as a criteria for elimination of FEPs the new category, "*__Regulation__ or, more broadly, scope and purpose of the assessment...*" The category is entirely subjective as applied and ignores valid technical considerations.

Page 6-23, lines 20 through 27

The paragraph describing FEPs requiring additional documentation appears to be prejudging a yet to be completed study. The statement is made, "the DOE has modeling or experimental work underway to increase understanding of the potential importance of some of these FEPs, but all are considered of low consequence.... The basis for eliminating these is not yet fully documented." Why are these considered to be of low consequence while the investigations are still underway?

Page 6-24, lines 5 through 8

The paragraph describing FEPs elimination on the basis that they represent a design modification notes that the use of backfill has been eliminated. Yet the DOE has a formal agreement with the State of New Mexico to include backfill in the design of the repository.

Page 6-24, lines 22 through 31

The paragraph describes the category of FEPs that have been eliminated citing the non-binding guidance which was intended for a generic site. Further, the paragraph suggests that the non-binding guidance on FEP elimination reflects screening decisions made by the EPA. Our recommendation is to delete the paragraph and the entire SO-R category.

Page 6-25, line 16 through page 6-26, line 16

It is stated that the "regulatory screening arguments are used largely to limit consideration of future disruptive human-initiated events and processes as discussed in Section 6.4.2." Future disruptive human-initiated events and processes should be evaluated for viability on the basis of probability and consequence. It is unreasonable to present circuitous arguments and a very selective interpretation of non-binding guidance as the basis for eliminating very plausible scenarios such as those associated with resource extraction in a resource rich area. The EEG recommendation is to delete this entire section as well as Section 6.4.2.

Page 6-27, Figure 6-6

Delete the category SO-R to reflect a technical evaluation of the performance of the repository.

Page 6-31, Line 15

Replace the phrase "form the engineered barrier system" with the verb "are." For compliance with 40 CFR 191, the seals in the drifts, shafts, and boreholes are not considered to be engineered barriers.[6-18]

Page 6-31, Line 22

The text mentions a "current set of engineered barriers" without identifying these barriers and without citing a reference for more discussion in the draft application. Identify the barriers.

Page 6-36, Table 6-5a

The comments on this table require a review of the relevant portions of the appendix SCR, which is given below.

Page SCR-64, Line 16 - 22

The paragraph appears to take the position that activities initiated outside the controlled area subsequent to the time of submission of the final application will not be accommodated in the application. Rather, the DOE will rely on periodic reappraisals. However, it seems shortsighted to postpone evaluating the impact of the activities surrounding the WIPP given the following observations.

- Mining, drilling, salt water disposal by injection, enhanced oil recovery, and well abandonment are human activities.
- The WIPP is located in the Potash Enclave.[6-19]

[6-18] Meyers, S. 1987. May 22 letter from S. Meyers, Director, Office of Radiation Protection, EPA, to G.A. Smithwick, Principal Deputy Assistant Secretary, Environmental Safety & Health, DOE.

[6-19] Olsen, J. A. 1993. *Federal Management of the Potash Area in Southeastern New Mexico.* In New Mexico Geological Society Forty-Fourth Annual Field Conference, October 6-9, 1993: Carlsbad Region, New Mexico and West Texas. Socorro, NM: New Mexico Geological Society, 39-41.

- The Potash Enclave represents 80% of the nation's domestic production and 57% of the nation's reserves[6-20] — a scarce resource not widely available elsewhere.
- Commercial mining in the Potash Enclave has been ongoing for more than 60 years[6-20] — an area with long history of mining.
- The WIPP Land Withdrawal Area contains economically minable potash reserves[6-20] — an attractive target for future production.
- The WIPP Land Withdrawal Area is surrounded by potash reserves and active potash leases.[6-21,6-20]
- Potash is obtained by mining[6-20] — a potentially disruptive activity.
- Subsidence occurs over potash mines propagates fractures through overlying aquifers to the land surface[6-22] and poses a hazard to petroleum well casings.[6-19]
- Water level rises in WIPP monitoring wells to the north potentially correlate with brine disposal from the potash industry — a direct impact on the hydrology of the area.
- The EPA has identified the absence of mining scenarios in WIPP performance assessment as a critical omission.[6-23]
- The resource evaluation by the NMBM&MR/Westinghouse[6-20] clearly demonstrates that there are proven and/or probable oil and gas resources under each and every section
    1) within the WIPP Land Withdrawal Area
    2) and surrounding the WIPP.

[6-20]Broadhead, R. F., F. Luo, and S. W. Speer. 1995. *Evaluation of Mineral Resources at the Waste Isolation Pilot Plant Site.* New Bureau of Mines and Mineral Resources. Carlsbad, NM: Westinghouse Electric Corporation.

[6-21]Silva, M. K. 1994. *Implications of the Presence of Petroleum Resources on the Integrity of the WIPP.* Albuquerque, NM: Environmental Evaluation Group. EEG-55.

[6-22]Sanchez, P. 1995. September 19 memorandum to Mel Marietta, Sandia National Laboratories on Subsidence Crack at WIPP 28.

[6-23]Oge, M. T. and M. Shapiro. 1994. October 18 letter from the U. S. Environmental Protection Agency to G. E. Dials, Manager, DOE Carlsbad Area Office. 4 pages + attachments.

- Oil and gas reserves are obtained by drilling through the Salado Formation and into the underlying oil and gas bearing formations.
- The oil producing formations in the vicinity of the WIPP also produce high volumes of mobile water.[6-20] Salt water disposal wells surround the WIPP Site and are injecting up to a million barrels of water per year per well into a formation underlying the salt formations.
- In 1988, WIPP monitoring wells experienced sharp water level rises which were strongly correlated with a nearby salt water disposal well operated by the oil and gas industry.[6-24,6-25] The observation strongly suggested leaking salt water disposal is influencing the regional hydrology in an aquifer considered to be a potential pathway for radionuclides.
- Southeast New Mexico has a history of waterflood problems with injected water migrating from adjacent properties through the Salado Formation.[6-26, 6-24, 6-25, 6-27, 6-21]
- The BLM recently denied an application for permit to drill wells within the WIPP Site Boundary citing concerns including the unknown effects of water injection on the repository,[6-28]

The WIPP is undeniably located in a resource rich area as shown in the Figure 8.

[6-24]Bailey, J. 1990. August 13 Memorandum from Certified Professional Geologist #7521, Petroleum Engineer at New Mexico State Land Office to Marsh La Venue, Intera Consulting Company, Contractor to Sandia National Laboratories on Water Level Rises in Culebra Dolomite Monitor Wells.

[6-25]LaVenue, M. 1991. January 28 Sandia National Laboratories Memorandum to distribution on the Anomalous Culebra Water-Level Rises Near the WIPP Site.

[6-26]Ramey, J.D. 1976. May 5 memorandum from the Director of the New Mexico Oil Conservation Division to John F. O'Leary on Water Flows in and near Waterflood Projects in Lea County.

[6-27]Hartman, D. 1993. November 22 letter to Sandia National Laboratories transmitting a copy of a Complaint of Trespass, Nuisance, and Waste filed in the Federal Court for the district of New Mexico, CIV93 1349M.

[6-28]Calkins, W.C. 1994. August 22 letter from W. C. Calkins, State Director, Bureau of Land Management, to the attention of Keith E. Bucy, Bass Enterprises Production Co.

Page SCR-66, Table SCR-3b

The draft application identifies 42 plausible scenarios and then eliminates 37 citing the DOE category SO-R. Among those eliminated by this DOE interpretation include:

Fluid injection:

- Salt water disposal
- Enhanced oil and gas recovery
- Hydrocarbon storage

Potash Mining

- (including solution mining)

Flow through abandoned boreholes.

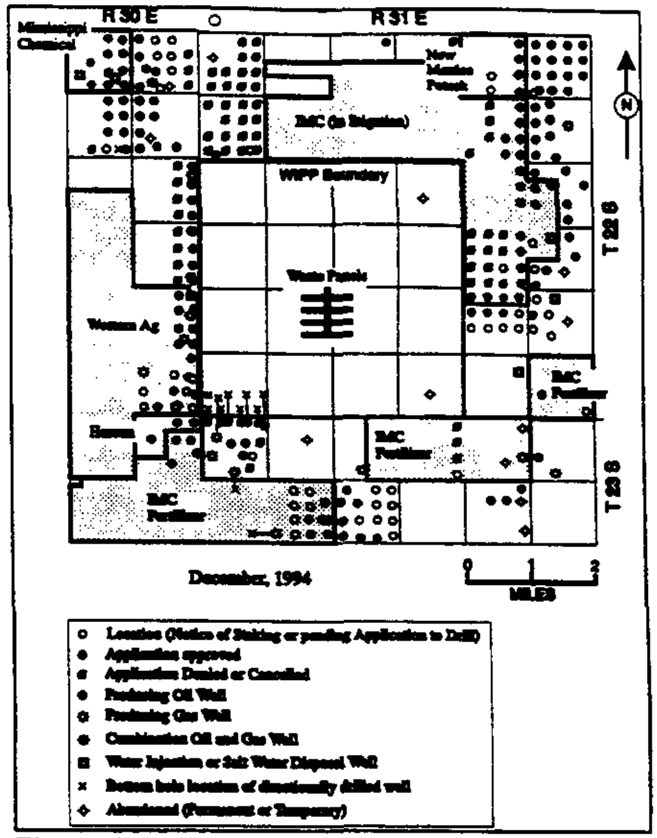

Figure 8. Natural Resources around WIPP site.

Page SCR-64, line 23 through page SCR-67, line 29

This paragraph acknowledges that the analyses of ongoing human initiated events and processes is underway and may be relevant when considering future initiated events and processes. But then the paragraph states that the extension of such analyses to anytime beyond October 1996 is speculative - an inconsistent position for an application that purports to calculate the behavior of a repository for the next 10,000 years.

Seals

Page 6-31, line 15

The statement, "Seals in drifts, shafts and boreholes form the engineered barrier system..." is wrong. The plugs and seals are not engineered barriers (see our comment on Section 3.3). The Panel Closure System shown in Fig. 3-1[6-1] has not been described. The vertical boreholes in the mine that extend upward and downward up to 100′ in the northern part of the WIPP excavations (abandoned in 1995) have not been plugged, and the DOE's WIPP

Experimental Area Mine Management Plan Phase I[6-29] justifies the decision on the basis that the boreholes will close by salt creep.

Salado Interbeds

Page 6-77, line 10

Discussion of the development of the simple interbed brine storage model from a literature search is referred to in Appendix PAR. While the model is described in the Appendix, the literature search is never mentioned.

Drum-Scale Variability in Spallings

Page 6-89 lines 1-9

It is stated that a sufficiently large volume of waste would be transported to the surface through spallings and that drum-scale variability can be neglected. Waste containers vary by several orders of magnitude in the activity of radionuclides they contain. The variation in the abundance of the relatively few activity level 4 or activity level 5 drums of Table 6-23 could dominate the activity of the spallings material. It needs to be demonstrated that the volume of waste entrained through spallings will be large enough to ensure average densities of radionuclides will reach the surface.

APPENDIX HYDRO

This appendix is a poor copy of the USGS Water-Resources Investigations Report 83-4016[6-30] and portions such as Figures 11, 12 and 16 are indecipherable. Originals of this report, that have not been marked up, do exist. If it is necessary to include this report as an appendix, reproductions from a better copy should be made,

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[6-29]U. S. Department of Energy. 1995. *Experimental Area Management Plan Phase I.*

[6-30]Mercer, J. W. 1983. *Geohydrology of the Proposed Waste Isolation Pilot Plant Site, Los Medanos Area, Southeastern New Mexico.* Washington, DC: U.S. Geological Survey. Water Resources Investigations 83-4016.

APPENDIX PAR

The formalized structure of Appendix PAR is very helpful. A specification of the equation number that first introduces the parameter in the description of the computational codes would increase the usefulness of the PAR appendix. Is the fracture spacing in the Culebra a SECOFL2D variable? Additional comments on this appendix are provided under the Appendix PAR heading.

APPENDIX BRAGFLO

The following criticism of the BRAGFLO code description may also be used as the EEG comments on code documentation in general. Appendix BRAGFLO presents a detailed and well developed description of the conceptual models implemented in the BRAGFLO code. The level of detail is, however, variable. For example, gas compressibility, Equation 31, is defined by a reference to a document that is not included in the DCCA. Without the referenced document, Equation 31 does not describe the model of gas compressibility.

BRAGFLO is apparently an isothermal code. This is never explicitly stated in the code description. More importantly, there is no defense given for an isothermal treatment of two-phase flow in WIPP. A discussion needs to be included to support such basic approximations. In addition, some assessment of the errors induced by approximations needs to be presented.

A reader friendly approach to identifying approximations is to 1) begin with the most general description of the phenomena to be modeled and then 2) introduce approximations that reduce the general description to the conceptual model implemented in the code. A section listing assumptions and limitations, such as NUTS.11, would also be very helpful.

Page BRAGFLO-21

BRAGFLO uses a user defined parameter to control the update frequency of the Jacobian matrix linearization. What assurances are there that the errors introduced by user control of code mechanics are acceptable? In general, assurances built into the codes are preferable to administrative controls.

Page BRAGFLO-48 Equation 128

Equation 128 is presented with almost no defense. If parameter n is an important parameter then Equation 128 must also be important and must be defendable. At the least, it must be shown that variance in parameter n is great enough to also cover conceptual model uncertainty. To aid in pursuing such issues, it would be helpful if the Appendix PAR variable name and page number were supplied when a new variable is introduced in a code description. In addition, when the variable is presented in the Appendix PAR it would help if the relevant equation number in the code description were listed as well as the code names.

APPENDIX CUTTINGS

The particular model used for calculations presented in the DCCA was not contained in Berglund (1992) and has not been documented in the DCCA. We understand that the experimental results did not support this model and it is now being discarded in favor of another model. We look forward to the complete documentation of the new model to be used for the final application (CCA).

Page CUTTINGS-10

The blowout calculation is limited to a five minute duration. The five minute limit is an important parameter. While the use of this parameter is justified in the text, it does not seem reasonable to have a fixed five minute time limit. Using a sampled parameter to represent this time limit is more justified. At least some runs should consider the situation of the blowout being allowed to run its course without intervention.

Page CUTTINGS-14

The list of sampled variables is helpful. It would also be helpful if the Appendix PAR variable names were listed along with the appropriate page number in Appendix PAR.

APPENDIX NUTS

This appendix contains material that seems to be in conflict with the usage of the code described on pages 6-97 and 6-98, *e.g.* Radionuclide decay. It is unclear whether the dual porosity and dual permeability features of the code will be used. Code descriptions should focus on those features that are used in the performance assessment modeling.

APPENDICES SECOFL2D and SECOTP2D

The code descriptions for SECOFL2D and SECOTP2D presented in the DCCA are insufficient to adequately defend the use of these codes for performance assessment. The conceptual models behind these codes are never discussed. Parameters are listed without any discussion of reasonable values. The lack of discussion of the use of a dispersion tensor for flow through a single fracture makes the use of Equation 1 questionable.

If the hydraulic transmissivity field of the Culebra Member is an important parameter as indicated on page PAR-230 then the conceptual models of flow and transport through the Culebra are also important. What is the basis for a parallel fracture model? What support is there for clay linings on the fracture walls? What is the influence of this assumption? If channeling is recognized as a possible important feature in anhydrite beds of the Salado Formation, why is it not considered as a possibly significant phenomena in the Culebra?

CHAPTER 7. ASSURANCE REQUIREMENTS

M

Purpose of Assurance Requirements

Page 7-1, lines 3-13

The document fails to state that the purpose of the assurance requirements in 40 CFR 191.14 is to provide the confidence needed for long-term compliance with the containment requirements of 40 CFR 191.13. The application should state the purpose and then show how the material that follows shows compliance.

The EPA, in 40 CFR 191.14, also notes that the Nuclear Regulatory Commission (NRC) has issued comparable provisions (10 CFR 60) applicable to facilities regulated by the Commission.

Page 7-1, line 36

After ".... effectiveness of those controls" add "in preventing or reducing radionuclide releases." Otherwise the reader is unaware of the reason for the controls.

Useful and Practical Active Institutional Controls

Page 7-2, line 3

The DOE interpretation is that active institutional controls (AICs) should be implemented as long as controls are useful and practical. DOE needs to specify how long they believe AICs are useful and practical.

Oversight Organizations

Page 7-2, line 23

Add EEG to the list of oversight agencies of AIC activities.

WIPP Active Institutional Control Program

Page 7-3, line 28

The steps identified for the WIPP AIC programs are so general and lacking in substance that it is difficult to comment meaningfully. The program should be clearly identified and defended for its projected effectiveness and duration.

Hot Cell as Post-Decommissioning Marker

Page 7-4, line 15

The text indicates that the concrete Hot Cell structure will be left in place. What are the plans for decontamination of that structure and disposal of radioactive material?

Uncontrolled Access to Site

Page 7-4, line 31 and Vol. II, page 13

While the site has 10,240 acres, the surface projection of the waste is only 120 acres. The text suggests that slant drilling is unlikely to occur in the remaining 10,120 acres into the repository. No explanation is offered for this assumption; particularly since the current experience in the Delaware Basin is contrary to the assertion. No restrictions on regular drilling in the site area outside the fenced area are identified which would be contrary to the requirements of active institutional control.

Description of Active and Passive Controls

Page 7-5, lines 30-33

A detailed description of the planned active and passive controls should be provided as a part of the Compliance Application and not "by October 30, 1997".

Monitoring Period
Page 7-7, line 18

Specify the length of time that monitoring would continue. DOE should have some estimate of the length of time that is realistic.

Monitoring
Page 7-7, line 20

Specify any other parameters to be monitored. Subsidence and groundwater in the Rustler are the only ones mentioned.

Groundwater Sampling
Page 7-7, line 21

How and when would the boreholes from the surface to the Rustler dolomite aquifers be plugged? Would the markers include this information?

Disposal System Monitoring
Page 7-8, line 25

How will the geochemical performance be assessed to substantiate assumptions regarding the characterization of brine and waste?

Page 7-8, line 27

What plans are there to monitor the efficacy of borehole plugs as a function of time?

Subsidence

Page 7-9, line 22

In view of the decision not to backfill the experimental area to the north immediately adjacent to the repository, how will one determine the effects of subsidence from the backfilled repository versus subsidence resulting from the experimental area?

Subsidence Measurements

Page 7-9, line 31

The subsidence studies should also predict Culebra settlement now as a result of potash mining. Data exist of the extent of Culebra settling where high potash extraction rates have occurred in the Basin. Such measurements can be made now in areas where potash has been mined to determine whether fracturing has been induced in the Culebra elsewhere in the Basin which could affect performance assessment calculations.

Environmental Radiation Surveillance

Page 7-11, line 1, Baseline Database

The environmental measurements obtained and published by EEG should be included. The EEG measurements cover a longer period of time than DOE's, contain specific radiochemical analyses which DOE has yet to implement, and the EEG Laboratory has participated in the EPA Quality Control programs with excellent results.

Preoperational Data

Page 7-12, lines 10-13

Preoperational data do not include the Aerial Radiological Survey of the Waste Isolation Pilot Plant and Surrounding Area[7-1] which identified ^{137}Cs within a few miles of the WIPP boundary.

[7-1]Berry, H.A., 1989. *An Aerial Radiological Survey of the Waste Isolation Pilot Plant and Surrounding Area, Carlsbad, New Mexico.* EG&G Energy Measurements. AMO-8809.

Future aerial radiological surveys listed on line 4 should include the Gnome site where measurable levels of fission products are on the ground surface. The location and movement of this contamination which contains radionuclides common to elements in the WIPP waste should be closely monitored so as not to be mistaken for WIPP related radioactive materials by future investigators.

Passive Institutional Controls

Page 7-13, line 26

Again, the purpose of PICs is to help provide confidence that the containment limits in 191.13 are met.

Perpetual Care

Page 7-13, line 44

DOE states that they will preserve knowledge of the site in perpetuity. That is much longer than the required 10^4 years.

Existing TRU Waste Markers

Page 7-14, line 7

DOE plans a number of elaborate markers and records. Please describe and reference markers and records currently used at TRU waste disposal sites in Nevada, LANL and ORNL for wastes buried prior to 1970.

Credit for PICs

Page 7-16, line 1

"The DOE believes that PICs will render human intrusion sufficiently unlikely so that the possibility need not be included in the CCDF." What is the basis for this statement? EEG believes it does not make sense to take any credit for a reduced future drilling frequency based on PICs, beyond 100 years.

Status of Passive Institutional Controls to Date
Page 7-16, line 19

The statement that DOE has been successful in gaining control of the subsurface to 6000 feet including the acquisition of oil, gas and potash leases is misleading since there are valid leases for slant drilling of 16 boreholes under the site. Please add a sentence to that effect to insure no confusion.

Buried Markers
Page 7-16, line 44

There is an excellent opportunity to place records in the SPDV experimental area adjacent to the repository now. Why not place messages there before it becomes unsafe to enter?

Missing Radiation Protection Standards
Page 7-22, line 27

The list of documents to be archived does not include a copy of the radiation protection standards used to protect the public health and the environment and the basis for them. There is no reason to believe that standards in place today will be the same in the long term future. Indeed, the allowable dose to the Nevada off-site community from weapons testing in the atmosphere in the 1950's was 3900 mrem per test series. Today, the allowable annual exposures being considered for waste disposal are 10 to 30 mrem. To deter future human intrusion, it is vital that future generations know what the acceptable risks were at the time of disposal.

Notification of Agencies
Page 7-23, line 1

After repeated requests by DOE, in 1992 Congress assigned the 4 mile x 4 mile BLM, DOI site to DOE in perpetuity. To date DOE has not delegated or assigned their authorities back to BLM, Dept. of Interior or to the State of New Mexico to establish a system to prevent drilling permits to be issued. Indeed, elsewhere in the text (Vol. II, Page 13) DOE states there is zero probability that slant drilling from a site within the 4 mile x 4 mile zone would intersect the repository. Hence, DOE would rely on their interpretation of current slant drilling practices in the Delaware Basin.

Archives
Page 7-23, line 14

DOE would rely on the local office of BLM, DOI to archive information. Local offices are consistently closing and reconsolidating. The information should be sent to all offices of BLM.

Monuments
Page 7-25, line 38

The plans call for expensive monuments. Consideration should be given to leaving the Hot Cell with 3 foot thick walls in place and using it as a monument to store records. This would save the cost of dismantling the Hot Cell and erecting a structure with thick walls to insure longevity.

Additional Study
Page 7-26, lines 1-8

Please add an additional study to evaluate the confusion to future generations where elaborate markers are placed at WIPP with TRU waste at 2150' depth and none are placed at pre-1970 TRU waste disposal sites at depths of a few feet.

Engineered Barriers
Page 7-26, line 35

DOE states that the proposed 40 CFR 194.44 imposes additional requirements. We disagree. The proposed criteria provide a basis to select or reject various proposed engineered barriers.

Page 7-26, line 43

DOE defines the "repository" as an engineered barrier. This is inconsistent with other regulatory agency definitions.

Commitment/Non-Commitment to Backfill

Page 7-27, line 1

DOE states that they will use backfill if appropriate. Line 43 acknowledges the Department has committed to include properly designed backfill in the repository. Which is the correct statement?

Need for Backfill

Page 7-27, line 2

DOE states that using backfill to fill voids or mitigate fires is not needed. That is not the primary purpose of using backfill, and the statement is irrelevant. Backfill can reduce the amount of brine that reaches the waste, reduce the amount of gas being generated, allow earlier room closure and minimize settlement in the overlying strata and reduce the probability of fracturing in the Culebra dolomite. Last but not least, it provides a use for some of the 10 million cu ft. of salt left over on the surface.

Evaluation of Engineered Alternatives

Page 7-27, line 11

The DOE Engineered Alternative Task Force only looked at engineered alternatives from the standpoint of changing the rate of gas generation or the total amount of gas that could be generated. It did not consider any other merits of engineered alternatives.

Defense in Depth Using Engineered Alternatives
Page 7-27, line 14

The DOE/EPA study is a cost-benefit analysis of engineered alternatives. As such it is not meaningful to assign a financial value to improved confidence in predicting that the probability is less than 1/1000 of releasing more than 10 x the Table 1 (40 CFR 191) limits to the accessible environment over 10,000 years. The purpose of the engineered barriers is to improve confidence in our ability to confine the wastes. It was never intended to be quantified.

Page 7-27, line 38

The DOE interpretation that only those engineered barriers and waste form modifications that are necessary to meet the calculated behavior of the transuranic wastes for 10,000 years is, EEG believes, a minimal approach. Relying on the calculations almost exclusively is contrary to the concept of multiple barriers and defense in depth adopted by virtually all organizations engaged in radioactive waste disposal. Also, the Assurance Requirements (40 CFR 191.14) require engineered barriers, irrespective of and in addition, to the ability to demonstrate compliance with the containment requirements
(40 CFR 191.13).

Multiple Engineered Barriers
Page 7-28, line 6

Although DOE repeatedly states they use multiple engineered barriers, the only ones planned are shaft seals. It is interesting to note that NRC will not give DOE any credit for shaft seals as an engineered barrier for HLW disposal in Nevada and DOE has accepted that position. Also, the EPA definition of Barrier (40 CFR 191-12) and the EPA stated position does not allow seals to be an engineered barrier (see our comment on Section 3.3).

Meeting 40 CFR 191.14(e) Requirements

Page 7-28, line 28

DOE states that the intent of this requirement was met during site screening and selection. EEG disagrees. Site screening and selection occurred prior to the 1985 promulgation of 40 CFR 191. Additionally, EEG raised a number of issues in correspondence with DOE in our attached letters of February 13, 1990, August 10, 1990, and December 27, 1991 that were not addressed in the 1993 DOE report "Implications of the Resource Disincentive in 40 CFR 191.14(e) at WIPP."

Page 7-28, line 36 and line 41

The statement that EPA discourages the location of repositories in areas in which valuable material resources are present is misleading in that it omits two other requirements specified in the 40 CFR 191.14(e). They include places where there has been mining for resources, expectations for exploration for scarce resources or a significant concentration of rare material. If a site fails the 3 mineral requirements, the standard requires the applicant to identify the potentially favorable characteristics of the site that outweigh the risks. That has not been done.

Presence of Resources

Page 7-29, line 40

See EEG's Comments on Appendix IRD.

CHAPTER 8. INDIVIDUAL AND GROUNDWATER PROTECTION REQUIREMENTS

To show compliance with the individual protection requirements, a dose calculation needs to be done. To show compliance with the groundwater protection requirements, a concentration calculation has to be made. The DOE has not done either calculation and has not performed the assessments required by 40 CFR 194.55. Hence, it is not possible to provide meaningful comments.

EEG COMMENTS
on the
DCCA APPENDICES

PARAMETERS
(VOLUME I. APPENDIX PAR)

It is disappointing that the DOE has postponed providing specific information on the following 23 of the 53 parameters sampled in the analysis presented in Appendix PAR. The information will not be available until the final CCA is issued.

Page	Parameter
46	Residual Brine Saturation of Halite
56	Threshold Pressure in Halite
60	Intrinsic Permeability of Anhydrite Layers and Marker Beds
82	Threshold Pressure of Anhydrite Layers and Marker Beds
84	Residual Brine Saturation of Anhydrite Layers and Marker Beds
87	Residual Gas Saturation of Anhydrite Layers and Marker Beds
108	Brine Storage Model for Unfractured Interbeds
113	Brine Storage Model for Altered Interbeds
214	Intrinsic Permeability of the Shaft Seals
226	Shear Strength of Waste in the Panel
240	Uranium Oxide State
243	Plutonium Oxide State
247	Neptunium Oxide State
249	Solubility of Aqueous Radionuclides in Oxidation State III
252	Solubility of Aqueous Radionuclides in Oxidation State IV
255	Solubility of Aqueous Radionuclides in Oxidation State V
258	Solubility of Aqueous Radionuclides in Oxidation State VI
261	Fracture Spacing in the Culebra
265	Partition Function for Americium in the matrix of the Culebra
269	Partition Function for Neptunium in the matrix of the Culebra
273	Partition Function for Plutonium in the matrix of the Culebra
275	Partition Function for Thorium in the matrix of the Culebra
279	Partition Function for Uranium in the matrix of the Culebra

Halite Permeability
Page 1

The permeability of the halite blocks in the BRAGFLO model represents the permeability of "impure halite" which is based on extensive testing. It needs to be demonstrated that this representation bound the influences of interbeds of other materials such as polyhalite and anhydrite. Such calculations should include consideration of enhanced anhydrite permeability due to high gas pressures.

Halite Specific Storage
Page 17

The BRAGFLO model represents regions of Salado halite that includes numerous interbeds of varying mineralogy. If halite specific storage is used to represent these regions, it should be demonstrated that the specific storage contribution of these marker beds can be neglected.

Gas Storage Model for Interbeds Altered by Interbed Fracture
Page 105

The range values (1/3 to 10^{-3}) of C_g given in the equations do not agree with the values (1/10 to 10^{-6}) given in the text. The values for other parameters in the equation should be given in the discussion. These are: h_g, e_g and r.

Brine Storage Model for Unfractured Interbeds
Page 109

The discussion for this parameter is identical to the discussion for the brine storage in altered interbeds and applies to that parameter rather than the unfractured interbeds.

Initial Liquid Saturation of Panel and Repository
Page 206

The initial liquid saturation of the panel and the repository is based on an EG&G INEL memorandum on waste from the Rocky Flats facility. The memorandum presents the data as pints per drum of waste. A recommendation is given in the memorandum that a poisson distribution should be used to characterize the per drum liquid content. The conversion of this data to initial liquid saturation of the panel and the repository is not presented nor is any reference made to a conversion. The cumulative distribution function used in the performance analysis is linear corresponding to a uniform distribution function. No mention is made of whether the recommended poisson distribution has been ignored or whether the uniform distribution is a result of the conversion of the per drum data to panel averages.

The data is from a single source. No discussion is presented about how representative this sample is to the waste to be stored in WIPP. The lack of a description of the data conversion process prevents an evaluation of whether the data used in the performance analysis adequately bounds saturation induced from waste from all potential sites.

SCREENING CRITERIA
(VOLUME I. APPENDIX SCR)

Major Concerns

1. Although various phenomena have been screened out on the basis of low probabilities of occurrence or insignificant consequences, we are concerned about synergistic effects of these independent events occurring which could have a substantial impact on the repository's predicted behavior.

2. There are no calculations or evidence provided to support the conclusions that various FEPs can be assumed to have little if any impact on probabilities or consequences, except for meteorite impact.

3. The impact of potash mining on subsidence and fracturing in the Culebra has not been addressed.

4. EEG does not believe that it is reasonable to automatically exclude human initiated events on the basis that the regulations do not require such analyses. This applies to the impact of potash mining on the geohydrological characteristics of the Culebra, fracturing in the Salado at the repository horizon from brine injection, or other man-made activities. DOE has the authority to self-regulate in other areas and the position taken by the Department to only address failure modes that are *required* by EPA to be addressed will undermine public confidence in the assertion that it is a world-class design.

5. What are the definitions and quantitative thresholds of "low probability" and "lower consequence" used to screen out various phenomena for consideration?

Regional Tectonics
SCR-8, line 19

Please provide an analysis to justify the deletion of regional tectonics on the basis of low consequence to the repository system performance.

Fracture Development
SCR-13, line 29

Naturally induced fractures affecting groundwater flow have been ruled out, but there does not appear to be a discussion of fracture development due to human initiated events.

Deep Dissolution
SCR-17, line 18

While deep dissolution has been ruled out on the basis of a low probability of occurrence, what is the calculated probability over 10^4 years?

SCR-18, line 11

The text states that deep dissolution is not a problem but that dissolution at depth is still taking place. Can this effect be bound?

SCR-19, line 2

Include a discussion on the age and mechanism of collapse breccias.

Flooding
SCR-23, line 2

Include a discussion on the evidence for and against downward percolation of water.

SCR-28, line 12

The position taken by DOE that assessments of the individual dose and impact on ground water are not required by EPA for the disturbed case is not particularly comforting. DOE should undertake such analyses.

Waste and Container Characterization as Described in Chapter 4
SCR-28, line 25

Contrary to the text, the container characteristics are not described in Chapter 4.

Nuclear Criticality
Section 2.3.2, Page SCR-38

EEG looks forward to a detailed analysis of the potential for nuclear criticality and the resultant heat generation. The EEG was actively involved in studying this issue in the 1981-85 period and sent two reports to the DOE. The issue should be reexamined in light of the current design of the repository, Waste Acceptance Criteria, Characteristics of the WIPP mine shafts, and the retardation characteristics of the Rustler aquifers. Both RH and CH-TRU Waste should be considered in such a study.

Copies of three letter reports, dated September 1981; December 30, 1993; and January 18, 1984, from Sanford Cohen and Associates are attached as Supplements 2, 3, and 4 to this report to help DOE prepare an up-to-date report on this subject.

Backfill Commitment
SCR-39, line 21

The text indicates that the repository will not be backfilled. This is contrary to the C&C Agreement between New Mexico and DOE.

Roof Falls
SCR 39, line 29

Add a discussion on the experience in the WIPP mine with roof falls.

Thermally Induced Stress
SCR 40, line 6

What is the basis of the assumption that the effects of thermally induced stress in the repository can be eliminated from performance assessment on the basis of low consequence and the documentation will be available in the final CCA?

The text notes that thermally induced stress could result in pathways for ground water flow in the DRZ, in the anhydrite layers and member beds, and through seals or enhance existing pathways. Please include the analyses to support the assumption of no consequence.

SCR-40, line 24

See EEG comment on SCR-38, line 5

SCR-41, line 3

Flow through sealed investigation boreholes has been eliminated on the basis of low consequence to P.A. An analysis of the impact of the 100 foot boreholes extending upward and downward from the repository horizon should be presented.

Thermal Convection
SCR-42, line 4

Although the statement is made that the extent of thermal convection arising from heat generation has yet to be done, DOE has eliminated thermal convection on the basis of low consequence. The conclusion appears premature.

Backfill
SCR 60, line 16

The DOE conclusion that backfill is not warranted on the basis of little impact on subsidence does not address other more relevant advantages from backfill such as the ability to restore the near field characteristics to the undisturbed rock quicker, to minimize the effects of roof fall in completed panels during the 35 year waste emplacement, to minimize gas generation by brine inflow, and others.

Human Initiated Events
SCR-60, line 34

EEG disagrees with the position taken by DOE not to evaluate the individual dose or the impact on groundwater because the regulations do not *require* them for human initiated events.

EEG disagrees with the DOE contention that human initiated events that might occur after 1996 should not be addressed.

SCR-61, line 5

EEG disagrees with DOE's contention that the effects of human actions after 1996 which may disrupt the disposal system do not have to be considered.

Deleting Potential Failure Modes
SCR-63, line 31

The logic presented by DOE for not considering various failure modes is to hold EPA responsible for the exclusion. This appears inconsistent with the stated aim of DOE to insure the full protection of the public health and environment.

SCR-64, line 6

DOE's position on post CCA submission is to only consider the effects of potentially disruptive events that occur prior to the 1996 Final Application. EEG does not agree with this and believes potentially disruptive events in the future such as brine injection to enhance oil recovery and potash mining effects should be considered.

Fluid Injection

SCR-72, line 11

DOE concludes that the effects of recent and ongoing fluid injection through boreholes outside the controlled area can be eliminated on the basis of low consequence to P.A. What is the basis for this conclusion?

Events More Severe than Bounding Events

SCR-73, line 11

Eliminating fluid injection from P.A. calculations since it is more severe than the bounding limit (inadvertent intrusion) defies common sense.

WIPP ACTIVE ACCESS CONTROLS AFTER DISPOSAL DESIGN CONCEPT DESCRIPTION DRAFT
(VOLUME II)

Summary

While a considerable amount of detailed information is presented, this section does not identify specific active institutional controls and how they will help fulfill the assurance requirements of 40 CFR 191.14(a) active institutional controls.

Nowhere in this section is the purpose of active institutional controls (AICs) listed. 40 CFR 191.14 states that it is to provide the confidence needed for long-term compliance with the requirements of 191.13 (40 CFR 191.13 containing the Containment Requirements).

The section also addresses passive institutional controls (PICs) without including a definition or explaining their purpose. There is no explanation of how and when the DOE will delegate or assign authorities obtained under the 1992 LWA to the Department of the Interior or to New Mexico to implement a system to prevent issuing a license or permit to drill or mine.

The title of this section does not match the EPA requirement. "Active Institutional Controls" has been changed to "Active Access Controls". Why?

Detailed Comments follow:

Paraphrasing the Regulations
Page 1, Section 1A

The language of the Regulations should not be paraphrased. Example: The text states that Title 40 CFR 191.12 defines Active Institutional Control as.... The exact language is, "Active Institutional Control means...."

Purpose of Active Institutional Controls
Page 1

The text correctly quotes 40 CFR 191. 14(a) but it should include the full 40 CFR 191.14 citation which states that the purpose is to provide confidence that the containment requirements in 191.13 will be met. It is not merely to control access to the site.

Passive Institutional Controls
Page 2

References to Permanent Markers should either be deleted or rewrite this section to clearly indicate that Passive Institutional Controls (PICs) are included as well as AICs. Permanent markers do not constitute active institutional control.

Documentation in Application
Page 2, Paragraph 2

Two other reports, Conceptual Decontamination and Decommissioning Plan and Long Term Monitoring Design are cited. Are they a part of the package to demonstrate compliance with 40 CFR 191.14(a) assurance requirements?

Long-Term Effects of Mining
Page 2

DOE is to be commended for acknowledging potential problems associated with mining.

Incorrect WIPP Mission
Page 3

Change the R&D mission of WIPP to one of disposal.

WIPP Waste Limits
Page 3, Paragraph 4

Since the limit on waste volume is specified, add limits of 5.1 million curies for RH-TRU and 1000 R/hour for 12,500 Cu ft of RH-TRU.

Design of Repository
Page 4

Where are panels 9 and 10?

Site Access
Page 5, Paragraph 2

Explain the term "occasional access to the site". It is unclear whether it means to intrude into the waste or have access to the surface.

Panel Seals
Page 8, Figure I-3

Also show a diagram of proposed panel seals.

Underground Markers
Page 11

Decide now whether to place markers underground in the non-backfilled experimental area adjacent to the repository. The opportunity will soon be lost since access will be too hazardous.

Page 13, Paragraph 2

"The salt formations do not support slant drilling due to insufficient consolidation of the salt material." What is the basis for this statement? The following sentence in the text concludes that it is not necessary to have a system to prevent slant drilling in the 4 mile x 4 mile area because it is unlikely. Can one assume that there are no plans by DOE to actively prevent vertical drilling in the remaining 10,120 acres of the WIPP site during the first 100 years? This appears to violate the EPA standard and the P.A. has not addressed this scenario of unrestricted mining during the first one hundred years.

Paraphrasing the Standards

Page 16

Top of page. Paraphrasing the exact language in the regulations can lead to confusion. For example, "Title 40 CFR.12 defines Active Institutional Control to include four elements." The verb "include" suggests that one is not necessarily limited to the following list whereas EPA intended it to be limited to <u>only</u> those items that follow.

Misinterpretation of the WIPP Land Withdrawal Act

Page 16, IV, Paragraph 2

Assuming that the mere existence of the 1992 WIPP law will insure the requirements are met without any enforcement for the next 100 years by implementing low technology barriers may be unduly optimistic.

Drilling Probabilities

Page 17, Paragraph 1

"The risk of drilling at a location outside the disposal area surface footprint and inadvertently intruding into the disposal area is essentially zero."

A. Do you mean "risk" or "probability"?
B. Where are the calculations to substantiate this statement?
C. On what basis is the writer confident that the current practice will apply for 100 years?
D. If slant drilling is not practical (as allowed) why has there been extensive slant drilling in salt formations?

Long-Term Monitoring

Page 22

The only long-term monitoring planned by DOE are measurements of subsidence. Other monitoring should be planned as well.

Page 27

The material to be archived should also include a copy of the standards since the allowable risks may be substantially different in the future and future generations may have a different threshold of an acceptable risk. This is much more important than many of the other reports.

Since the EPA standards urge the reader to see comparable provisions issued by the NRC for high level waste, include a comparison of items not being done at WIPP and add 10 CFR 60 to the list of references.

What are the plans for markers, records and active institutional control for TRU waste that has been buried to date? List those plans in the references since those PICs may not all survive. Include an explanation why we have markers for TRU waste buried at 2150 feet and none for TRU waste buried in shallow formations so that future generations can understand our logic.

BIENNIAL ENVIRONMENTAL COMPLIANCE REPORT (BECR)
(VOLUME II)

Background

While DOE is a regulatory agency and DOE Orders are applicable to this project, DOE is not identified as such in the list of regulatory agencies. It is essential that public accountability of compliance with DOE requirements be included. The BECR report provides detailed information on the status of compliance with laws, regulations and standards by a number of regulatory agencies. Unfortunately, the report omits any information on the status of compliance with regulations issued by a key regulatory agency, namely the U.S. Department of Energy. An analysis of the DOE Orders, and the reviews and approvals by the Office of Environment Safety and Health (ES&H) and the Defense Nuclear Facilities Safety Board (DNFSB) should be included.

It should be made clear that the Administrator of EPA or the State, as appropriate, shall determine whether DOE is in compliance with all the regulations and permits listed in Sect. 9(a)(1). Use the full, exact citation in the Land Withdrawal Act.

The cutoff date of a year prior to reporting is needlessly long. It should be six months.

WIPP LWA Requirement
Page 1.2

Provide the specific citation, Section 9(a)(2), in the 1992 LWA that this section shows compliance with.

Codification of Regulations
Page 1-3, 1.3.2

The description of the mechanism for promulgating regulations by federal regulatory agencies is good. It should be noted that DOE, as a regulatory agency, has not published proposed regulations in the Federal Register nor codified them in the Code of Federal Regulations.

DOE has issued regulations as DOE Orders without a public review process. The text on page 13-2 acknowledges that the DOE Orders are not considered to be at the same levels as those in the Code of Federal Regulations. DOE is now beginning to codify regulations in the CFR.

Page 2-8

40 CFR 268.10-12 requires waste for treatment to be evaluated. If the DOE treats mixed TRU waste, additional documentation should be provided.

CRCLA Requirements

Page 3-4

While DOE was required to submit a preliminary assessment for WIPP to EPA by August 5, 1994, the March 31, 1995, DCCA indicates that the brief preliminary assessment is still in preparation. What is the status?

Page 3-4

The March 31, 1995 DCCA states, "An official Local Emergency Planning Committee will be established in 1994." What is the status?

NRC Standards

Page 5-1, Paragraph 3

The statement is made that "NRC standards and requirements are incorporated into DOE Orders." Generally this is not true.

NRC and DOT

Page 5-1

"The NRC's requirements pertain to WIPP only in the transportation of TRU waste from the generator sites to WIPP."

Transportation regulations are established by the U.S. Department of Transportation (DOT). The design of the Type B shipping containers is licensed by NRC under 10 CFR 71.

NESHAPS Limits
Page 6-12, 6.2.2

While EEG agrees that the NESHAPS limit of an effective dose equivalent of 10 mrem/year will not be exceeded, the use of CAP-88 in the 1990 FSAR calculations was applied incorrectly. See EEG-52

Mission of DOE
Page 13-1, Paragraph 2

Contrary to the assertion, the U.S. DOE is not solely involved in national defense activities.

DOE Regulatory Authorities
Page 13-1

An analysis of the DOE system of Orders, notices, and directives to protect the public, the environment and workers from adverse consequences from DOE operations should be included in this section.

RH-TRU Waste Transportation
Page 15-1

There are two types of transuranic wastes to be shipped to WIPP. CH-TRU and RH-TRU waste. The 28 pages of Chapter 15 only describe the shipping container for the CH-TRU waste. Nothing is included on the RH-TRU container which may have 1/3 of the total radioactivity. Revise this section to include the status of the design, and schedule for the RH-TRU container submission to NRC with the expected date of certification.

Compliance

Page 16-1

While DOE is not required to do so, the Department might request the U.S. Department of Transportation to make an evaluation of DOE's determination of compliance with the materials outlined in this section. The same applies to all regulatory agencies in the BECR.

Federal Land Policy and Management Act

Section 18 should provide specific information on the plans to remove the 10 million Cu ft of salt that will be left over at the completion of the project.

BOREHOLE DATA OF SOUTHEASTERN NEW MEXICO
(VOLUME II)

The compilation on borehole data for southeastern New Mexico is incomplete and does not include all oil and gas wells. While there is a reference in Volume I (page 2-114) to a report being prepared on D..aware Basin boreholes, the compilation should be available now, particularly since DOE states that the report being prepared is associated with the prediction of future drilling rates.

Other wells that appear missing from the inventory include:

Engle
USGS 4
USGS 1
USGS 8
LRL 7
DD1
Hudson Federal
Culbertson-Erwin
Bootlegger Ridge
Gulf 1-A
Pogo
Union
Danford
Belco
Culbertson
Covington
Masho 1
Masho 2
Shell
Tidewater
Bilbrey
Barclay State #1
James Ranch
James E.
Martha
Dolores
Federal
Federal
Phillips
Wright
David
Dunes
State
I-P.G.-4
Barclay Federal #1
Medano State Comm #1
Forty-niner Ridge Unit #3
Getty "24" Federal #5WD, #'s
Neff "13" Federal #'s 2,3,4,5,6,7,8

None of the boreholes listed in Subsurface Exploration Borehole Data Base have drilling records prior to 1978. Were there none or are the records unavailable?

M

BASELINE INVENTORY REPORT (BIR)
VOLUMES III AND IV

The projected quantities of TRU waste have changed substantially from the February 1995 Baseline Inventory Report (BIR) Rev. 1 estimates used in the DCCA to the December 1995 BIR Rev. 2. An explanation is needed, particularly since DOE is considering a redefinition of defense TRU waste. Additionally, the existing design of 7080 m^3 for RH-TRU waste will not accommodate the 27,000 m^3 of RH-TRU waste to be emplaced in the walls of the rooms.

	REV. 1 2/95 (m^3)	REV. 2 12/95 (m^3)
RH-TRU Waste	4800	27000
CH-TRU Waste	120,000	110,000
Total	125,000	140,000

Commercial TRU Waste
ES-1

Why is commercial transuranic waste included in the inventory since it is specifically precluded both by the NM/DOE C&C Agreement as well as Public Law 102-579?

Disposal Inventory
Page 1-4

The volume shown for CH-TRU waste is high by a factor of 100,000.

Particulate waste
Page 1-5
The text states that all particulate wastes will usually be immobilized prior to shipment to WIPP. This form is not identified as a Waste Matrix Code Group nor is it defined in the Glossary. How will it be immobilized?

RH-TRU Waste Inventory

Page 4-2

The allowable projected volume has an unwarranted multiplier in the expression of 10^5.

CH-TRU Waste Quantities Incorrect

Page 4-2

"The total volume of projected CH-TRU waste from the IDB in Table 4-1, if added to the stored waste volumes from the IDB, exceeds the capacity of WIPP (176,000 m^3)." No, it does not. The sum of the existing and projected volumes from Table 4-1 is less than 176,000 m^3. The whole purpose of the scaling equation on this page is to note that there will be unused space for 30.5% of the design volume or 1.9 x 10^6 cu ft.

Estimating the Total CH-TRU Waste at Each Site

While an elaborate description is provided of the method to calculate the CH-TRU waste at each site the results of the calculations are not provided in either Chapter 4, Volume I, or in Volume III or Volume IV. They should be shown.

The origin of the 0.65 factor is not shown. The text should note that it is

$$\frac{72{,}000}{64{,}600 - 14{,}600 + 62{,}000}$$

The 14,600m^3 is a correction for low-level waste.
The 62.000 M^3 is a correction for the Savannah River (SR) TRU waste.

Estimating the Total RH-TRU waste at Each Site

Page 4-3

The result of the calculations are not shown.

It would be simpler to show

Existing Waste + Projected Future Waste + Vacant Space = Design Capacity

Vacant Space = 5182 m^3 or 73% of the RH-TRU waste capacity.

The opposite conclusion is presented on page 4-4 which states that the volume of RH-TRU waste identified by the sites exceeds the capacity of the repository.

Low-Level Waste
Page 4-5

It appears that half the waste that has been characterized as TRU may be Low-Level Waste. More information is needed on this.

DECONTAMINATION AND DECOMMISSIONING PLAN
(VOLUME V)

M

As the title implies, the plan is conceptual in nature and does not provide specific details of the decommissioning process, but it is appropriate that the plan be conceptual and general in nature. It should be expected that regulatory requirements for decommissioning and decontamination and technical capabilities will change prior to facility closure. Appropriate commitments are present and the plan is reasonable.

- Estimates of the amounts of metal to be emplaced in the repository following D&D should be provided.

- What are the plans for TRU and LLW generated during decommissioning?

Specific comments follow:

Page 1, paragraph 3

The reference for the waste acceptance criteria for decontamination and decommissioning (DD-WAC) should be provided for review.

Page 2, paragraph 1

"Mined salt remaining after closure and berm construction will be disposed under Section 2 and 3 of the Minerals Act of 1947."

The requirements of the Act should be discussed in the plan rather than just making reference to the applicable Sections. There will be about 10 million Cu ft of salt left over at the end of the project and a commitment needs to be made to remove it.

Page 2, paragraph 3
Regarding stakeholder involvement.

The actual commitments of NEPA should be specified in the plan, rather than making general references to the Act.

Page 3, paragraph 7

The hot cell may remain as part of a permanent marker.

There is no explanation why the Hot Cell would be allowed to remain as a marker. Plans to decontaminate the Hot Cell should be included.

Page 26, paragraph 1

Reference to shaft seals.

What is an acceptable sealing technique? The basis for establishing such criteria should be provided.

Page 27, paragraph 1

Radiation survey techniques.

Reference the criteria for radiation surveys.

Page 27, paragraph 2

Environmental monitoring.

The criteria for environmental monitoring should be provided.

GEOLOGICAL CHARACTERIZATION REPORT
VOLUMES VI AND VII

M

Considerable site characterization work has occurred since the publication of the GCR. New Issues have arisen, some of which have been resolved and the others remain unresolved.

In August 1979, the EEG published EEG-2 (App. III to EEG-3), titled Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volumes I and II, December 1978. A number of EEG reports and papers have since been published (see the list of EEG reports at the end of this report) that relate to the geological characterization issues. The EEG Comments on Chapter 2 of the DCCA reflect the EEG's up-to-date position on many of these issues.

STATISTICAL SUMMARY OF THE RADIOLOGICAL BASELINE PROGRAM FOR THE WASTE ISOLATION PILOT PLANT
(VOLUME VIII. APPENDIX RBP)

Project Gnome Environmental Radioactivity

Page 1-3

The paragraph about project Gnome states that the surface radioactivity has been reduced to approximately background levels. EEG has conducted a radiological survey of the area and found significant levels of Pu-238, Pu-239+240, and Am-241. The results were published in EEG-58, Radionuclide Baseline in Soil near Project Gnome and the Waste Isolation Pilot Plant, Jim W. Kenney, Paula S. Downes, Donald H. Gray, Sally C. Ballard, July 1995.

The paragraph about the Test Phase should be deleted since these plans are no longer in effect.

Fission Products in Groundwater Samples

Pages 5-7

The reported presence of the fission product Sr-90 in groundwater samples does not appear correct.

Long Lived Radionuclides

Page 6-1

Contrary to the assertion, ^{90}Sr and ^{137}Cs are generally not considered to be long-lived radionuclides as are transuranics.

References

Page 9-1

Add the following EEG publications:

EEG-47, Kenney, Jim W., and Sally C. Ballard, Preoperational Radiation Surveillance of the WIPP Project by EEG During 1989, December 1990.

EEG-49, Kenney, Jim W., Preoperational Radiation Surveillance of the WIPP Project by EEG During 1990, November 1991.

EEG-51, Kenney, Jim W., Preoperational Radiation Surveillance of the WIPP Project by EEG During 1991, October, 1992.

EEG-54, Kenney, Jim W., Preoperational Radiation Surveillance of the WIPP Project by EEG During 1992, February 1994.

EEG-58, Kenney, Jim W., Paula S. Downes, Donald H. Gray, and Sally C. Ballard, Radionuclide Baseline in Soil Near Project Gnome and the Waste Isolation Pilot Plant, July 1995.

Illegible Graphs
Pages A-1 through A-52

The graphs in the appendix, Date Histograms and Probability Distribution Models are not legible.

QUALITY ASSURANCE PROGRAM DESCRIPTION
(VOLUME VIII. APPENDIX QAPD)

The "QAPD" Appendix, consisting of the June 1994 CAO Quality Assurance program Description (QAPD) revision 0, does not specifically address QA as related to any of the 40 CFR 191 requirements, and became effective well after the bulk of the work described in the rest of the DCCA was completed.

The "Draft Compliance Application Guidance (CAG) Document for 40 CFR Part 194 Federal Register Draft" of September 1995 (EPA 402-R-95-014) which postdates the DCCA, provides guidance to the proposed 40 CFR 194.22 for "...submission of information...demonstrating the establishment and execution of Quality Assurance programs..." (p. 22-23). It should be noted, however, that the DCCA states specifically that the requirements of 40 CFR 194.22 are not addressed (p. 5-1, lines 15-17).

The "QAPD" appendix was addressed in several of our comments on Chapter 5 of the DCCA. The bulk of these comments compare the requirements in the proposed 40 CFR 194.22 concerning NQA-1, NQA-2 (part 2.7), and NQA-3 against both the CAO QAPD revision 0 (the "QAPD" appendix) and the draft revision 1 currently under review by CAO. The conclusion is that neither version requires adherence to all of the NQA standards as proposed in 40 CFR 194.

IMPLEMENTATION OF THE RESOURCE DISINCENTIVE IN 40 CFR PART 191.14(e) AT THE WIPP
(VOLUME VIII. APPENDIX IRD)

EEG does not believe the report "Implementation of the Resource Disincentive in 40 CFR Part 191.14(e) at the Waste Isolation Pilot Plant DOE/WIPP 91-029 Revision 1, June 1993" satisfies the Assurance Requirement 40 CFR 191.14(e), which states the following,

> "Places where there has been mining for resources, or where there is a reasonable expectation of exploration for scarce or easily accessible resources, or where there is a significant concentration of any material that is not widely available from other sources, should be avoided in selecting disposal sites. Resources to be considered shall include minerals, petroleum or natural gas, valuable geologic formations, and ground waters that are either irreplaceable because there is no reasonable alternative source of drinking water available for substantial populations or that are vital to the preservation of unique and sensitive eco-systems. Such places shall not be used for disposal of the wastes covered by this part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future."

Since WIPP fails all three Criteria (previous mining for resources, reasonable expectation of future exploration, and significant concentration of a rare material) DOE needs to provide documentation on the favorable characteristics. It is important to note that the purpose of the Assurance Requirements is to provide confidence needed for long-term compliance with the Containment Requirements of 40 CFR 191.13.

EEG reviewed the August 1991 draft of the report and provided detailed comments in our December 27, 1991 letter to the WIPP Project Director (Supplement 5). Also attached are copies of the EEG's February 13, 1990 (Supplement 6) and August 10, 1990 letter (Supplement 7) on this subject. There was no response to questions raised in our three letters (see Supplement 8).

Page 12

The DOE concludes from the Natural Resources Study: "The conclusion of this study is that activities related to potash and hydrocarbon resource extraction and solution mining from within (and outside of) Control Zone IV, using currently available and applicable technology, will not compromise the integrity of the WIPP waste emplacement facility and increase the likelihood of a breaching event." This statement may not be justified in the light of the extensive oil, gas, and potash extraction activities in recent years and the case of Hartman vs. Texaco (see the comments on Chapter 6).

DOE Natural Resources Study
Page 13, paragraph 2 & 3

The specific conclusions reached from the natural resource study need to be reconsidered on the basis of the Hartman vs. Texaco case and the expected waterflooding activities in the vicinity of the WIPP site.

Probability of Resource Extraction in Zone IV
Page 13, and page 16

The summary paragraph states "...any resource recovery operation will be reviewed by the Bureau of Land Management (BLM) (for surface claims) and the Minerals Management Service (for underground claims) prior to its implementation." (page 13) and "the DOE did commit to working out arrangements with the BLM to assure that the DOE receives notification of resource development proposals in the vicinity of the WIPP site." (page 16).

A number of examples were cited in EEG-55 to indicate problems with the assumptions.

Basis of 1980 Site Selection
Page 27

"... the Eastern New Mexico area is not very productive, and has not been subjected to a lot of drilling."

This is a false statement.

Page 30

At the end of section 4.2.1, Table 4-1 should be table 4-2.

Page 32

Table 4-3 should be table 4-4.

SEPTEMBER 1994 WIPP SITE ENVIRONMENTAL REPORT FOR CY 1993
(VOLUME IX. APPENDIX SER)

Preface

"All activities pertaining to the Test Phase will now be conducted at the INEL." The alcove tests would have accounted for most of the waste to be used in the Test Phase. These tests are not being conducted at INEL nor anywhere else.

Additionally, bins that had been characterized at great expense at INEL to measure gas generation have not been used for that purpose at INEL.

The report does not include measurements obtained by EEG over the past decade and published eight reports. There is surface radioactivity caused by the Plowshare atomic weapons test in 1963, six miles southwest of the WIPP site. The document should also reference the EEG work in this area.

Prerequisite to Shipping Waste to WIPP
Page 2-2

Contrary to the statement, the shipment of wastes to WIPP are not predicated on the completion of bench-scale tests at INEL.

"Subsequent to a successful completion of the test phase, the WIPP will be designated as an operational facility and TRU waste will be transported... to the WIPP site." The test phase has been cancelled.

Radioactive Waste at WIPP
Page 3-2

"Most of the waste slated to be sent to the WIPP site is TRU waste." It is all TRU waste.

Potentiometric Surface of Culebra

Page 7-19

The potentiometric surface of the Culebra dolomite in Figure 7-3 is different from that shown in Chapter 2.

Environmental Data from 1989 thru 1993

DOE did not report radiochemical data from environmental samples between 1989 and 1993. Most radiochemical results reported before and after this time were reported as "less than detectable". Such reporting does not allow for determination of a numerical radionuclide baseline.

Concentrations of Gases

Page 6-3

Annual average concentrations for the five gases identified are not provided.

Page 6-3

The air quality monitoring section states, "initial indications show H_2S, SO_2, and NO_x, data values at or below the lower level of detection for these analyzers." The lower limits of detection should be specified for these instruments.

SUPPLEMENT 1
(Chapter 2, DCCA)

EEG COMMENTS ON THE COMPLIANCE STATUS REPORT FOR THE WIPP
(DOE/WIPP 94-019, Rev. 0)
GENERAL REMARKS

The Compliance Status Report (DOE/WIPP 94-019, Rev. 0) for the WIPP project contains descriptions and status of resolution of issues related to the WIPP's compliance with the applicable standards and regulations of the Environmental Protection Agency (EPA). The Environmental Evaluation Group (EEG) has been studying these issues for many years and has a different perspective from DOE on their status of resolution and importance. The differences can perhaps be resolved through further discussion or may require additional field and/or laboratory investigations.

These comments are arranged according to the chapters in the Compliance Status Report (CSR). When a topic is discussed in more than one chapter in the report, the comments are consolidated for the chapter where the topic is first discussed. Specific suggestions for the compliance application are provided, when appropriate. These comments are a part of our continuous review of the compliance issues.

The Compliance Status Report appears to have been prepared by a number of authors, and portions have been apparently taken from other documents. The quality is therefore highly variable. This review addresses only the significant errors or omissions. It is hoped that other more formal WIPP documents, such as the compliance application, will be more carefully prepared.

The EEG recommends that the scientific issues be resolved through scientific arguments and additional analytical or experimental work where necessary. When an issue is very difficult to resolve, it may be acceptable to leave it unresolved on the basis of low probability or low consequence. However, if many significant issues remain unresolved, it may result in loss of credibility of the scientific effort spent on the project. Subject the issues to the SPM process only after the best scientific data and arguments have been analyzed and debated. Moreover, certain issues, such as the knowledge of the hydrologic recharge and discharge areas and the position of the water table, may not directly affect the input parameters for the performance assessment calculations but are nonetheless important for demonstrating confidence in a basic understanding of the site characteristics.

EXECUTIVE SUMMARY

The Purpose of WIPP

The description of the purpose of the WIPP project continues to remain confused in the DOE documents. "Research and development facility to demonstrate the safe disposal of radioactive waste..." has never adequately described the purpose of WIPP, even though it is the language in the 1979 Act authorizing WIPP. The first sentence in the Executive Summary of the CSR, "WIPP...has been sited and constructed to meet the criteria established by the scientific and regulatory community...", is also unnecessarily convoluted. The following straightforward statement is suggested to describe the purpose of the WIPP project for use in all the WIPP project documents: "The Waste Isolation Pilot Plant is planned to be a permanent geologic repository for transuranic waste generated by the defense activities of the United States."

As appropriate, additional statements about the DOE being the manager of the waste and the repository, the EPA being the certifier of compliance with the environmental regulations, etc., can be added.

CHAPTER 1 - INTRODUCTION

Project Overview

Only through a full description of the checkered history of the WIPP project can the inconsistencies and contradictions in the project be fully explained. For example, the WIPP facility has not been constructed to "determine the efficacy of an underground repository for disposal of TRU waste" (CSR, p. 1-1, second paragraph). Study of the in situ geomechanical and geohydrological behavior of the repository did not require excavation of the full-fledged repository and waste handling facilities, or the heated room experiments. The WIPP facility was constructed in the 1980s because the DOE had planned to emplace underground all the then existing (200,000 drums) transuranic contact-handled (CH-TRU) waste, and limited quantities of high level waste for experiments, before assessing the WIPP's suitability as a permanent repository. Similarly, for those who may not be familiar with the DOE desire to conduct a "test phase" involving emplacement of waste in the Panel 1 rooms and in the alcoves, the provisions of the Land Withdrawal Act are hard to explain. This section should describe the plans prior to October 1993, the reasons for the DOE decision to abandon the idea of testing with the waste at WIPP, and the effect of that decision on the requirements of the Land Withdrawal Act.

The DOE Energy Systems Acqisition Advisory Board (ESAAB) decision (p. 1-2, last paragraph) was made specifically to start the test phase, so the characterization of this decision to mark "the end of the construction phase" is curious. Since only one-eighth of the planned repository has been excavated, how could the construction phase have ended, anyway? Also, since the CSR and the Experimental Program Plan describe a number of site characterization activities yet to be conducted at WIPP, how could Lappin (1988) have "brought to termination the WIPP site characterization phase" (p. 1-2, third paragraph)? Similarly, it is misleading to state that "The Final Safety Analysis Report (FSAR) was then published." (p. 1-2, last sentence). The 1990 FSAR did not even evaluate the safety of conducting the bin and alcove experiments, that had been planned for WIPP. An Addendum to the FSAR was published in 1991, but it addressed only a small part of the planned tests. A new FSAR is needed to assess the safety of the disposal operations.

Past efforts to represent a very checkered history of the project as a tidy phased development have not succeeded and have only confused successive newcomers on the project. For example, the DOE first announced the end of the Site Characterization phase in 1981, then in 1983, and now it is 1988, but the site characterization is not yet complete because the DOE has not, until now, given a high priority to assessing the facility as a permanent repository. It is not necessary to rewrite history. The project is finally on the right track. Only an awareness of the past mistakes and disassociation with the past short-sighted approaches will keep it there.

The Project Overview should include an assessment of the potential difficulties in carrying out the disposal and decommissioning activities because of the age of the facility. The facility was constructed for a 25 year operation starting in 1988. Since the earliest date to start disposal now is 1998, what is the effect of this 10 year delay on the stability of the excavations and safety of operations?

Site Selection Process

1957 NAS Report: Frequent references to the 1957 National Academy of Sciences (NAS) report (The Disposal of Radioactive Waste on Land, A Report of the Committee on Waste Disposal of the Division of Earth Sciences, NAS-NRC Publication 519, April, 1957) in the WIPP project publications necessitates pointing out some recommendations of that committee which would be useful for the WIPP project to follow:

> "The Committee has in no sense done the research so that such expressions of opinion as are contained herein are predicated on the assumption that the research will be done before any final conclusion is reached on any type of waste disposal." (p. 2 of the report).
>
> "We stress that the necessary geologic investigation of any proposed site must be completed and the decision as to a safe disposal means established before authorization for construction is given. Unfortunately such an investigation might take several years and cause embarrassing delays in the issuing of permits for construction." (p. 4 of the report, underlining added).

It should also be pointed out that the report was written for disposal of high level liquid waste in salt cavities and as such has very little relevance to WIPP.

Omissions in the History of the WIPP Site Selection: Any history of the WIPP site selection process should include the following important milestones.

- The original WIPP site was abandoned after the borehole ERDA-6 was drilled at that location in 1975 and encountered extreme geologic deformation and a pressurized brine reservoir at a depth of 2708 ft. Testing in 1981 indicated that the brine reservoir encountered by ERDA-6 contains 100 million liters of brine.

• The two mile criterion was changed to one mile, since a new suitable site could not be found that would be two miles away from any existing drill holes through salt. The new site was selected so that there were no boreholes through salt within one mile of zone II within the WIPP site. The repository was designed to be in the northern part of zone II (see Fig. 8-9, p. 8-17, WIPP Final Environmental Impact Statement, Vol. 1).

• Borehole WIPP-12, located in Section 17, T22S, R31E, within the present WIPP site, 1 mile north of the center of the site and just north of the Zone II, was drilled between November 9 and December 7, 1978, to a depth of 2785.8 ft, 48.3 ft in to the Castile Formation. The original purpose was primarily to investigate an anticlinal structure inferred from seismic reflection profiling. Following a suggestion by the EEG. DOE deepened the well in October-November, 1981, to the base of the Castile Formation, to a total depth of 3925 ft, and in the process encountered pressurized brine at a depth of 3016 ft. Brine started flowing out of the well at a rate of 350 gallons per minute and 1.14 million gallons of brine flowed out of the borehole before the well was controlled.

Based on the results of an extensive series of flow tests conducted in 1981-82, the brine reservoir penetrated by WIPP-12 is estimated to contain 17 million barrels (2.7 billion liters) of brine. The different pressure potentials and some differences in geochemistry between ERDA-6 and WIPP-12 encounters were interpreted to suggest a lack of communication between the two. There was no consensus on the origin and age of the reservoirs. Following a suggestion from the EEG, the WIPP repository was relocated in 1982 to be in the southern part of the WIPP site.

• The WIPP site is much richer in natural resources than was assumed at the time of site selection. The site now is surrounded by more than 100 oil and gas wells within 2 miles of the WIPP site boundary (Silva, 1994).

Regulatory Framework

Section 1.3 should state that the Environmental Protection Agency (EPA) has the authority to approve or disapprove the DOE's determination of compliance with the EPA standards.

Also, add at the top of page 1-9 that the State of New Mexico entered into an agreement with the DOE, soon after the EPA Standards (40 CFR 191) were vacated, to continue the performance assessment work as though the provisions of those Standards remained applicable (C & C Agreement, 2nd Modification, August 4, 1987).

Compliance with RCRA

There may be similarities between the No Migration Variance Petition (NMVP) process for the now-defunct test phase, and the same process for the disposal phase, but there were no procedural precedents set, as the CSR claims (p. 1-8). The NMVP granted by EPA for the test phase incorporated dilution with ventilating air, and that will clearly not happen during the disposal phase. Moreover, the statement about "no migration" on page 1-8 is simplistic. In fact, EPA applies the Draft of Subpart S of 40 CFR 264 (55 FR 30798 *et seq*, 1990) as "standards" that should not be exceeded. EPA has agreed to apply the soil standards for the relevant chlorinated hydrocarbons to the WIPP.

CHAPTER 2 - SITE DESCRIPTION/SITE CHARACTERIZATION

Drilling for Oil and Gas Around WIPP

Oil is being produced from the Delaware Mountain Group Sandstones just outside the WIPP site on all sides, and gas is produced from a well drilled directionally beneath the WIPP site. It is misleading to suggest that these sandstones have been "targets for hydrocarbon exploration elsewhere in the Delaware Basin." (p. 2-9). Furthermore, there is no mention of the deeper stratigraphic units like the Atoka Formation, from which gas is being produced through a directionally drilled gas well located beneath the WIPP site.

Breccia Pipes

Any discussion of Breccia Pipes in the Delaware Basin (e.g. Sec. 2.1.2.2) should address Roger Anderson's hypothesis of formation of the Castiles in the Delaware Basin and other suspected Breccia Pipes in the Basin cited by Anderson and Kirkland (1980) and Anderson (1980). The WIPP project has also not addressed Davies (1984) criticism of the Snyder and Gard (1982) conceptual model of the formation of breccia pipes. Without addressing these alternate conceptual models, the project should not claim that the breccia pipes are confined to the Capitan Reef.

Alternative Conceptual Models for the Culebra

Geological descriptions and interpretations of the observations of the Culebra Member (Sec. 2.1.2.6.2) present only one set of ideas. In many instances, alternative conceptual models exist which should be included. For example, only by ignoring a lot of existing data can it be stated that "density of open fractures in the Culebra decreases to the east". The pattern of fracture distribution and corresponding transmissivity values distribution is too complex to be explained away in a simple statement like that and as expected, has become more complex with additional data acquisition.

Lowenstein (1987) presented an alternative explanation to the Holt and Powers (1988) and Powers and Holt (1990) interpretation of the distribution of halite in the Rustler Formation. Based on a detailed sedimentological study of the Culebra cores from a number of wells at the WIPP site, Lowenstein (1987) interpreted four distinct dissolution zones in the Rustler Formation.

The respective thicknesses of the Rustler and the upper Salado (Chaturvedi and Channell, 1985, Fig. 8, p. 23) call into question the Beauheim and Holt (1990) proposition that dissolution of the upper portion of the Salado Formation may have caused subsidence and fracturing in the Culebra (p. 2-17). The Rustler Formation is 450 ft thick four miles east of the center of the WIPP site and only 300 ft thick from the center of the site westward. The upper Salado (from the top of the Salado to Marker Bed 103), on the other hand, maintains a uniform thickness of about 190 ft over the WIPP site and only decreases in thickness west of the Salado dissolution front that coincides with the western margin of the WIPP site. It would be more logical to postulate the gradational removal of salt from the Rustler Formation itself to have caused fracturing in the Culebra over the WIPP site. West of the Salado dissolution front (west of the WIPP site), both the Salado and the Rustler have been affected grading into total collapse in the Nash Draw.

If the high transmissivity zone in the southeastern part of the WIPP site is related to the dissolution of gypsum fillings in the Culebra fractures, then the high T zone may extend to the south-central part of the WIPP site (p. 2-21 and Fig. 2-12).

Retardation Through Clays in the Culebra

This section (page 2-21) asserts:

> "--- clay fracture-linings may play an important role in the chemical retardation of radionuclides transport through the Culebra---."

This conclusion is based on the X-Ray Diffraction and Analytical Electron Microscopy analysis of samples collected primarily from clay rich layers of the Rustler Formation from cores of wells drilled primarily in the Nash Draw. Four reports are cited to support this conclusion. These reports are based on the work of Terry Sewards and others at the University of New Mexico under contract to the Sandia National Laboratories.

Sewards, et al, 1991 (a) contains mineralogical analysis of core samples from a single well, WIPP-19, and presents no claim for clay filled fracture linings in the Culebra.

Sewards (1991) presents data on the "whole rock" as well as the "fracture surface" compositions of samples of cores collected from 6 wells (WIPP-26, 27, 28, 29, 30, 32) in the Nash Draw, one borehole (WIPP-33) between the Nash Draw and the WIPP site, and three boreholes (WIPP-12, 13, and 34) in the northern part of the WIPP site. Clays are expected to be present in the Nash Draw cores because of extensive dissolution, weathering, and erosion in that area. WIPP-33 is located in a sink hole and processes similar to Nash Draw have operated there as well. Boreholes 12, 13 and 34 are located north of the WIPP repository and upstream from the direction of flow of water in the Culebra. Furthermore, the cores from these wells were selected from known clay seams. For example, the only sample from WIPP-12 (CS-1) came from the zone 838.5 to 838.7 ft below the surface. The Basic Data Report for WIPP-12 (Sandia National Laboratories, 1982) identifies mud seams at 837.7 and 840.7 ft depths.

Three Sandia National Laboratory scientists (WIPP Performance Assessment Department, 1992, pp. A-127 to A- 131) correctly evaluated the Sewards (1991) report and stated the following:

> "Sewards (1991) measured and reported clay abundance for eighteen Culebra samples; thirteen from locations to the north and/or west of the WIPP site, and five from the north end of the WIPP site. None of these samples was from wells along fast transport paths. Because Sewards (1991) was focusing on clay abundance and compositional analyses, it is likely that samples were selected for analysis based on visual appearance of clays. Thus, these data may not be representative of clay abundance on fracture surfaces in the area of interest for transport modeling." (WIPP Performance Assessment Department, 1992, Memo from Craig F. Novak, et al to Martin S. Tierney, p. A-127 to A-131).

Having made this statement, it is surprising that the authors of the memo, Messrs. Craig F. Novak, Fred Gelbard and Hans Papenguth, nevertheless recommended assuming the probability of the existence of relative thickness of clay linings in the Culebra fractures to be as high as 0.5.

Sewards et al., 1991 (b) presents mineralogy of 107 samples collected from the cores of 8 wells, 3 of which are located within the WIPP site. However, clay fraction separates (<2 microns) were obtained for only three samples: "WIPP-12 #3, a clay-poor dolomite; WIPP-12 #16, a clay-rich dolomite; and H6B #3, a shale." X-Ray Diffraction analysis was performed on the clay fractions from these three samples, and one sample (H6B #3) was analyzed under the electron microscope. The electron microscopy on this one sample casts doubt on the accuracy of the X-Ray Diffraction technique used:

> "There is, however, a discrepancy between the results of the quantitative XRD analysis and the results of the AEM investigation of sample H6B #3. In that sample, the XRD results show that the sample contains approximately 50% corrensite. When imaging was attempted on the AEM, it was extremely difficult to find any corrensite at all; the dominant phases appeared to be serpentine, illite, and chlorite." (Sewards et al 1991 b, p. VII-19).

The conclusion of this report, quoted below, clearly demonstrates how very limited information has been used to make important interpretations:

> "The fact that corrensite is the dominant phase in the Culebra samples is important. Corrensite has a high CEC and high surface area, thus it is able to sorb radionuclides very efficiently in the event of a low pressure breach in the WIPP facility. Although the clay minerals of only three samples were investigated, the results of Sewards et al., 1991 show that mixed-layer chlorite/smectite is the dominant clay phase throughout the Rustler Formation, so it is reasonable to suggest that the same is true in the Culebra unit." (Sewards et al, 1991 b, p. VII-19).

Sewards et al., 1991, mentioned in the above quotation, is Sewards et al., 1991 a of this review (Sewards et al, 1991 b of CSR), i.e., "Mineralogy of the Rustler Formation in the WIPP-19 core". As stated earlier, that report makes no claim for clays lining the Culebra fractures. Corrensite is only interpreted to be present in some of the samples, as one mineral among many, when powdered bulk samples were analyzed through X-Ray Diffraction. How can this observation lead to the statement cited above?

The final report by Sewards (Sewards et al, 1992), cited in the CSR, presents mineralogical analysis from 47 samples. Of these, 17 samples were taken from the Culebra, and of these only 9 are from the WIPP site - 6 from the Air Intake Shaft and 3 from WIPP-12. The report states the following with respect to the existence of clay in the fractures of the Culebra Samples:

"Only small amounts of clay can be sampled from the Culebra fracture coatings; therefore, initial technique and model development for adsorption studies on WIPP clays (Park et al., in review) were carried out with material from a black shale layer in the unnamed member. This material, so-called CorWIPP, is 94% corrensite and is described as Sample AIS-15 in this report. Corrensite has a high cation exchange capacity and affinity for the uranyl ion in dilute solution (Park et al., in review) and could provide significant radionuclide retardation in fractures in the Culebra." (SAND90-2569, p. 28).

The above quotation clearly identifies the problem with using Terry Sewards' work to conclude that corrensite clay lined fractures in the Culebra may provide retardation for radionuclide migration through the Culebra. The argument is based on a sample from a "black shale layer" obtained from the lower part of the Rustler Formation, below the Culebra, because not much clay could be sampled from the Culebra fracture coatings! And yet, this information is used to argue that "significant radionuclide retardation in fractures in the Culebra" could be present. It is also the basis for continuing research on the adsorption properties of Corrensite, model development for retardation properties of the Culebra, and the credit for radionuclide retardation taken in the performance assessment work to date.

Any reference to the existence of corrensite or other clay minerals lining the fractures in the Culebra Dolomite member of the Rustler Formation at the WIPP site should be deleted from the project documents because there is no basis for this assumption.

Supra-Rustler Hydrology

The hydrology of the strata overlying the Rustler Formation is poorly understood and serious effort to understand it has not been made (Sec. 2.1.2.7). Basic hydrological parameters such as the location of the water-table and the recharge and discharge areas must be known as clearly as possible, if only to establish the credibility of site characterization. EEG has made specific suggestions for field work in this area since 1985. As long as the position of the water table is not known, it is not possible to say that "Most of the Dewey Lake Red Beds Formation is unsaturated." (p. 2-26, first sentence).

Conceptual Model of Contaminant Transport in the Culebra

The discussion of this topic on page 2-30 is incomplete and presents a single conceptual model while the DOE has decided to perform an important series of field tests to resolve the issue. At this stage, a full discussion of the status of understanding of the mechanism of contaminant transport would include single versus double porosity flow, the role of matrix diffusion and the channeling model.

The estimated flow times in the Culebra, when integrated over the general flow path from the storage panel area to the compliance boundary, range from 100 to 1000 years. The performance assessment has assumed matrix diffusion to retard the radionuclide transport, but the degree of matrix diffusion affecting the transport is not clear. The INTRAVAL participants have pointed out that a conceptual flow-model based entirely on channeling also fits the current hydrological field data, but the current modeling utilizes a dual porosity concept instead. With the channeling model, there would be no matrix diffusion. Sandia National Laboratory plans to start a 7-well tracer test to address these questions. Unless and until these issues are resolved, there is no basis to favor a particular conceptual model.

Culebra Hydrochemical Facies

Section 2.2.2.1 should be revised to assign proper credit for the issues discussed in this section. The EEG has raised the issue of the inconsistency between the inferred direction of flow in the Culebra aquifer and the chemistry of water since the early 1980s and has published three reports on the subject. The issue was first raised by the EEG in 1983 as follows:

> "The unexplained decrease in TDS and a change in the general chemical nature of the Culebra water from sodium and chloride at the site to magnesium, calcium, and sulfate south of the site indicates that insufficient data are presently available to adequately characterize the flow system south of the site." (Neill, et al, 1983, p. 79).

Ramey (1985, Fig. 7) elaborated on this issue and presented the concept of geochemical zonation of the Culebra water. Chapman (1988) further explored the problem and provided a hypothesis to account for the decreasing total dissolved solids in the direction of flow, as follows:

> "As groundwater moves from north to south across the area, the Total Dissolved Solids (TDS) decrease by an order of magnitude and the major hydrochemical facies change from Na-Cl to Ca-SO_4. The only plausible mechanism to effect this change is the influx of a large quantity of low TDS water. The possibility of recharge in the southern area is enhanced by the presence of solution and fill features such as the gypsum caves in the Forty-Niner Member of the Rustler near the Gnome site. These features could behave as conduits supplying fresher water to deeper Rustler units." (Chapman, 1988, p. iv).

The Siegal et al. (1991) report was prepared following a suggestion by the EEG which was incorporated as a requirement of the DOE/State of New Mexico Agreement for Consultation and Cooperation. The EEG considers this issue to remain unresolved, and unless it is resolved, an adequate understanding of the hydrology of the Rustler Formation cannot be claimed.

Hydrogen and Oxygen Isotopes in Groundwater

The EEG (Chapman, 1986) compiled stable isotope data from throughout southeastern New Mexico and compared them to data from the WIPP area. The stable isotopic compositions of most samples of groundwater from the Rustler Formation were found to be similar to the composition of other, verifiably young, groundwater in the area. Though the stable isotope data cannot indicate ages for water in the various aquifers, neither did the data show any distinction between most Rustler groundwater and verifiably young groundwater. A small number of samples, primarily from the Rustler/Salado contact east of Nash Draw, had isotopic compositions that are not characteristic of recently recharged meteoric water. These waters' enrichment in heavy isotopes may be due to mixing with deeper groundwater (supported by the stable isotopic composition of Salado fluid inclusions and Castile brine) or to exchange between the groundwater and hydrous minerals.

A comparison of the heavy isotope enrichment observed in evaporating waters and the composition of the water at WIPP-29 and Surprise Spring showed that the isotopic composition of these Nash Draw waters could be derived by evaporating Rustler groundwater. Based on stable isotopes, both WIPP-29 and Surprise Spring could be discharge areas for Rustler groundwater moving from elsewhere in Nash Draw and the east.

The enrichment in heavy isotopes found in the water from pools in the Carlsbad Caverns was used by Lambert (1986) as evidence that the relatively depleted Rustler water was recharged during a past, more pluvial, time. However, the uniqueness of the isotopic composition of water in the Caverns' pools suggests that rather than representing the composition of recent recharge, the heavy isotopes are enriched by evaporation and equilibrium isotope exchange in the humid cave environment. Recharge in the extreme karst environment near the cavern may also favor isotopically heavy precipitation.

Radiocarbon Ages of Groundwater

The discussion in section 2.2.2.3 is based on Lambert (1986), although the report is not identified. This report was reviewed for EEG by Dr. Fred Phillips of the New Mexico Institute of Mining and Technology in 1987 who found the conclusions of the report, now presented in the CSR, to be unacceptable. Reasons for our position, based on the review by Dr. Phillips, are discussed below.

While it is true that all of the samples (excluding H-5C, which may possibly be contaminated) are probably in the age range 10,000 to 16,500 years B.P., the ages of the water samples vary in a systematic fashion from youngest (10,000 years) in the north to oldest (16,500 years) in the south (with the exception of H-5, which is clearly on a different flow path than the other ^{14}C sampling wells). This corresponds to the pattern expected from the north-to-south flow direction inferred from the physical hydrology. Thus a more reasonable interpretation of the ^{14}C age distribution is that only a segment has been sampled in the middle of a large-scale flow system. Additional ^{14}C samples to the north and/or east might well yield Holocene ^{14}C ages. Also, well H-5, although it may be contaminated, may also indicate active recharge.

The major conclusion of the report (Lambert, 1986, p. 5-10 and 81) was, "Because of the questionable validity of the assumptions necessary in applying radiocarbon and radiochlorine dating methods in the evaporite environment of southeastern New Mexico, and because of the previously demonstrated susceptibility of these components to contamination in this groundwater system, these methods will not be pursued beyond this feasibility study." The EEG finds this conclusion to be unnecessary because good results have been obtained from uncontaminated wells. Ground-water systems are fundamentally not amenable to intensive sampling and thus in all ground-water investigations (whether physical or geochemical) assumptions regarding the system are necessary. Useful results can be obtained, even given a wide range in parameters assumed for the ^{14}C dating model. With a properly conducted field study of the system, the parameters could undoubtedly be constrained much more closely and much better refined dates obtained. Because interpreting WIPP site flow patterns by physical hydrology alone is very difficult and uncertain, and because ^{14}C tracing may hold the best hope of elucidating the flow system, the very negative viewpoint expressed by Lambert (1986) is considered by the EEG to be totally unwarranted.

The contamination issue is even more clearcut. Certainly, it is true that a majority of the wells sampled during this study did not yield useful results due to contamination. One does not need to be an expert in ^{14}C to predict that wells crammed with "shredded paper, cottonseed hulls, peanut shells, and various proprietary organic additives" (Lambert, 1986, Section 4.2.6) will not yield meaningful ^{14}C dates! There is very little logic in arguing that because wells deliberately injected with organic material were contaminated, all other wells must also be. Contrary to the statement by Lambert (1986, p.23), contamination during drilling is not "inescapable". The best evidence of this is that four of the wells drilled without organic circulation-loss additives did not show any sign of contamination. There is no evidence that this groundwater system is unusually "susceptible" to contamination. Any system is susceptible to inappropriate drilling practices, and appropriate practices should yield acceptable results at the WIPP site.

Based on the data contained in the report, the EEG came to a different conclusion. In all cases, where ^{14}C could reasonably be expected to give useful results, it did so. Although there were only a limited number of uncontaminated samples, the geographic distribution of the resultant ages is hydrogeologically reasonable. A carefully designed program should be undertaken to expand the number of useful ^{14}C samples and to constrain their interpretation. The EEG advised the DOE not to abandon this potentially very informative avenue of investigation in 1987 and the EEG recommendation was incorporated in the 1988 modification to the DOE/State of New Mexico Consultation and Cooperation Agreement, as follows:

> "Conduct additional radiocarbon studies on Rustler groundwater. The study will consist of two parts. At least 6 wells will be samples to investigate further questions of contamination and system stability raised in SAND86-1054; completion of this study may require resampling of one or two wells known to be contaminated at the time of earlier sampling. In addition, several (approximately 10) new radiocarbon samples will be collected during sampling as part of the Water-Quality Sampling Program (WQSP), in the hope of obtaining direct evidence of groundwater residence times. Samples from the WQSP will be restricted to the near-WIPP environment (not including Nash Draw), and will include reasonable numbers of samples from both high- and low-transmissivity holes. Serious consideration will be given to conducting limited investigations of the metabolic pathways of modern vegetation at the WIPP, and to carbon analysis of both soil gas and soil carbonate, if evaluation indicates these studies would improve the confidence in modeling of WIPP release scenarios."

The target date for completion of this study was September, 1989.

The EEG recommends initiating this study without further delay using the following guidelines:

(1) avoid sampling all wells known to have organic circulation-loss prevention agents added;
(2) sample existing wells at larger distances from the WIPP site that may yield information on

recharge areas, in addition to unsampled wells near the site; (3) collect data on the metabolic pathway characteristics (and thus $\delta^{13}C$) of present vegetation and the $\delta^{13}C$ of modern soil gas and soil carbonates, and (4) use quantitative geochemical modeling to investigate the chemical and isotopic evolution of carbonate species in Rustler groundwater.

Given this approach to a ^{14}C groundwater investigation, there is a high probability of greatly enhancing our understanding of the groundwater flow system at the WIPP site.

Uranium-isotope Disequilibrium Data

The Lambert and Carter (1987) report was reviewed for the EEG by Dr. John Osmond in 1987. Dr. Osmond is the co-inventor of the Uranium-isotope Disequilibrium technique applied to the study of groundwater flow, as acknowledged in the first sentence of Section 2.2.2.6 of CSR. Based on Dr. Osmond's review, the EEG provided comments on the Lambert and Carter (1987) report to the DOE through a letter dated 12/2/1987. The following is a summary of those comments.

The limitations of the application of uranium systematics to groundwater interpretations should be kept in mind:

1) one usually cannot deduce from the uranium data alone the direction of groundwater flow,
2) one usually cannot determine the flow rate of groundwater itself by the use of U-234 decay rates.

The same isotopic data can be used to model water flow in more than one direction. This is because changes in isotopic ratio can be caused either by true ageing (decay or growth of U-234) or by water-rock or water-water interactions. Researchers in this field usually have independently derived information as to flow directions, which they can use to deduce the possibility of uranium leaching or the mixing of two or more groundwater sources.

Investigators can sometimes determine, in deep confined aquifers, the rate of movement of uranium in the system. The rate of flow of the water itself, however, must be inferred from one's estimate of the retardation factor for uranium in that particular aquifer.

That an aquifer is "confined" is usually an assumption of the modelling of slow-moving systems. Mixing with undefined waters, whether from recharge or other aquifers, negates any evolutionary conclusions. The authors of this report recognize the potential problem, but argue against leakage, perhaps too readily.

Finally, when uranium leaching or adsorption is inferred, it should be remembered that only the grain or fracture surfaces of the host rock are involved. The concentration of uranium on these surfaces can be much different than the concentration values of the whole rock.

Therefore, the principal conclusions of the report must be regarded as possibly overstated: 1) it is possible, but not proven, that the Rustler system can be modelled as a confined aquifer, 2) it is plausible that the flow regime has changed direction, but alternative interpretations based on a more steady-state model are readily visualized, and 3) although the inferred rate of movement of uranium through the aquifer near the site is probably about right, the flow rate of the water itself could be appreciably faster.

The basic pattern of occurrence of uranium isotopes in the Rustler ground water in the western half of the study area, as pointed out by the authors, is consistent with a two-source mixing model. These two end members could be water masses represented by H4 and W29 (Fig. 10), or by a water with very little U-238, but considerable excess U-234, that has leached to varying degrees uranium from the aquifer rock. The regression line on Fig. 15 implies that these two end members are leached uranium (infinite concentration) with an atomic ratio (A.R.) of 1.55 and water of zero concentration of U-238 but carrying 13.4 ppb (U-238 equivalent) of U-234.

The authors make use of this pattern to make three different interpretations. Each interpretation is plausible to some degree, but taken together they are somewhat inconsistent.

The most logical has to do with a possible westward flow direction of water from the site toward Nash Draw. Low concentration water (with respect to U) gradually dissolves uranium with lower A.R. values. No information regarding flow rate derives from this model.

The least plausible interpretation assumes that the decrease in A.R. westward is the result of U-234 decay, which leads to deductions regarding low U movement rates (not necessarily low water flow rates). It is recognized by the investigators that such a model is suspect where uranium concentration values are increasing; leaching, if ignored, produces inferred flow rates which are too low.

The third interpretation is inconsistent with the first, so the authors postulate an earlier flow regime and ask as to why the A.R.'s are so high to the East. Such values depend on fractionation processes that often require time periods commensurate with the half-life of U-234, and therefore are nearly always down-flow. In this case, argue the investigators, the estimates of time are apt to be conservative because leaching would hold the A.R. values down.

In all of their modeling, the authors of this report display considerable knowledge and insight; they do not flagrantly misinterpret the data. Their assumptions are made clear. Nevertheless, one aspect of uranium isotope systematics in groundwater is neglected, and could affect their models. In any ancient system, uranium has been moving for much longer than the period of time being modeled. The distribution factor between dissolved and adsorbed uranium (related to retardation) means that any interactions between water and rock are probably independent of whole-rock uranium concentration values. It is the concentration of uranium on adsorption surfaces, rather than that inside the rock particles, which determines how much fractionation occurs, and how fast relative to water movement. The concept of "reducing barrier" is often cited to explain concomitant decreases in U concentration and increases in A.R. over short distances.

The potentiometric contours of the Culebra suggest two flow lines in the study area: to the west, flow is more or less directly south; in the general area of the site, however, there appears to be an easterly flow in the north, a southeasterly flow at the site, and a southerly and westerly flow to the South.

If we postulate a general source area anywhere to the North, with the usual reducing barrier not far from the point of recharge, then all of the water would enter the area with a high A.R. and a low concentration. Water flowing southward in the west would dissolve uranium and take on the higher U and lower A.R. fingerprint. Water flowing in the east would move slower, dissolve less uranium, and have its A.R. altered only gradually with time. When the flow looped west, dissolving and "mixing" with rock-derived uranium would occur.

This scenario combines the three models proposed by Lambert and Carter: mixing in the west and southwest, increasing A.R. due to recoil-type fractionation in the north, and decay of excess U-234 in the general area of the site. If this model has merit, we can deduce uranium movement rates in the aquifer near the site which are consistent with those values proposed by the investigators. Because of the retardation factor, the water flow rate could be higher.

All of these remarks concern the Culebra unit of the Rustler. There are not enough data from the other units to do any regional modelling. However, the fact that none of the A.R. values from above and below are as high as some from the Culebra suggests that the latter is the "tightest" with respect to uranium mobility.

Apparently the data regarding oxidation potential of the Culebra waters is inconclusive; and the same might be said about the other hydrologic and geochemical information that might be used to demonstrate that the Culebra is truly confined. Uranium isotopic data has often been used as evidence in such interpretations. Most deep confined aquifer waters carry uranium at very low concentration levels, on the order of .1 to .001 ppb., and with quite high A.R. values, anywhere from 2 to 20 or more. The Culebra waters have higher uranium concentration than do truly reducing aquifers suggesting the possibility of leakage from shallower horizons. However, the fact that the isotopic data can be used to model flow in systematic ways suggests that such invasions are not the predominant process. Any such oxidative tendencies would favor interactive models (uranium leaching) over the fractionation and time-related models emphasized by Lambert and Carter (1987).

Regarding flow rates and groundwater residence time, Lambert and Carter (1987) consistently confuse <u>uranium</u> residence time with <u>groundwater</u> residence time. The data presented in the report do not allow for the calculation of groundwater ages. Even when the appropriate retardation factors and grain and fracture surface characteristics are known, there are still serious questions about applying uranium isotopic data to determine basic groundwater flow characteristics. Davis and Murphy (1987), Simpson et al (1985), and Hussain and Krishnaswami (1980) all express serious reservations about the reliability of uranium-disequilibrium dating because of the many difficult-to-substantiate assumptions involved.

The amount and reliability of the data are also questionable. Outside of Nash Draw, the authors have only four wells on which to base conclusions of changes in flow direction. It is important to consider the dual-porosity nature of the Culebra, indicated by the recent hydrologic testing. The very high activity ratios at H-4 and H-5 may be related to the low-transmissivity, matrix flow found at those wells. Conversely, the lower activity ratios at H-6 may be the result of rapid groundwater flow through fractures. More data east of Livingston Ridge, and from fracture-flow areas such as near H-11 and DOE-1 must be collected before any confidence can be placed in conclusions about flow paths.

Considering the serious questions of groundwater contamination in Nash Draw raised by Lambert (1987), there should be an in-depth discussion of the reliability of the presented analyses of a trace constituent like uranium. If contamination with organics is as pervasive in the Nash Draw wells as reported in SAND86-1054, this would very likely alter redox conditions near the wells. Oxidation-reduction potential is an important control on uranium content. Though the authors state on page 6 that the uranium values and isotope ratios have been perturbed at W-29 by wastewater dumping, they then proceed to use this value throughout the report, for instance as an important part of their argument for recharge in southwest Nash Draw.

As previously mentioned, redox conditions are an important factor in modeling uranium behavior. Field evidence (Eh values as reported in Uhland and Randall, 1986 and Uhland et al, 1987) and the relatively high uranium values both argue against reducing conditions in the Culebra. There is no evidence for the "reducing barrier" required by Lambert and Carter's model. The authors should provide some discussion of the physical requirements of the model relative to known aquifer characteristics.

The section on "Implications" for recharge, karst flow, and climate change presents insufficient discussion for reaching the presented conclusions on this broad topic. For instance, if no recharge is supposed to be occurring, there should be some discussion of what happens to rainfall. There is no integrated surface drainage, there are numerous gaps in the Mescalero caliche, and 20 inches of annual rainfall has been common the last few years. The role of southwestern Nash Draw (SWND) is another point requiring additional discussion. The authors present contradictory hypotheses in this section. Lambert and Carter's item number 2 on page 45 says SWND is a recharge area, while item number 4 on page 46 calls for discharge in that area.

Contradictory statements are also made regarding the degree of vertical interconnection in Nash Draw. Item 5 on pages 46 and 47 (Lambert and Carter, 1987) argues that the Magenta and Culebra are freely connected at W-25 and W-27 (as previously discussed in Chaturvedi and Channell, 1985, though overlooked in Lambert and Carter's references). However, item 4 on page 46 argues that recharge to sinkholes in the Tamarisk member cannot be interpreted as providing recharge to the Magenta or Culebra. Are the authors proposing that the Magenta and Culebra are well-interconnected, but not the intervening Tamarisk? Some discussion of this extraordinary hypothesis is warranted. Likewise, more discussion must also be provided of the author's assertion that the dominant process at W-33 is alluvial infilling. The continued presence of this large depression, even after the springs have ceased to flow, argues against infilling at the surface. We are not aware of any evidence or studies that support the author's statement.

In light of the above comments on the Lambert and Carter (1987) report, all the assumptions arising from the conclusions of that report should be reexamined.

Physical Hydrogeology of the Bell Canyon/Capitan Flow Regime

This section (2.2.5) presents contradictory interpretations of the postulated flow between the Culebra and the Bell Canyon aquifers if a connection was made between the two. Mercer (1983) concluded that the flow would be downward, and Beauheim (1986) concluded it would be upward. What is the project's latest position on this issue?

Resources

The estimates of resources reported in the 1980 Final Environmental Impact Statement (FEIS) and all other DOE reports have been shown to be wrong by current exploitation in the field (Silva, 1994). We understand that the DOE has recently contracted with the New Mexico Bureau of Mines and Mineral Resources to prepare new estimates based on current data and look forward to the results of that study.

Background Environmental Conditions

The statement (Section 2.4, p. 2-44), "The effort to establish environmental baseline conditions at the WIPP facility was initiated in 1975.", is wrong.

The earliest environmental data reported by WIPP was collected in 1985. The first report which contained the 1985 data was the Annual Site Environmental Monitoring Report for the Waste Isolation Pilot Plant CY 1985, (DOE-WIPP 86-002).

The WIPP facility is designed to handle and dispose of several million curries of transuranic elements. The environmental baseline has not established a range of specific transuranic elements. The Compliance Status Report only reports gross alpha and gross beta ranges which are several orders of magnitude greater than the fall-out levels of transuranic elements reported for New Mexico by EPA and LANL. This very important portion of the baseline has not been adequately determined by WIPP's Environmental Radiological Surveillance Program.

Climatology and Meteorology

Geological effects of climate change, i.e., dissolution, subsidence, change in hydrological properties of the subsurface strata, etc., should also be considered in scenario screening, in addition to varying the hydraulic head.

Gas Generation

There is considerable discussion (Sec. 2.7.1) of the gas generation model and its development. However, here is a system that can be validated in the laboratory to some extent. What is needed now is not refinement or simplification of the gas generation model, but some laboratory experimentation to see if the right chemical reactions are being modeled. If the model persists in including hydrogen as a product, while actually methane is produced (as is commonly produced in the anaerobic parts of landfills), the model will lead to erroneous conclusions. Testing the gas generation model assumptions in the laboratory is most important.

Salado Formation

The project position on the preferred conceptual model for brine flow from the Salado Formation into the repository should be developed and justified. If it cannot be done without additional analytical or experimental work, then that work should be identified. The EEG does not agree with the strategy of treating various conceptual models to be of equal importance when overwhelming evidence exists that a particular model is far superior than others in explaining the observed phenomena. The EEG recommends that the brine inflow into the repository from the Salado Formation be modeled by assuming Darcy flow in salt, impure salt and fractured anhydrite of the marker beds, and using the in situ measured permeability values for these layers.

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SUPPLEMENT 2
(Appendix SCR, DCCA)

CRITICALITY REVIEW

FOR THE

WASTE ISOLATION PILOT PLANT

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September, 1981

Prepared for the Environmental Evaluation Group, State of New Mexico, under a Task Order

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TABLE OF CONTENTS

1.0 INTRODUCTION

This report discusses the potential for accidental criticality in the Waste Isolation Pilot Plant. Accidental criticality is defined as the inadvertent assemblage of a critical configuration during the processing, storage, or transportation of fissionable materials. A critical configuration occurs when fissionable materials are brought together in such a way that the number of neutrons produced by fission are exactly equal to the number lost by non-fission absorption and leakage--a so-called "chain reaction" occurs. In a "safe," or subcritical configuration, non-fission absorption and leakage predominate.

Inadvertent criticality is of concern because a self-sustaining nuclear chain reaction releases instantaneous radiation--which is hazardous to the health of workers in the vicinity--and creates fission products--which present a hazard to the environment if they are not contained. Thus it is standard practice to conduct detailed analyses of potential criticality prior to the handling of fissionable materials, and to design processes and procedures such that "at least two unlikely, independent, and concurrent changes in process conditions (are required) before a nuclear incident is possible."[1]

The Waste Isolation Pilot Plant (WIPP) is a facility planned to store transuranic (TRU) waste in a mined bedded salt medium well below grade.[2] TRU waste is defined as waste contaminated with certain alpha-emitting radionuclides, including plutonium, transplutonium nuclides, and uranium-233--all fissionable. These wastes are categorized into two classes: contact-handled (CH) and remotely handled (RH), which are separated on the basis of the surface-dose rate.

The wastes originate in a number of DOE laboratories and facilities, and thus are packaged in a variety of containers of differing compositions, geometries, and sizes. Moreover, both the radioisotopic and the inert (defined here as non-radioactive) composition of the packages vary considerably. Thus it has become necessary to define certain bounding conditions for the wastes in order to address several issues in the design and operation of the repository. This is particularly important in addressing the issue of criticality.

This work does not include the performance of any new, detailed physics calculations. Rather, we have reviewed existing criticality analyses as they apply to the current design of WIPP. The objective is to determine if existing analyses are adequate in demonstrating criticality safety. If they are not, a secondary objective is to determine, from the extrapolation of existing analyses, if inadvertent criticality is likely to pose a serious problem.

We are concerned with the emplacement configuration of TRU wastes. Spent fuel, experimental configurations, and transportation are considered outside of the scope of this review. This exclusion also applies to long-term alterations of the emplacement configuration, potentially involving dissolution, transport, and reconcentration of radioisotopes.

The following Section (2.0) describes briefly the characteristics of the TRU wastes and their containers planned for emplacement within WIPP, and the currently envisioned storage configuration. Summaries are then given of the existing analyses which examine the potential for criticality in WIPP. Section 3.0 discusses the validity of the existing analyses in demonstrating criticality safety in WIPP, and extrapolates to determine if criticality is a serious problem. Finally, Section 4.0 provides conclusions and recommendations.

2.0 BACKGROUND

2.1 Waste Description and WIPP Storage Configuration

Waste compositions and package descriptions are given in the FEIS[2] and the SAR.[3] However, a supporting document[4] provides the best summary description of the salient information, and this is reproduced here in Tables 1 through 3.

The CH storage rooms are about 13 ft. high by 33 ft. wide by 300 ft. long, separated by 100 ft. wide pillars of salt. When the waste material has been emplaced in the storage room, it will be covered with crushed salt backfill at the end of each shift or as required.

According to existing drawings,[5] if a storage room is devoted exclusively to 55-gallon drums, these will be stacked 3 tiers high, 15 drums wide, and an unspecified number of drums long. A storage room could contain as many as 144 drums along the 300 ft. dimension.

If the storage room is devoted exclusively to 83 gallon overpacks these would be stacked 3 tiers high, 10 drums wide, and as many as 135 drums long. Boxes would be stacked 2 tiers high, 6 boxes wide, and as many as 37 boxes long. Other configurations might consist of 83 gallon drums on top of M-3 Bins.

The RH storage area utilizes the walls of the CH waste storage rooms and entries. The RH wastes are contained in Schedule 20, carbon steel pipes, 10 ft. long and 24 in. in outside diameter. These pipes are emplaced horizontally in the pillars of the waste storage area. Current designs envision that the RH waste canisters will be placed on 8 ft. centers. The canisters will be stored in horizontal sleeved holes 6 ft. deeper than the canister lengths.

Table 1
(From Reference 4)

CONTACT HANDLED WASTE CONTAINERS

Package Description	Dimensions	Maximum Fissile Content (grams)
DOT-7A Boxes†		
a. FRP-coated plywood	4' x 4' x 7'	350*
b. Cleated plywood	Random	*
c. Steel boxes (M3-Bins)	50" x 58" x 72"	*
Drums		
a. 55-gallon, 17C	24" dia. x 35" length	200
b. 30-gallon, 17H	19" dia. x 29" length	100
c. 55-gallon, DOT 6M	24" dia. x 35" length	500
d. 83-gallon**	26" dia. x 43" length	200

† Packaged in steel overpack for storage.

* Limited to 5 grams in any cubic foot.

**Used as overpacks for 55-gallon drums.

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Table 2

(From Reference 4)

ISOTOPIC CONTENT OF CONTACT HANDLED WASTE DRUMS AND BOXES

Isotope	Total Mass Per Drum, grams	Total Mass Per Box, grams
Pu-238	2.5×10^{-3}	4.0×10^{-3}
Pu-239	7.5	12.0
Pu-240	0.5	0.81
Pu-241	2.7×10^{-2}	4.4×10^{-2}
Pu-242	2.4×10^{-3}	3.9×10^{-3}
Am-241	1.5×10^{-3}	2.5×10^{-3}
Total	8.03	12.86
Typical Fissile Content, grams	7.5	12.0
Typical Plutonium Content, grams	8.0	12.8
Maximum Allowable Fissile Content, grams	200.0	350.0

Table 3

(From Reference 4)

REMOTE HANDLED WASTE ISOTOPIC CONTENT

Isotopes	Mass in Waste, grams
Co-60	0.093
Sr-90/Y-90	59.3
Ru-106/Rh-106	2.0×10^{-8}
Cs-137/Ba-137m	0.5
Eu-152	0.1
Eu-154	3.1×10^{-2}
Pu-238	0.042
Pu-239	126.7
Pu-240	8.7
Pu-241	0.46
Am-241	2.5×10^{-2}
Total	195.95

M

2.2 Classical Criticality Considerations

The minimum critical mass of a Pu^{239} sphere, moderated and reflected by H_2O, is 520 gms.[6] The ratio of hydrogen to plutonium in the minimum mass sphere is approximately 800. Measurements with polyethylene-moderated systems revealed a minimum Pu^{239} critical mass of 370 gms.[7]

The critical loading of an infinite slab is dependent only on the areal density of fissile material. For slabs consisting of homogeneous mixtures of plutonium and water, the limiting areal density of Pu^{239} is 0.25 gm/cm².[8]

2.3 The SAR Criticality Analysis

The SAR criticality safety analysis is contained in a supplementary document.[4] The calculations were performed using the multi-group, discrete-ordinates, transport theory code, ANISN, in the P_1-S_4 approximation. 27-group cross sections, generated by the AMPX code system, were used in the analysis. The methods were validated by analyzing two critical assemblies.

The RH wastes were modeled as an infinite slab of plutonium, conservatively omitting the steel canister and the other parasitic neutron absorbers. Mixtures of Pu/concrete/water, Pu/glass/water, and Pu/steel/water were considered, in an attempt to simulate both fixed and non-fixed waste forms. The highest calculated k_∞ was 0.11, for the 100% concrete/Pu mixture. The calculated k_∞ of the 100% water/Pu mixture was 0.045.

The 17C 55-gallon drum was selected as the typical CH waste container. It was assumed that the drum is uniformly filled with a homogeneous mixture of Pu^{239} and hydrogen. It was further assumed that 25% of the waste is comprised of combustible material (hydrocarbons), at a packing fraction of 0.5, and at a density of 0.5 gms/cm³. This defined a minimum hydrogen to Pu^{239} ratio of approximately 2000. The calculations were performed for higher ratios of H to Pu^{239}. A 90-mil polyethylene liner was assumed to be present on the inside of the 16 gauge steel drum wall.

The results of the calculations, for the three drum loadings considered, are reproduced in Figure 1. The average drum loading was determined by assuming that 3% of the drums contain the maximum 200 gm plutonium, and the remainder contain the typical 7.5 gm. These k_∞ results are for an infinite array of drums, presumably modeled by using a reflecting boundary condition in cylindrical geometry.

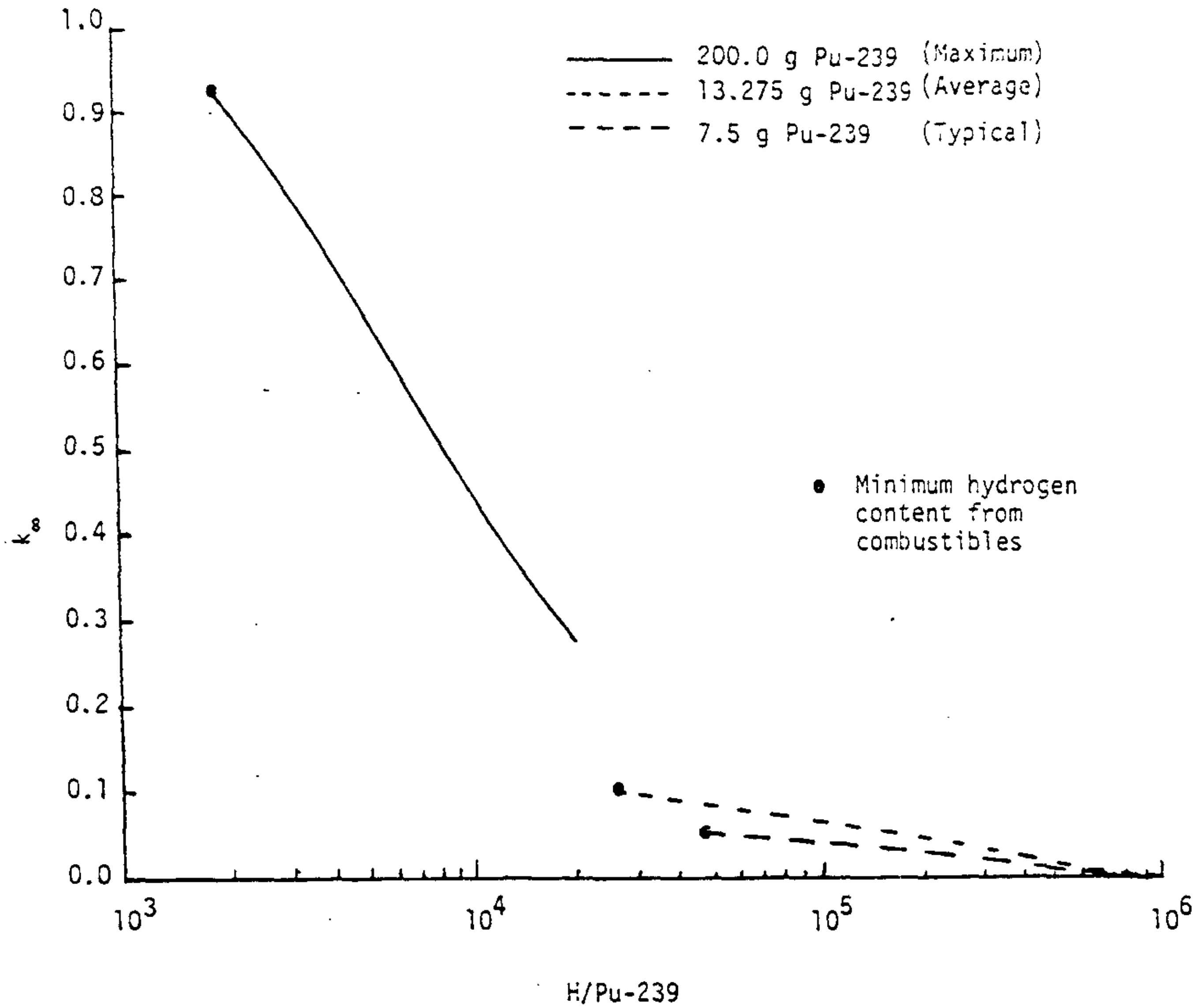
2.4 The Rockwell Hanford Operations Calculations

An extensive series of criticality calculations on arrays of 55-gallon drums containing plutonium was performed at Rockwell Hanford Operations.[9] KENO-III and KENO-IV Monte Carlo codes were used, with 18 energy group cross sections generated by the GAMTEC II code. The drum arrays were assumed to be square, however, the somewhat higher fissile densities in triangular arrays were simulated by using a slightly reduced radius. A reflecting boundary condition was used to simulate infinite arrays. For finite vertical dimensions, the actual number of tiers of drums was simulated.

An infinite soil reflector, found to be more effective than water, was used outside of the drums for calculations of finite dimensions. Most of the calculations were performed for fissile loadings of 200 gm Pu^{239} per drum; a few calculations examined higher fissile loadings. Water was used as moderator in most calculations; some calculations explored the effect of polyethylene and cellulose as moderator.

Figure 1

(From Reference 4)



Infinite Multiplication Factor as a Function of H/Pu-239 for Contact Handled Wastes in 17C 55-Gallon Drums

A large number of parameters were studied in this work. These include:

- The hydrogen to Pu^{239} ratios
  - ∿ 100 to ∿ 2500
- Fissile mass
  - 200 to 400 gm Pu^{239}/drum
- Iron mass in the drum
  - 0 to 29 Kg
- Reflectors
  - 1 to 3 ft of soil
  - 1 ft of water
- Pu^{239} - H_2O mixture density
  - Full drum volume down to full theoretical density
- Pu^{239} - H_2O mixture shape
  - Full radius, flattened
  - Height to diameter ratio = 1.5
- Array shape
  - Infinity by infinity by one to seven tiers high
  - Three-dimensional arrays
- Effect of polyethylene drum liner
- Effect of substituting polyethylene and cellulose for water
- Effect of array collapse

No attempt will be made to summarize all of the results here (approximately 200 separate calculations were performed). However, the most significant contribution of this work is the clear demonstration of the important effect that shape and density of the fissile material in the drum have on the results. The results demonstrate that modeling the plutonium-moderator mixture as uniformly distributed throughout the drum is nct a conservative assumption. This is most clearly demonstrated in Figure 2, reproduced from Reference 9.

Figure 2 contains 3 sets of curves--corresponding to three heights of the array--an infinite number of tiers, 6 tiers, and 2 tiers. Each set of curves is displayed for two hydrogen to plutonium ratios, 1325 and 529. (Note that for the finite number of tiers, the higher H/Pu leads to higher k_{eff} values; this direction is reversed for the infinite number of tiers.) For any one of the curves, the point at the right (100% of drum volume occupied by fissile material) corresponds to the Pu^{239} - H_2O mixture smeared uniformly over the entire drum volume. As we move to the left, the mixture is compressed, either by flattening (denoted by ▭ and ◇) or by "scrunching" into a cylinder with H/D = 1.5 (denoted by □ and ◇). The mode of volume reduction does not appear to affect the results down to roughly 35-40% reduction in volume for the 2 and 6 tier calculations. At this point the H/D = 1.5 results depart significantly from the flattening results.*

These results demonstrate the significant positive effect on k_{eff} of reductions in volume occupied by the fissile-moderator mixture--as much as +0.40 for the H/D = 1.5 compression. For flattening alone, the effect is smaller--a maximum of +0.17. This effect is derived from the smaller fractional leakage for the compressed shapes, which results in a smaller fractional neutron absorption in the iron drum walls. For the full volume,

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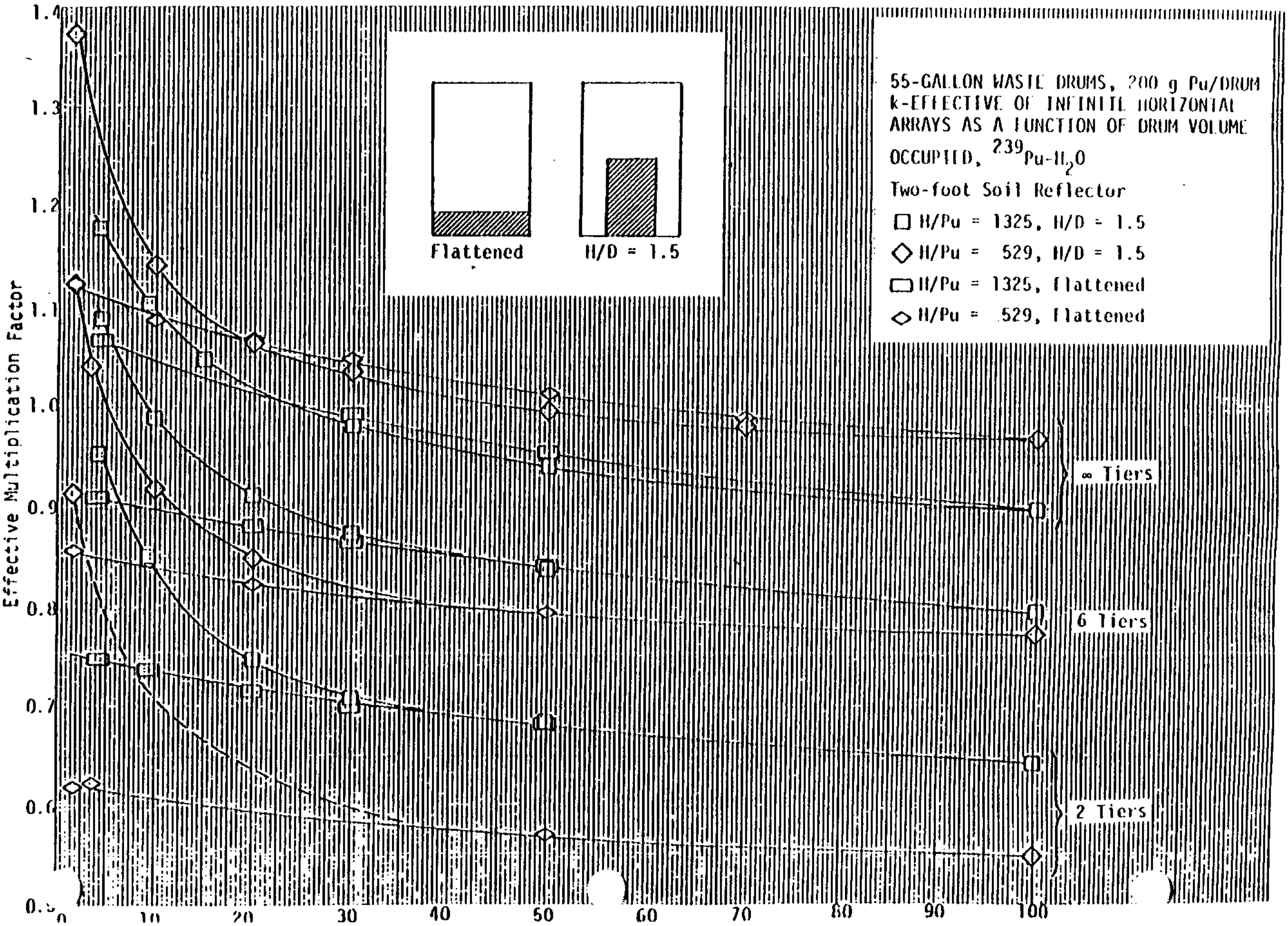
*There is separation between the two results for all percent reductions in drum volume for the infinite tiers. The author points out the crossover in the curves, but pleads ignorant as to its physical explanation.



(From Reference 9)

smeared material, the fractional absorption in the drum walls compared to total absorptions plus leakage is 34% (for $\infty \times \infty \times 6$ arrays). This is reduced to 27% for the full density, flattened shape, and further reduced to 17% for the full density, H/D = 1.5 shape.

2.5 Other Analyses

Criticality analyses on storage arrays have also been performed at EG&G Idaho. The first set of calculations examined arrays of 17C 55-gallon drums containing 200 gm of Pu^{239}.[10] The analysis was performed using the KENO-IV Monte Carlo Code with 16-group Hansen and Roach cross sections. Parameters varied were the hydrogen to plutonium ratio, the array height, and density and shape of the fissile material within the drum.

For an array five drums high, a maximum k_{eff} of 0.68 was obtained at H/Pu ≅ 1200. This is lower than the six tier result of Reference 9, but only by approximately .01 to .05 when the effects of the iron content, height difference, and polyethylene liner are taken into account. The effects of density reduction, both by flattening and reduction in radius, are roughly comparable in magnitude to the results presented in Reference 9, although the radial compression was not accomplished in exactly the same way. Similarly, the effects of height reduction are roughly comparable to the results given in Reference 9, although the magnitude of the effect is not quite as large.

In another set of calculations, EG&G analyzed arrays of DOT-7A, FRP-coated plywood boxes containing a maximum of 350 gm plutonium. The analyses were accomplished using the one-dimensional discrete ordinates code, SCAMP, with 16-group Hansen and Roach cross sections. For array heights of 16 ft., the maximum calculated multiplication factor is approximately 0.64 for H-Pu systems. For a graphite-Pu mixture containing only the additional container wood, the maximum k_{eff} is 0.88 for a 16-ft. high array at optimum C/Pu ratio.

Two sets of relevant criticality calculations were also performed in Silver Spring, using 27-gp. cross sections (generated from the GAM-THERMOS Library using the SCALE program) in the KENO-IV Monte Carlo Code. The first set, for 17C 55-gallon drums, was designed to provide an independent check of the Rockwell Hanford Operations calculations for infinite arrays. We have reproduced these results alongside the appropriate Rockwell Hanford Operations curves in Figure 3. Most of the Silver Spring calculations were designed to simulate the full volume, uniformly smeared configuration (lower curve). Only one calculation was performed for the full density, H/D = 1.5 configuration (top curve). Note that all of the Silver Spring calculations predict higher k values, ranging from +0.01 to +0.14 (the iron density was too low by approximately 2 Kg in the most widely discrepant calculation.), than the comparable Rockwell Hanford Operations calculations. For completeness, the WIPP SAR result for the lowest ratio of hydrogen to plutonium examined is also shown. This result is to be compared against the full volume, uniformly smeared curve (extrapolated).

A few calculations were also performed in Silver Spring for 6M drums containing 500 gm of Pu. The results indicated that infinite arrays of 6M containers without wood between the inner and outer containers may be substantially supercritical.* The infinite arrays containing wood between the inner and outer containers appear to be safely subcritical (highest calculated k_{eff} = 0.46).

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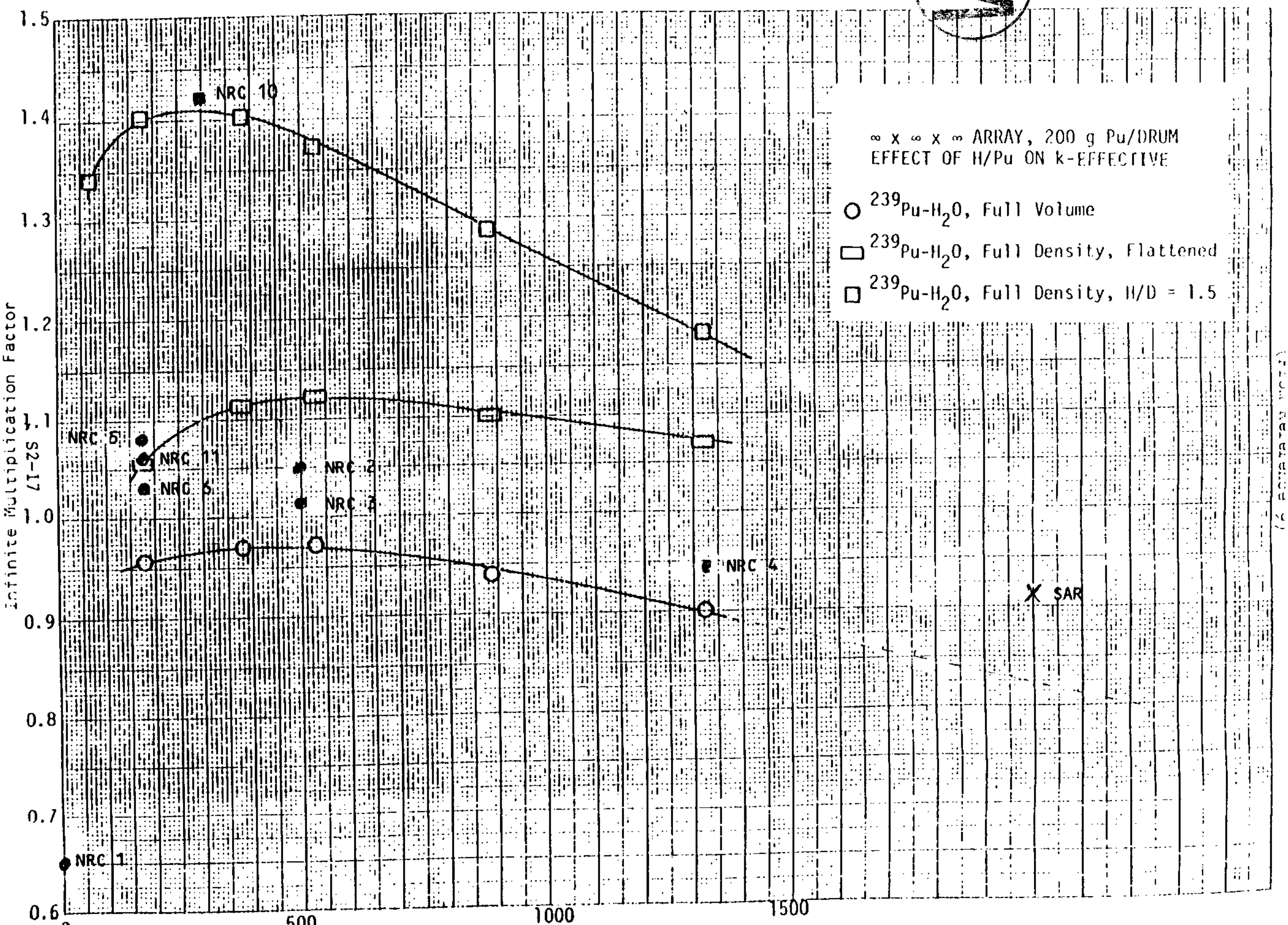
*For an infinite array of 6M containers (no wood) with 500 gm of unmoderated Pu^{239}, the calculated multiplication factor was 1.06. For the same configuration with moderator added to the plutonium (H/Pu ≅ 63), the calculated multiplication factor was 1.62.


∞ x ∞ x ∞ ARRAY, 200 g Pu/DRUM
EFFECT OF H/Pu ON k-EFFECTIVE
$^{239}Pu-H_2O$, Full Volume
$^{239}Pu-H_2O$, Full Density, Flattened
$^{239}Pu-H_2O$, Full Density, H/D = 1.5
Infinite Multiplication Factor
1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
500
1000
1500
NRC 10
NRC 5
NRC 11
NRC 6
NRC 2
NRC 3
NRC 4
NRC 1
SAR

3.0 DISCUSSION

3.1 Validity of the Existing Analyses

The SAR Criticality Analysis

The RH waste analysis appears conservative and the results indicate that the storage configurations are far subcritical for either fixed or non-fixed waste forms, and in the event of complete flooding by water.

Moreover, the safe neglect of all configurations of CH waste except the 17C 55-gallon drums also appears justified. The FRP-coated plywood boxes are shown to be safely subcritical in Reference 11; in fact, classical criticality considerations dictate their safety.*

According to Reference 4, the 83-gallon drums are used only as overpacks on the 55-gallon drums. The ratio of iron to allowable fissile content in the 30 gallon drum is higher than that of a 55-gallon drum,** so a 30-gallon drum array should be subcritical if a comparable array consisting of 55-gallon drums is subcritical. Finally, as long as the wood reinforcement is present, an infinite array of DOT 6M drums was shown to be safe by the calculations performed in Silver Spring.

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*For the 13 ft height limitation in WIPP, the areal density of Pu^{239} is a factor of six below the 0.25 gm/cm^2 critical areal concentration for $H\text{-}Pu^{239}$ systems.[8]

**This is true for most 30- and 55-gallon drums. However, at least two 17H 30-gallon drums weigh less than one-half (27.2 lbs. and 31.4 lbs.) of at least one 17H 55-gallon drum (66.2 lbs).[12] These drums are, however, greater than one-half of the weight assumed in the Rockwell Hanford Operations 55-drum calculations.[9]

The SAR analysis of the 17C 55-gallon drums considers an infinite array in three dimensions. This is conservative because the drums in WIPP will be stacked three tiers high by 15 drums wide. Although three different plutonium contents were modeled, only the 200 gm loading is conservative unless the actual plutonium content will be measured for each drum.

Two assumptions are made in the analysis which are not conservative. The first is the assumed lower limit in the ratio of hydrogen to plutonium (roughly 2000). This assumption is apparently related to a statement in the SAR regarding the combustible content of the wastes. However, the use of the combustible content as a constraint on the range considered for the hydrogen to plutonium ratio does not appear justified. According to the analysis presented in Reference 9 (reproduced in Fig. 3), the difference in the infinite multiplication factor between an optimally moderated array (H/Pu ≅ 300) and one in which H/Pu ≅ 2000 (extrapolated from the curve given in Reference 8) is approximately 0.4.* It is noteworthy that the 200 g Pu curve in Figure 1 is climbing steeply toward k_∞=1 at the assumed maximum H/Pu.

The second unconservative assumption is that the plutonium-moderator mixture is spread uniformly throughout the drum. As demonstrated in References 9 and 10, the least reactive configuration is the one in which the fissile material occupies 100% of the drum volume (see Figure 2). In fact, as discussed in Section 2.4, the effective multiplication factor of the full density configuration (with H/D=1.5) is higher than that of the uniform configuration by as much as 0.40.

Although the combined effects of these two unconservative assumptions are not additive, they may in fact exceed the opposing conservative effect of the infinite array approximation. Therefore, the SAR criticality analysis

*However, the range is not nearly as great for heterogeneous and/or finite arrays.

does <u>not</u> demonstrate criticality safety for the WIPP storage configuration.*

<u>The Rockwell Hanford Operations Analyses</u>

As discussed in Section 2.4, the Rockwell Hanford Operations analyses explored a wide variety of parameters. Certain approximations and assumptions applied consistently throughout the analysis are conservative, tending to bias the calculated multiplication factors on the high side. The most obvious of these are:

1. The ninety-mil polyethylene liners** for 55-gallon drums were omitted from most of the calculations. Incorporation of these liners in the calculations was found to decrease k_{eff} by about 0.03 (at minimum densities) to approximately 0.1 (at maximum densities).

2. Most of the calculations assumed 23 kilograms of iron in the drum, less than the 29 Kg of iron in 17C 55 gallon drums.*** Increasing the iron content by 6 kilograms in the calculations decreases k_{eff} by about 0.015 (at maximum densities) to approximately 0.08 (at minimum densities).

---

*Reference 4 rightly points out that the analysis conservatively omitted parasitic neutron absorption in miscellaneous materials admixed with the plutonium. Although this is undoubtedly true, the waste materials admixed with the fissile material are too variable and poorly defined to rely upon for criticality safety.

**These are available on the Hanford plant drums[9] and were incorporated in the SAR criticality analysis. However, some of the drums at EG&G Idaho have 10-mil polyethylene liners;[10] the extent to which liners are applied to drums from other facilities is not known.

***Some care must be exercised in pinning down the amount of iron in 55-gallon drums. According to one source,[12] the drums range in weight from 55.6 lbs to 66.2 lbs.

3. The existence of the poison, Pu^{240}, was neglected. It is estimated that approximately 7% of the plutonium consists of this isotope.[4] The poisoning effect of this isotope is not negligible, but the magnitude has not been determined.

4. A reduced drum radius was used in the calculations to simulate the higher average fissile density found in triangular arrays. Since square drum arrays are planned for WIPP,[5] this assumption is also conservative. The magnitude of this effect is also not known.

The calculations performed in Silver Spring, however, revealed some discrepancies which are not in the conservative direction (see Figure 3). Most of these calculations provided an independent check on the full volume infinite array analysis of Rockwell Hanford Operations. Eliminating the results which are not comparable on the basis of iron densities (Nos. 2 and 5 in Fig. 3) or cross section structure (No. 11 in Fig. 3), the multiplication factors calculated in Silver Spring are higher than those of Rockwell Hanford Operations by approximately +0.01 to +0.08. The single result for the full density array implies that the discrepancy is significant only for the full volume cases.

The source of this discrepancy, the multi-group iron cross sections, appears to have been identified at Rockwell Hanford Operations.[13] Most of the calculations have been redone, and a revised report is in draft form. However, the revised calculations presumably do not demonstrate changes in the results for arrays with 6 tiers or less.

One additional aspect of the Rockwell Hanford Operations results is worthy of note. This is the analysis of array collapse. Array collapse is credible in the underground repository through waste containment or structural failures. Although waste containment failure is essentially assured over the long-term, this review concentrates on the short-term, operational phase of the repository, for which structural failure, at a minimum, should be considered.

The results given in Reference 9 indicate that the increase in multiplication factor brought about by 1-dimensional (i.e., vertical) collapse is negligible. 3-dimensional collapse, however, can lead to an increase in k_{eff} of +0.25 for initially flattened, full density 12 x ∞ x 5 drum arrays.

3.2 Criticality Safety in WIPP

As discussed in the previous section, the criticality analysis in support of the SAR does not demonstrate the safety of 17C 55-gallon waste drum storage arrays in WIPP. None of the many configurations analyzed in Reference 9 is identical to the proposed storage configuration in WIPP. Nevertheless, the safety of the WIPP storage configuration can be inferred from the Rockwell Hanford Operations results.*

The most reactive, physically realistic configuration analyzed in Reference 9 is the ∞ x ∞ x 6 array of drums containing 200 gm of Pu^{239} in a full density, flattened configuration. The fissile material is optimally moderated (H/Pu ≅ 1100) and the vertical dimension of the array is infinitely reflected with soil. The predicted effective multiplication factor is approximately 0.92.

Other results presented in Reference 9 permit an estimate of the effect of additional leakage to be expected from the actual storage configuration. The effect of reducing the vertical dimension from 6 to 3 tiers is estimated to change the multiplication factor by roughly -0.08. The effect of reducing the width of the array from infinity to 15 drums is estimated to be approximately -0.04 in k_{eff}.

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*This statement and the subsequent remarks are predicated on the assumption that the revised analysis (yet to be released) does not result in higher predicted values of k_{eff} for arrays of 6 tiers or less.

Moreover, several additional conservative approximations and assumptions inherent in all of the calculations were pointed out in Section 3.1. The combined effect of these additional conservative assumptions, although not explicitly analyzed, could easily amount to -0.05 to -0.10 in k_{eff}.

Although these negative contributions to the effective multiplication factor are not additive, the combined effect is to provide an additional cushion of conservatism to the analysis. Therefore, it can be concluded that the 55-gall drum storage array in WIPP will be safely subcritical ($k_{eff} <$ 0.95).

In arriving at this conclusion, two very reactive configurations analyzed in Reference 9 have been ignored. The first is the H/D=1.5 shape in the drum, shown to be higher by as much as +0.2 in k_{eff} than that of the flattened shape. That the fissile moderator mixture could assume such a shape in a significant number of drums is considered to be physically unrealistic. The second is the three-dimensional collapse of the array, shown to result in an increase in k_{eff} by as much as +0.25. Although a one-dimensional collapse is considered to be possible (and, according to Reference 9, of negligible consequence), a complete three-dimensional collapse is difficult to envision.*

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*Of course, over the long-term, such an effect is fair game. The long-term, however, is outside of the scope of this review.

4.0 CONCLUSIONS AND RECOMMENDATIONS

Criticality safety in WIPP has not been demonstrated in the SAR. However, a review of independent analyses suggests that criticality safety is assured in the planned configuration for TRU waste storage.*

Criticality safety is dependent on the assumption that no mechanism exists to radially compact the wastes in individual drums or to compress the entire array in all three dimensions. Although this assumption appears reasonable, some thought should be given to potential failure modes that could conceivably undermine its validity. Moreover, a reliable assay method must be specified to assure that the content of plutonium in the drums is less than the prescribed limit (200 gm, for 55-gallon drums).

Other configurations for waste storage in WIPP would require additional analysis before criticality safety can be assured. For example, a configuration in which the drums were to be stacked on their sides has not been shown to be safe. Moreover, if 6M drums containing 500 gm of plutonium are to be stored in WIPP, assurances must be given that each drum will contain the specified wood reinforcement.

Finally, thought should be given to long-term effects that could assemble a critical mass through dissolution, transport, and reconcentration of the fissile material.

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*This conclusion must be regarded as tentative until the revised results of the Rockwell Hanford Operations analyses are released.

5.0 REFERENCES

1. ERDA Manual Chapter 0530, Nuclear Criticality Safety; Approved December 21, 1976 (recently cancelled).

2. Final Environmental Impact Statement, Waste Isolation Pilot Plant, U.S. Department of Energy, October 1980.

3. Safety Analysis Report, Waste Isolation Pilot Plant, U.S. Department of Energy, revised in January 1981.

4. M.H. Lipner and J.M. Ravets, "Nuclear Criticality Safety Analyses for the Waste Isolation Pilot Plant Project," Westinghouse Advanced Energy Systems Division, WAES-TME-3025, April 1980.

5. Repository Level Waste Stacking and Configuration Plan and Sections, Bechtel Drawing No. 51-U-001, Revision E.

6. H.C. Paxton, J.T. Thomas, D. Callihan, and E.B. Johnson, Eds., "Critical Dimensions of Systems Containing U^{235}, Pu^{239}, and U^{233}, USAEC Report TID-7028 (1964).

7. L.C. Davenport and J.K. Thompson, "Survey of Criticality Parameters for Pu^{239} in Organic Media," Trans. Am. Nucl. Soc. 77, p. 419, 1977.

8. J. T. Thomas, Ed., Nuclear Safety Guide, TID-7016, Rev. 2, 1978.

9. W.A. Blyckert and R.D. Carter, "Criticality Parameters of 55-Gallon Waste Drum Arrays," Rockwell Hanford Operations, RHO-SA-133, November 7, 1980.

10. R.R. Jones, Independent Criticality Analysis of 17C Drum Storage at RWMC, EG&G Idaho, Inc., RE-P-81-033, May 1981.

11. R.R. Jones & G.E. Putnam, Independent Criticality Analysis of RWMC Storage and Disposal of Waste with 177 g/m³ Fissile Material Limit, EG&G Idaho, Inc., RE-P-81-050, May 1981.

12. R. Odegaarden, U.S. Nuclear Regulatory Commission, Private Communication, September 4, 1981.

13. R.D. Carter, Rockwell Hanford Operations, private communication, August 31, 1981.

SUPPLEMENT 3
(Appendix SCR, DCCA)

SC&A Inc.

S. COHEN AND ASSOCIATES

RECEIVED

1984

ENVIRONMENTAL EVALUATION GROUP

December 30, 1983

Mr. Robert H. Neill
Director
Environmental Evaluation Group
State of New Mexico
320 E. Marcy Street
P.O. Box 968
Santa Fe, New Mexico 87503

Subject: Reviews of WAESD-TR-83-0015 and TME-3025 Rev.1

Dear Bob:

I have reviewed the subject documents (References 1 and 2 in the attached list) and offer the following comments for your consideration.

In its original WIPP criticality safety analyses,[3] DOE addressed both remote-handled (RH) and contact-handled (CH) wastes. The revised WIPP criticality safety analysis[2] addresses only CH waste. The WAESD report[1] considers the criticality safety of RH waste.

The new RH waste criticality analysis[1] has a different orientation than the original analysis.[3] The original analysis estimated k_∞ for one nominal amount of Pu-239 (126.7 gm), assumed to be uniformly distributed in various solid-water mixtures. The assumed compositions were estimated to be substantially subcritical ($k_\infty \leq 0.109$).

The new analysis <u>determines</u> criticality <u>limits</u> for an array of RH waste containers under double accident conditions. A subcritical margin of 5% Δk is the objective, modified to a value of 8% Δk to account for calculational methods and cross section data uncertainties (at 3σ). The study resulted in two types of limits -- a concentration limit and a mass limit. For those cases in which uniformity of fissile concentration can be assured (the criterion is a maximum of 50% void averaged over any 5 liter volume within the container), a fissile concentration limit of 1.9 gm/liter was derived.* In all other cases, a mass limit of 240 gms obtains (190 gms and 160 gms for fissile assay errors of 25% and 50%, respectively).

Although we do not have the resources to attest to the validity of the results, the RH waste criticality analysis appears to have been professionally executed. The array of containers was modeled using a three-dimensional Monte Carlo code

*Note that this concentration is equivalent to a fissile content of approximately 3 kg in an RH container, roughly a factor of 24 higher than the nominal amount of Pu-239 assumed in the original criticality analysis.[3]

(KENO-IV). Sensitivity to variations in parameters was checked using a one-dimensional transport code (XSDRNPM), which also generates an appropriate neutron spectrum. ENDF/B-4 cross sections were used, with resonance self-shielding accomplished with the NITAWL code. Methods were benchmarked against seven plutonium critical experiments. The calculations considered a number of constituents in the waste matrix, various reflectors surrounding the array, a full range of moderation (H/Pu-239), and compaction/settling of the waste pieces. Additionally, several accident configurations were examined, and double accident conditions were assumed in establishing the limits. In summary, the methods are state-of-the-art and the investigators explored the sensitivity of the results to a very wide range of parameters.

We turn now to the revised CH waste criticality analysis.[2] In my 1981 review of the original CH waste criticality analysis,[3] I pointed out two assumptions which were not conservative.[4] The first was the assumed lower limit on the ratio of hydrogen to plutonium (roughly 2000). The second was the assumed homogeneous distribution of the plutonium throughout the waste.

In the revised CH waste criticality analysis, the former assumption was relaxed, and k_∞ was calculated over the entire range of hydrogen to plutonium ratios. For the maximum fissile content of 200 gm Pu-239, the 17C 55-gallon drum infinite array is critical over the range of $40 < H/Pu\text{-}239 < 1500$. The maximum calculated k_∞ is approximately 1.2 at a hydrogen to plutonium ratio of approximately 400. However, DOE dismisses these results by stating that "the simultaneous occurrence of a very large array of drums all containing the maximum allowable fissile loading combined with uniform interspersed moderation is considered incredible."

In a February 1982 letter from the WIPP Project Office to the EEG,[5] DOE argues persuasively against the possibility of a significant fraction of the drums being at maximum density. The letter states that "the data package to be provided with every container of waste to be shipped to WIPP will contain the results of an assay of the fissile content in accordance with the WIPP Waste Acceptance Criteria. This assay will be sufficiently accurate to alert the WIPP operator to any trend toward increased fissile loadings."

In its revised criticality analysis, DOE did <u>not</u> relax the second assumption, that the plutonium is admixed homogeneously throughout the waste. In fact, the original erroneous language was not changed, namely that "modeling the plutonium as homogeneously distributed throughout the waste is very conservative since this ignores geometric self-shielding." As demonstrated in Reference 6 and discussed in my 1981 review,[4] compressing the fissile-moderator mixture leads to significant increases in reactivity because it results in a smaller fractional leakage and less parasitic absorption in the drum walls.

In the February 1982 letter from the WIPP Project Office to the EEG,[5] DOE correctly points out that "reactivity is not significantly affected by settling of the drum's content until the total drum content reaches approximately 30% of the total drum volume." However, DOE further contends that "this settling must occur independent of crushing of the drum, a situation we believe incredible in view of the nature of the drum contents and the limited handling activity involved." I do not agree. This configuration could simply be realized with partially filled drums (with the 70% remainder of the drum empty) or material which has settled to the bottom of the drums.

However, the DOE analysis, coupled with administrative limits on drum loading, would assure subcriticality. The average drum loading (13.275 gm Pu-239) would surely remain subcritical (k_∞ of the homogeneous, infinite array at optimum moderation is less than 0.4), even under conditions of partially filled or settled material in the drums (although this was not explicitly demonstrated by the DOE analysis).

Although I don't suggest that any more resources be expended on this issue, I am still perplexed by DOE's analytical approach to this problem. As discussed in my 1981 review, it is possible to demonstrate subcriticality of a finite array of maximally loaded drums in a flattened configuration.* Relying on this most conservative analysis, DOE would not have to impose administrative limits on drum loading or configuration.

I hope that the foregoing comments are useful to you in your review of these recent DOE documents. Please feel free to contact me if you should have any questions concerning my comments.

Sincerely,

Sanford Cohen

Attachment

SC/gh

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*In fact, the Rockwell Hanford analyses[6] have already done this. At the time of my 1981 review, the Rockwell Hanford calculations were being revised because of changes in the iron cross sections. The revised analyses did not result in higher predicted values of k_{eff} for arrays of 6 tiers or less.[7]

SUPPLEMENT 4
(Appendix SCR, DCCA)

S. COHEN AND ASSOCIATES Inc.

RECEIVED

JAN 20

ENVIRONMENTAL
EVALUATION GROUP

January 18, 1984

Mr. Robert H. Neill
Director
Environmental Evaluation Group
320 E. Marcy Street
P.O. Box 968
Santa Fe, New Mexico 87503

Dear Bob:

We have completed our analysis of the postulated WIPP reconcentration criticality, and discuss our results in this letter. In summary, we learned that for the material concentrations that you have postulated, a criticality is indeed likely if the high fissile concentration obtains and the dimension of the aquifer is greater than roughly one-half meter. For such a high fissile concentration, the multiplication factor is not affected significantly by the postulated range of carbon adsorption, non-TRU brine composition, or low iron adsorption. High iron adsorption does significantly reduce the multiplication factor, but the thick aquifer is probably still critical. On the other hand, a criticality does not appear achievable if the low fissile concentration obtains for any combination of the other parameters.

The input material concentrations, based on your letter of July 20, 1983*, modified by telephone conversations with Jim Channell on December 19, 1983, are given in Attachment I. The resulting homogeneous atom densities used in the computer analyses are given in Attachment II. A number of the elements contained in Attachment I have been omitted from the calculations. The reasons for these omissions and other assumptions used in computing the atom densities are as follows:

- The calculated atom density of U-233 is three orders of magnitude lower than that of Pu-239, given a uranium distribution coefficient (K_D) of 10; thus U-233 was omitted from the calculation.

- The macroscopic thermal absorption cross sections and potential cross sections of several elements were calculated to be at least three orders of magnitude lower

*Attachment to letter from Robert H. Neill to Sanford Cohen, entitled "Inputs to Criticality Calculation."

than the corresponding macroscopic cross sections for hydrogen, and thus these elements were omitted from the calculations. These omitted elements are barium, cesium, strontium, bromine, flourine, iodine, phosphorus, aluminum, copper, manganese, silicon, and zinc.

- Cross sections for the element chlorine were not available on the master data tape. Chlorine could not be disregarded in the calculations because of its relatively large absorption cross section. Therefore, chlorine was replaced by an equivalent amount of boron, based on the relative thermal neutron (0.025 ev) absorption cross sections of the two elements, i.e.:

$$N_B = \frac{(33.6 \text{ barns})}{755 \text{ barns}} N_{Cl} ,$$

  where N_B and N_{Cl} are the atom densities of boron and chlorine, respectively.

- The element lithium was replaced by the appropriate atom density of lithium-6. The predominant isotope, lithium-7, is relatively transparent and can be safely neglected.

- The "Miscellaneous" material in Case 1 brine is assumed to be nitrogen.

- The hydrogen and oxygen atom densities for Case 2 brine are derived by assuming that the difference between the specific gravity (1.215 gm/cc) and the total dissolved solids (0.328 gm/cc) represents the density of water in the brine.

The computer calculations were performed using the NITAWL and XSDRNPM computer codes installed on the CDC Cybernet system.* NITAWL extracts 123-group cross sections from the master cross

*The codes are summarily described and the input data specified in the AMPX-II manual, "AMPX: A Modular Code System for Generating Coupled Multigroup Neutron-Gamma Libraries from ENDF/B," ORNL/TM-3706, March 1976 (December 1978, Revised).

section library[*] and prepares them as input to XSDRNPM. It additionally performs any required resonance calculations (only for Pu-240 in our calculation) using the Nordheim Integral Method. XSDRNPM calculates the neutron spectrum and the eigenvalue for a one-dimensional system, accepting fine-group cross sections from NITAWL. It additionally collapses the weighted fine-group cross sections to any specified multi-group set, for input to a multi-dimensional code. For all but one of our calculations (to be described later) we used XSDRNPM in the homogeneous approximation (infinite medium), thus computing the infinite multiplication factor (k_∞).

In all of our calculations, we collapsed cross sections to calculate the diffusion area:

$$L^2 = \frac{D}{\Sigma_a} = \frac{1}{3\Sigma_a \Sigma_{tr}} ,$$

where D is the diffusion coefficient and Σ_a and Σ_{tr} are the macroscopic absorption and transport cross sections, respectively. We also computed the buckling using the following relationship[**]:

$$B^2 = \left(\frac{\pi}{700 + \frac{1.42}{\Sigma_{tr}}}\right)^2 + \left(\frac{\pi}{d + \frac{1.42}{\Sigma_{tr}}}\right)^2 ,$$

where the first quantity accounts for leakage from the depth (7m) of the slab and the second quantity from the width (d=0.5m or 5.0m) of the slab. (Leakage from the 7m depth is, in all cases examined, negligible.) Then, the effect of leakage on the multiplying system is computed using the one-group, diffusion approximation:

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*The master library is taken from GAM-II (fast cross sections) and THERMOS (thermal cross sections) cross section sets prepared in the 1960s, and is poorly documented. According to representatives of Oak Ridge National Laboratory, it will be documented in the SCALE manual, which is yet to be published.

**This assumes an unreflected configuration. In actuality, our assemblies are probably reflected by rock. We have neglected the effect of this reflection in our analyses, rendering the results conservative. (The effect of reflection would be to increase slightly the k_{eff} of the assemblies.)

$$k_{eff} = \frac{k_\infty}{1 + L^2B^2} \ .$$

We examined the accuracy of the above approximation by mocking up the actual geometry (0.5m wide, unreflected slab) in a P_1, S_4*, XSDRNPM spatial transport calculation. We used Case A (Hi fissile, brine 1, no adsorbed Fe, no adsorbed C) for the calculation. The spatial transport calculation resulted in a k_{eff} of approximately 0.83. This is to be compared with an estimated k_{eff} of 0.97 obtained in the one-group, diffusion approximation. Thus the one-group, diffusion approximation appears to underestimate the effect of leakage for the thin slab and thus overestimates the effective multiplication factor. The overestimation in k_{eff} is approximately 0.14 for the 50cm thick slab. Such an error does not significantly affect the results of the study, because it translates into less than 20cm of additional thickness for an unreflected slab. Moreoever, we have assumed in our analysis an unreflected configuration, and the slab would most likely be reflected by unsaturated rock, thus reducing the critical slab thickness.

The final results of the criticality calculations are given in Attachment III. The actual computer output that these results are based on are being sent to you under separate cover. The calculated value of the infinite multiplication factor, k_∞, is tabulated in column 3. The effective multiplication factors, for each slab width, are given in columns 5 and 6. For the five cases identified as A through E, the infinite multiplication factors are also the eigenvalues calculated in corresponding XSDRNPM runs. For the cases denoted with primes, the infinite multiplication factors were obtained by weighting the microscopic fission and absorption cross sections over the unprimed spectra (A' and A" over the spectrum calculated in Case A; E' and E" over the spectrum calculated in Case E), and computing:

$$k = \frac{\nu\Sigma_f}{\Sigma_a} \ ,$$

using the appropriate number densities for the primed cases. This approximation should be quite accurate for the high fissile cases, since the perturbations are small. For the lo fissile

*The P_1 stands for first order quadrature of the scattering anisotropy; S_4 stands for four discrete angles represented in the spatial transport calculations.

cases, the approximation is less accurate, but sufficient for demonstrating trends for these assemblies, which are estimated to be far subcritical under any of our variations.

The results given in Attachment III demonstrate that an *infinite configuration of the hi fissile concentration is far* supercritical and roughly invariant under all of the modifications examined, with the exception of the hi adsorbed iron case. *The insensitivity of the hi fissile case can be ex*-pained by the fact that, with the exception of the hi adsorbed iron case, approximately 75% of the absorptions are in the Pu-239.

Conversely, all of the lo fissile concentration cases are subcritical by a substantial margin. This is because only approximately 35% of the absorptions (only 18% for the hi adsorbed iron case) are in the Pu-239. For the lo fissile case with Brine 1, hi adsorbed carbon, and no adsorbed iron, 12% of the adsorptions are in the calcium, 8% in the hydrogen, 35% in the boron (simulated chlorine), 4% in the non-fissile plutonium, and the remaining 16% in the other nuclides.

Leakage from the 5 meter slabs is insignificant, so that k_{eff} is essentially equivalent to k_∞. Leakage from the 0.5 meter slabs is significant; the one-group diffusion analyses indicate that for hi fissile concentrations, with the exception of the hi adsorbed iron case, the configurations may be barely critical ($0.96<k_{eff}<1.07$). Transport calculations indicate that leakage is underestimated. However, we have neglected reflection by the surrounding rock. Therefore, it may be safely concluded that the thin slabs are critical in the thickness range of 0.5 to 1.0 meters.

Two additional perturbations, not tabulated in Attachment III, were examined. The first was the effect of the removal of Pu-238 from Case A.* This results in an increase in k_∞ of approximately 0.01, which is a negligible effect. The second was the effect of the removal of boron, used to simulate the chlorine, from Cases A and E. The results are increases in k_∞ of 0.10 for Case A (hi fissile) and 0.36 for Case E (lo fissile). The results indicate that a 100% error in the simulation of chlorine by boron would not alter the major qualitative results *for the high fissile cases, but might for the low fissile cases.*

---

*Pu-238 has a relatively short half-life, and is unlikely to be present to any significant degree in a repository several hundred years after waste emplacement.

The environmental consequences of a reconcentration criticality incident are highly uncertain. The release of fission products depends on the number of fissions, which in turn depends on the ability of the configuration to remain critical. Most historical criticality incidents result in modest bursts of approximately 10^{16} to 10^{18} fissions; however, as many as $\sim 10^{20}$ fissions have been recorded.* The historical incidents involving solutions generally proceed in a succession of bursts until the geometry is destroyed by the expulsion of the liquid from the confined configuration. This occurs from the heating and subsequent expansion of the liquid. (10^{20} fissions corresponds to approximately 10^4 Mw-sec, or approximately 10^7 BTU.)

The reconcentration criticality postulated here could have a different physical behavior. The fissile material is deposited on the rock and would presumably remain in place after the brine has been expelled from the generated heat. Moreover, the system would probably fill with fluid again because the source is a flowing aquifer. Thus, the most likely physical behavior is a continual "chugging" of the system, resulting in a continual series of bursts, each resulting in, say, approximately 10^{16} fissions, until the reaction is quenched by the poisoning effect of fission products. Possibly Oklo is the closest analogy.

The quantity of fission products produced can be estimated once the total energy release is determined. However, because of the location of the incident, the consequences to the accessible environment should not be very high. The noble gases may find their way to the atmosphere, but most of the radioiodine would probably be retained in the aquifer or the rock. If Oklo is indeed a reasonable analogy, most of the non-volatiles should be retained in the rock in close proximity to the site of the critical configuation.

I hope that this letter and the Attachments are useful to you in your assessment of the likelihood of a reconcentration criticality resulting from dissolved WIPP transuranic wastes. If you or your staff have any question relating to any of this information, please do not hesitate to call me. I am sending the computer output under separate cover.

Sincerely,

Sanford Cohen

Attachments

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*William R. Stratton, "A Review of Criticality Accidents", LA-3611, September 1967.

M

Attachment I

MATERIAL CONCENTRATIONS

In Rock (with porosity = 10%)

Element	Density (gm/cc)
Calcium	0.435
Carbon	0.247
Magnesium	0.251
Oxygen	1.045
Hydrogen	0.00234
Sulfur	0.019

TRU Content of Brine

Nuclide	Concentration (mg/l) Hi Fissile	Low Fissile
U-233	1.1	0.11
Pu-238	0.17	0.017
Pu-239	6.6	0.66
Pu-240	0.32	0.032

Concentration factor for rock - 4000

Other Constituents of Brine

Element	Concentration (mg/l)	
	Case 1	Case 2
Oxygen	644	See attached chemistry for WIPP-12 brine
Hydrogen	95	
Carbon	138	
Iron	222	
Sodium	115	
Chlorine	175	
Misc. (assume Nitrogen)	55	

Adsorbed Carbon

Concentration in Rock (mg/cc)	
Low Adsorption	Hi Adsorption
50	500

Adsorbed Iron

Concentration in Rock (mg/cc)	
Low Adsorption	Hi Adsorption
100	1000

TABLE C.7

CHEMICAL COMPOSITION OF BRINES
SUMMARY OF STATISTICS
ERDA-6, WIPP-12, AND UNION WELLS[1]

SAMPLE TYPE: / LABORATORY: / LOCATION:		FLOW SAMPLE / D'APPOLONIA / ERDA-6					FLOW SAMPLE / D'APPOLONIA / WIPP-12					FLOW SAMPLE / D'APPOLONIA / UNION				
FIELD DETERMINATIONS:	UNITS	NO. OF ANALYSES	MINIMUM	MAXIMUM	AVERAGE[2]	CV[3]	NO. OF ANALYSES	MINIMUM	MAXIMUM	AVERAGE[2]	CV[3]	NO. OF ANALYSES	MINIMUM	MAXIMUM	AVERAGE[2]	CV[3]
Temperature	°C	40	31.0[4]	26.7	26.7[5]	0	30	24.2	28.8	26.7	3	--	--	--	--	--
pH	Standard Units	40	6.0	6.3	6.17	0.8	30	6.6	7.28	7.06	5	4	6.55	7.3	7.10	3
Eh	Millivolts	40	-160	-31	-113	8	30	-130	-105	-115	13	4	-230	-184	-213	14
Specific Gravity	--	30	1.216	1.222	1.218	0.2	30	1.210	1.220	1.215	0.3	4	1.210	1.220	1.216	4
Specific Conductance	µmhos/cm @ 25°C	30	331,000	633,000	473,000	3	30	420,000	599,000	540,000	3	4	499,000	542,000	526,000	0.4
Alkalinity[6]	mg/l	20	2245	2910	2600	5	35	2473	3040	2800	3	3	1935	2320	2100	9
Carbonate	mg/l	20	0	0	0	0	35	0	0	0	0	3	0	0	0	0
Hydroxide	mg/l	20	0	0	0	0	35	0	0	0	0	3	0	0	0	0
Chloride	mg/l	30	170,200	210,100	188,000	3	33	171,000	197,000	187,200	4	3	183,200	185,400	183,900	0.7
Sulfate	mg/l	30	13,700	24,400	19,100	9	40	16,200	21,300	18,500	6	3	18,600	20,100	19,300	4
Total Hardness (as $CaCO_3$)	mg/l	23	2235	6730	3640	6	25	5440	6515	6050	4	3	8950	9160	8970	2
Total Iron	mg/l	19	0.03	0.83	0.23	70	13	0.06	0.49	0.27	70	3	0.13	1.3	0.62	120
Hydrogen Sulfide	mg/l	30	172	837	360	30	30	682	1160	940	10	3	344	613	490	6
LABORATORY DETERMINATIONS:																
pH	Standard Units	10	6.29	6.73	6.42	2	13	7.14	7.80	7.40	3	3	7.2	7.34	7.31	0.4
Specific Conductance	µmhos/cm @ 25°C	10	400,000	510,000	490,000	7	13	480,000	810,000	637,000	16	3	500,000	500,000	500,000	0
Total Dissolved Solids	mg/l	10	320,000	340,000	330,000	3	13	310,000	340,000	328,000	2	3	300,000	510,000	390,000	27
Total Suspended Solids	mg/l	10	33	220	87	60	13	0	92	43	65	3	24	96	70	57
Cations:																
Barium	mg/l	10	0.10	2.3	0.76	100	13	<0.1	0.90	<0.31	100	3	1.5	2.0	1.7	16
Calcium	mg/l	10	470	520	490	3	13	200	420	310	18	3	330	350	340	3
Cesium	mg/l	9	2.4	2.6	2.5	3	10	1.2	1.9	1.6	14	--	--	--	--	--
Lithium	mg/l	10	210	270	240	8	13	220	330	300	13	3	355	365	360	2
Magnesium	mg/l	10	330	540	450	19	13	1600	1700	1600	3	3	1900	2300	2100	10
Potassium	mg/l	10	2800	4400	3604	12	13	2500	3300	2900	8	3	3500	4600	3900	14
Sodium	mg/l	10	100,000	116,000	112,000	3	13	113,000	180,000	138,000	12	3	109,000	115,000	111,000	3
Strontium	mg/l	10	16	20	18	12	13	10	26	19	23	3	11	12	11	5
Anions:																
Alkalinity[6]	mg/l	10	2600	2700	2600	2	13	2500	2800	2700	3	3	1100	1600	1300	8
Bromide	mg/l	10	750	940	880	9	13	300	600	310	16	3	410	500	460	17
Chloride	mg/l	10	160,000	180,000	170,000	4	13	160,000	220,000	170,000	8	3	160,000	180,000	170,000	6
Fluoride	mg/l	10	1.6	1.9	1.7	6	13	2.0	4.3	3.4	16	3	0.88	1.0	0.92	6
Iodide	mg/l	5	15	32	20	31	5	16	29	24	22	--	--	--	--	--
Sulfate	mg/l	10	14,000	18,000	16,000	7	13	16,000	20,000	18,000	7	3	30,000	34,000	32,000	10
Nutrients:																
Ammonia (as Nitrogen)	mg/l	10	840	920	870	2	13	320	430	370	11	3	300	340	310	7
Nitrate (as Nitrogen)	mg/l	10	370	880	620	13	12	260	1300	550	43	3	370	480	440	14
Phosphate (as Phosphorus)	mg/l	10	0.26	0.40	0.37	19	13	<0.10	0.8	<0.3	100	3	<0.1	<0.1	<0.1	0
Other Elements:																
Aluminum	mg/l	10	0.20	3.9	2.4	33	13	1.4	3.9	2.0	37	3	2.6	3.4	2.9	18
Boron	mg/l	10	370	890	600	15	13	790	1600	990	16	3	1000	1300	1100	16
Copper	mg/l	10	0.19	0.96	0.46	53	11	0.36	0.66	0.61	30	3	<0.1	0.4	0.3	60
Iron	mg/l	10	2.4	6.9	3.6	37	13	1.5	4.3	2.7	26	3	1.2	2.6	2.0	49
Manganese	mg/l	10	3.6	7.8	6.8	18	13	0.18	0.92	0.71	30	3	0.6	1.0	0.8	25
Silica (as SiO_2)	mg/l	9	36	51	45	17	10	41	75	57	23	--	--	--	--	--
Zinc	mg/l	10	0.30	0.64	0.33	30	13	0.17	0.31	0.37	20	3	<0.1	1.4	0.63	110

NOTES:

[1] Analyses performed by D'Appolonia. Samples containing drilling fluid contamination excluded from this table.

[2] Average = Arithmetic Mean.

[3] CV = Coefficient of Variance (%) = $\frac{\text{Standard Deviation}}{\text{Average}} \times 100$.

[4] Borehole temperature averaged 31.0°C during Activity ERDA-6.8 from 10/31/81 to 11/4/81 (measured at 403 feet below the surface).

[5] Borehole temperature averaged 26.7°C during Activity ERDA-6.9 (measured at approximately 2672 feet below the surface).

[6] Values are reported as mg/l HCO_3^-. However, analyses of inorganic carbon average only 340 mg/l HCO_3^- in WIPP-12 and 900 mg/l HCO_3^- in ERDA-6.

"--" = Parameter not analyzed.

Attachment I (Cont.)

Attachment II

HOMOGENIZED ATOM DENSITIES (atoms/cc X 10^{24})

Element/Nuclide	Case A Hi Fissile, Brine 1, No Ads.Fe, No Ads.C	Case B Hi Fissile, Brine 1, No Ads.Fe, Hi Ads.C	Case C Hi Fissile, Brine 1, Hi Ads.Fe, No Ads.C	Case D Hi Fissile, Brine 2, No Ads.Fe, No Ads.C	Case E Lo Fissile, Brine 1, No Ads.Fe, Hi Ads.C
Hydrogen	7.07 X 10^{-3}	7.07 X 10^{-3}	7.07 X 10^{-3}	7.33 X 10^{-3}	7.07 X 10^{-3}
Lithium-6	0.0	0.0	0.0	1.83 X 10^{-7}	0.0
Boron	1.32 X 10^{-5}	1.32 X 10^{-5}	1.32 X 10^{-5}	1.89 X 10^{-5}	1.32 X 10^{-5}
Carbon	1.31 X 10^{-2}	3.82 X 10^{-2}	1.31 X 10^{-2}	1.24 X 10^{-2}	3.82 X 10^{-2}
Nitrogen	2.36 X 10^{-4}	2.36 X 10^{-4}	2.36 X 10^{-4}	3.95 X 10^{-6}	2.36 X 10^{-4}
Oxygen	4.17 X 10^{-2}	4.17 X 10^{-2}	4.17 X 10^{-2}	4.23 X 10^{-2}	4.17 X 10^{-2}
Sodium	3.01 X 10^{-4}	3.01 X 10^{-4}	3.01 X 10^{-4}	3.61 X 10^{-4}	3.01 X 10^{-4}
Magnesium	6.21 X 10^{-3}	6.21 X 10^{-3}	6.21 X 10^{-3}	6.21 X 10^{-3}	6.21 X 10^{-3}
Sulfur	3.57 X 10^{-4}	3.57 X 10^{-4}	3.57 X 10^{-4}	3.68 X 10^{-4}	3.57 X 10^{-4}
Potassium	0.0	0.0	0.0	4.47 X 10^{-6}	0.0
Calcium	6.54 X 10^{-3}	6.54 X 10^{-3}	[illegible].54 X 10^{-3}	6.54 X 10^{-3}	6.54 X 10^{-3}
Iron	2.39 X 10^{-4}	2.39 X 10^{-4}	1.10 X 10^{-2}	2.91 X 10^{-9}	2.39 X 10^{-4}
Pu-238	1.72 X 10^{-6}	1.72 X 10^{-6}	1.72 X 10^{-6}	1.72 X 10^{-6}	1.72 X 10^{-7}
Pu-239	6.65 X 10^{-5}	6.65 X 10^{-5}	6.65 X 10^{-5}	6.65 X 10^{-5}	6.65 X 10^{-6}
Pu-240	3.21 X 10^{-6}	3.21 X 10^{-6}	3.21 X 10^{-6}	3.21 X 10^{-6}	3.21 X 10^{-7}

Attachment III

RESULTS

Case	Description	k_∞	$L^2(cm^2)$	k_{eff}	
				5.0m	0.5m
A	Hi Fissile, Brine 1, No Ads.Fe, No Ads.C	1.40	135.	1.39	0.97
A'	Hi Fissile, Brine 1, No Ads.Fe, Lo Ads.C	1.40	130.	1.39	0.97
A"	Hi Fissile, Brine 1, Lo Ads.Fe, No Ads.C	1.38	129.	1.37	0.96
B	Hi Fissile, Brine 1, No Ads.Fe, Hi Ads.C	1.41	92.4	1.41	1.07
C	Hi Fissile, Brine 1, Hi Ads.Fe, No Ads.C	1.18	101.	1.17	0.88
D	Hi Fissile, Brine 2, No Ads.Fe, No Ads.C	1.37	132.	1.36	0.95
E	Lo Fissile, Brine 1, No Ads.Fe, Hi Ads.C	0.68	134.	0.67	0.46
E'	Lo Fissile, Brine 1, Hi Ads.Fe, Hi Ads.C	0.35	56.9	0.35	0.29
E"	Lo Fissile, Brine 1, No Ads.Fe, No Ads.C	0.68	175.	0.67	0.43

SUPPLEMENT 5
(Appendix IRD, DCCA)

ENVIRONMENTAL EVALUATION GROUP

AN EQUAL OPPORTUNITY / AFFIRMATIVE ACTION EMPLOYER

7007 WYOMING BOULEVARD, N.E.
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December 27, 1991

Mr. W. John Arthur, III
Project Director
WIPP Project Integration Office
U.S. Department of Energy
P.O. Box 5400
Albuquerque, NM 87115

M

Dear Mr. Arthur:

EEG has reviewed DOE/WIPP 91-029, "Implementation of the Resource Disincentive in 40 CFR Part 191.14(e) at the Waste Isolation Pilot Plant," August 1991. We do not believe that the report accomplishes the objective of satisfying the requirement of 40 CFR 191.14(e) nor does it adequately address concerns expressed in our August 10, 1990 letter (attached). Also, it appears that DOE has not asked EPA's opinion about whether this report would satisfy the 191.14(e) requirement.

However, EEG wishes to be constructive and look to the future to compensate for the lack of this compliance. Because the site has not been shown to possess favorable characteristics to compensate for the handicap of a resource-rich site, its compliance with the containment requirements should be very conservative. Human intrusion into the site should be considered a high probability, engineered modifications of the waste should be seriously considered, and the reliance for long-term integrity should rest on engineered barriers in addition to the geology.

If you agree with this suggestion, it would be necessary to:

(1) abandon the DOE efforts to modify the Human Intrusion portion of the Standard. Suggested modifications would reduce or eliminate the only quantitative deterrent in the Standard against deliberately choosing a resource-rich site;
(2) make a commitment to include robust engineered barriers in the WIPP design similar to NRC and NWTRB recommendations for the high-level repository; and
(3) seriously examine the options for repository design and waste form modification to minimize the release from human intrusion.

We believe that this approach would be more productive than continuation of our six-year-old debate about whether compliance with 40 CFR 191.14(e) has been shown. If you do not agree with this constructive approach, we will have to insist on your publishing a report that shows compliance with the resource disincentive assurance requirement.

Our detailed comments on the report are enclosed.

Sincerely,

James K. Channell
Robert H. Neill
for Director

RHN:js
Enclosure

cc: James Bickel, DOE/ALO
Arlen Hunt, DOE/WPO
Mark Frei, WIPP Task Force
William Gunter, EPA

COMMENTS ON "IMPLEMENTATION OF THE RESOURCE DISINCENTIVE IN 40 CFR PART 191.14(e) AT THE WASTE ISOLATION PILOT PLANT (DOE/WIPP 91-029, August 1991)

General Comments

This report states that the "resource disincentive" assurance requirement (40 CFR 191.14(e) that was in the remanded 1985 40 CFR 191 Standard and expected to be in the repromulgated standard has been satisfied. We disagree. The report states "In addressing the natural resource provision of 40 CFR Part 191, the DOE does not propose to provide justification for the selection of the WIPP site." Rather, the report presents the history of how natural resource issues were evaluated during the site selection process. The contention is that the evaluation was extensive, with outside reviewers (including EEG), satisfied the NEPA process, and concluded that the use of the site for a TRU waste repository was of greater benefit than the possible development of the resources. The point was also made that the entire site selection process was completed prior to the issuance of the EPA Standards which contain the "resource disincentive" assurance requirement.

Our page-by-page comments follow. The comments recognize that much of the text is quotes from various documents and we believe it is historically accurate. However, some of these quotes give a misleading picture of the current situation and its applicability to the "resource disincentive."

Page-By-Page Comments

Page 1. The introduction fails to describe the event that prompted DOE to issue a strategy plan. It was a requirement specified in the 1987 modification to the C&C Agreement between DOE and the State of New Mexico.

Page 9, first paragraph, EEG is quoted (in a 1983 report) as suggesting that the loss of resources "is perhaps best handled by the NEPA process" and that health and safety issues from the attractiveness of the resource should be addressed by evaluating the increased probability of human intrusion.

This is still our position. The ultimate determination that a resource-rich site is acceptable can come only after evaluating it against a standard that adequately reflects the increased attractiveness of the site to human intrusion. However, it appears that DOE and SNL are engaging in activities designed to reduce or eliminate the effect that resources have on the human intrusion scenario in the 1985 EPA Standard.

Page 10, second paragraph. The EPA ESAB is quoted as saying that "it may be possible by suitable engineering technique to recover the resources without disturbing a nearby repository or to mitigate the effects of potential human intrusion. The site and engineered barriers should be seen as a system, ..."

EEG is uncomfortable with the concept of recovering resources on the WIPP site (currently permitted by DOE with the existing gas leases) and any general policy to permit this should be considered only after extensive discussions with non-DOE organizations. Also, there are still no commitments by DOE to any type of engineered barrier system to mitigate the effects of human intrusion.

Pages 12 and 61. EPA expects that sites with resources would be used only "if it is reasonably certain that they would provide better overall protection than the practical alternatives that are available." On page 61 the report says "The conclusion is that the favorable characteristics of the site uniquely qualify it for a repository for defense TRU wastes. These characteristics more than compensate for the likelihood of a future disturbance." What practical alternative to WIPP has been evaluated to determine if the repository provides better overall protection? Storage on the surface? Also, what are the favorable characteristics of the site that uniquely qualify it for a repository?

Pages 14 and 53. The report points out that "care has been taken to avoid such brine reservoirs within the site area." (page 14) and "when the Los Medanos site was initially screened for the WIPP project it was thought that the facility was positioned outside of the known Carlsbad Potash District, and would therefore have a minimal impact on potash resources." (page 53).

The presence of brine reservoirs and potash resources on the site were considered undesirable before site characterization. When it was found they existed on the site it was decided they were acceptable.

Page 13. "There is no indication that an alternative site for the demonstration would pose reduced risk."

Is there any indication that an alternative site would not pose reduced risk? Has the WIPP site been compared to any alternative site?

Pages 16-18. The statement is made three times on these pages that "the consequences of future events, including resource extraction, are acceptably small."

The determination that consequences are acceptably small cannot be made until compliance with the EPA standard is shown. Since compliance is not scheduled to be shown until about 1995 this statement is premature. Also, the standard requires that only the consequences of exploratory drilling be evaluated. Resource extraction does not need to be evaluated.

Page 24. Reference is made to the favorable hydrologic regime at the WIPP and quotes a 1983 report.

The Culebra model now being used is somewhat different than in 1983. Is this statement still correct?

Page 26. EEG-11 (Channell, 1982) is one of the references cited when claiming that "future human intrusion in search of mineral resources will not significantly impact public health and safety."

It is best not to generalize too much about what a report is saying. The EEG-11 scenarios resulted in maximum calculated doses to a nearby resident of >1 rem (committed effective dose equivalent) per year of inhalation and maximum quantities of radionuclides to the surface that were about 2.5 times that permitted by the 1985 EPA Standard. The report concluded that quantities brought to the surface were great enough compared to the 1981 draft of the EPA Standard to require a more detailed evaluation. Furthermore, the data have changed considerably since 1981. For example, the inventory is now believed to be about 10 times as great, the existence of a brine reservoir under the site about 12 times as great, and the amount of brine that might flow to the surface could be about 5 times as great.

Page 48. The following quote was made from the 1978 Geological Characterization Report: "The selection criteria used, however, was sufficient to establish that the site selected was adequate, safe, and acceptable."

We suggest that these words exaggerate the acceptability and safety of the site. The fact is that DOE does not expect to be able to show compliance with the 1985 EPA Standard before 1995. The site cannot be assumed to be safe and acceptable until it is shown to be in compliance with the EPA Standard.

Pages 49-58. It would have been helpful to have given in-place (gross) and net values of resources with 1991 market prices. Also, the efforts to minimize the impact of not mining langbeinite (pages 54, 56, 59) are not very convincing.

Page 60. The statement is again made that the consequences of an inadvertent intrusion into the repository are small. However, two sentences later the more accurate statement is made: "The final determination of the acceptability of the site will be based on compliance to the performance assessment requirements of 40 CFR 191 Subpart B."

Conclusions on Resource Disincentive

1. DOE did openly address the resource issue during site characterization and had interactions with appropriate State and public organizations. They appear to have satisfied the NEPA process. However, we are surprised there was not more public concern raised about the denial of resources, especially langbeinite.

2. Siting a repository in a resource-rich area has always been considered undesirable and DOE should have expected that when standards were finally enacted they would contain some penalty for such sites. DOE's siting approach was to try and find a site in a resource-rich area that contained lesser amounts of resources than surrounding areas. When the chosen site was found to contain more potash resources and Castile brine reservoirs than originally believed these features were considered acceptable.

3. The report suggests that DOE has compared this site against alternatives and shown that it is an overall superior

location. EEG is unaware that DOE has ever compared the WIPP site against alternatives or identified those favorable characteristics that compensate for choosing a resource-rich area. Thus, we conclude that DOE has not justified the choice of this resource-rich site over a resource-poor site.

4. DOE has incorporated no waste form modifications or engineered barriers in the repository design that would mitigate human intrusion effects.

5. Preliminary results by SNL suggest that the WIPP site might be able to meet the Containment Requirements of 40 CFR 191 despite the resource effect and no design modifications to mitigate the effects of human intrusion. However, since it is not certain the Containment Requirements could be met DOE is doing the following:
   (a) Recommending that the Standard be revised to separate the human intrusion scenario from the Complementary Cumulative Distribution Function. This would downgrade the importance of the human intrusion event and make it easier for WIPP to comply;
   (b) Recommending that the Standard be revised to permit alternatives to the generic radionuclide release limits allowed to reach the accessible environment. This could permit a site performance assessment to meet a lesser standard in some cases;
   (c) SNL is using expert panels on the future, site markers, and site barriers in an attempt to justify reduction in the maximum exploratory drilling rate specified in EPA Guidance. If successful this exercise would have the effect of reducing or eliminating any penalty for choosing a resource-rich site.

6. The probable form of the 1985 EPA Standard and the human intrusion guidance for resource-rich sites was reasonably

well known by mid-1983 when the Decision for Repository Construction was made.

7. EEG has always recognized that the WIPP site is in a resource-rich area and we have never contended that this should be grounds for automatically rejecting the site. However, we believe that since DOE picked a resource-rich site and was aware of the penalties likely to be in the 1985 Standard before they began construction of the repository, they should be prepared to show compliance of the WIPP site with those standards and not try to obtain compliance by getting this portion of the Standard modified.

The proof of the suitability of the site can only be determined by showing compliance with the Containment Requirements with Guidance for a resource-rich site and not by unverified claims that the site is superior to alternatives.

SUPPLEMENT 6
(Appendix IRD, DCCA)

M

ENVIRONMENTAL EVALUATION GROUP

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February 13, 1990

Mr. Arlen Hunt
Acting Project Manager
WIPP Project Office
U. S. Department of Energy
P. O. Box 3090
Carlsbad, New Mexico 88221

Dear Mr. Hunt:

The question has arisen on the Department's plans to demonstrate compliance with the natural resource Assurance requirement of the EPA Standard, 40 CFR 191.14(e). As you know, that particular requirement states that places where there has been mining for resources, a reasonable expectation of future exploration or a significant concentration of a scarce material should be avoided in selecting disposal sites. The requirement states,

> "Such places shall not be used for disposal of the wastes covered by this Part unless the favorable characteristics of such places compensate for their greater likelihood of being disturbed in the future."

A recently published Sandia National Laboratory report (SAND 88-1452, Bertram-Howery et al, p. VI-2) states the following with respect to compliance with the natural resources part of the Assurance Requirements (40 CFR 191.14.e):

> "The WIPP project met this requirement when the site was selected, and the Project will issue a finding to that effect."

The site was selected in the seventies and I don't believe that the Project has ever taken the position that the scientific evidence at that time provided any documentation for conclusions on the characteristics of the site--favorable or otherwise. In addition, our understanding was that the Department intended to publish an analysis similar to the October 20, 1988 document which was subsequently withdrawn.

Please advise whether the SAND 88-1452 statement reflects the DOE/WPO official position.

Sincerely,

Robert H. Neill
Director

RHN:LC/lsb/ct

cc: Mr. James E. Bickel, Asst. Mgr. for Projects and Energy Programs, DOE-ALO
Mr. Leo P. Duffy, Special Asst. to the Sec. for Coordination of DOE Waste Management, DOE-EH
Ms. Jill E. Lytle, Deputy Asst. Secretary for Nuclear Materials, DOE
Mr. Mark Frei, Chairman, WIPP Task Force

SUPPLEMENT 7
(Appendix IRD, DCCA)

ENVIRONMENTAL EVALUATION GROUP

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7007 WYOMING BOULEVARD, N.E.
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August 10, 1990

Mr. Arlen Hunt
Project Manager
WIPP Project Manager
U. S. Department of Energy
P. O. Box 3090
Carlsbad, New Mexico 88221

M

Dear Mr. Hunt:

On February 13, 1990, EEG asked your office how WPO would show compliance with the natural resource Assurance requirement of the EPA Standard 40 CFR 191.14(e). After 5.5 months, you wrote back on July 31, 1990 to say that the requirement was met when the site was selected, (presumably in 1980 when the WIPP FEIS compared different sites) and you reiterated the position stated in the Sandia December 1989 report that you expect to publish a short report at some unspecified future date that will cite the favorable characteristics.

Fundamental Concerns

This raises some very fundamental concerns on the manner in which DOE is regulating itself in demonstrating compliance with the EPA Standards for safe disposal of TRU wastes at WIPP.

1. Was this conclusion reached by DOE as the implementing agency entrusted with the responsibility of insuring that the EPA Standards are met, or as DOE, the regulated agency that must do the actual demonstration?

2. What other parts of the EPA Standards can DOE, as either the regulator or regulated merely say have been demonstrated at some time in the past? Would the Department as regulator be willing to provide a written list of those portions of the Standards which have been met? It is interesting to note that NRC, as the regulator for HLW disposal, is writing criteria to provide clear guidance to DOE on what they must do to show compliance with 40 CFR 191 as part of 10 CFR 60.

3. Have you asked EPA whether your approach to declare portions of the standards to have been met and then document it in the future is what they had in mind? The May 22, 1987 letter by the Director, Office of Radiation Programs, EPA to the Deputy Assistant Secretary DOE, indicates that your position would not be sufficient. Examples like this provide the basis for not allowing the same party to be both a regulator and the regulated.

4. Has DOE-OCRWM asked NRC if they would accept such logic that DOE had satisfied this requirement when they selected Yucca Flats some years ago for a high-level waste repository?

<u>DOE Progress in meeting Assurance Requirements over past 5 years</u>

You point out that EEG often states that DOE has made no progress with the Assurance Requirements (40 CFR 191.14) since they were promulgated 5 years ago and provided examples of progress.

It is important to remember that 3½ years ago DOE said the assurance requirements would be completed by October 1988. Specifically, EPA noted that DOE stated at a March 26, 1987 meeting, "i.e., that projected compliance with Subpart A and th assurance requirements of Subpart B will be shown <u>prior</u> to waste receipt, currently scheduled for October 1988." We are unaware of any published progress.

Active Institutional Controls

You cite the identification of soil preparation techniques and the selection of seed species as progress in active institutional controls. Since the purpose of active institutional controls as defined in the EPA Standards is to prevent radiation exposure and protect the public health in the post-decommissioning phase from radioactive materials located at a depth of 2150 feet in the repository, the examples of work cited by you will not be of any value in this regard. You appear to misunderstand "performing maintenance operations or remedial actions at a site" (40 CFR 191.12(f)(2)) to mean site reclamation when it actually refers to preventing radioactive releases. After 12 years of study and the expenditure of almost $1 billion, one would expect progress in active institutional controls to include specifying how long you intend to leave a fence around the property or keep a watchman on the payroll to prevent human intrusion.

NRC requires early warning monitoring systems to detect any changes in the HLW repository and DOE is designing the facility to handle this including underground sensors to measure any radionuclide migration. Is it not appropriate that WPO should do the same?

Passive Institutional Controls

Your letter states, ". . . through the administrative land withdrawal, the DOE is able to protect the lands from any entry that would compromise the integrity of the disposal system." There is only a request pending by DOE to the Department of the Interior for administrative land withdrawal which has not been acted upon and it is incorrect to imply that the action has occurred. Further, DOE must publish the design of permanent markers, etc. to prevent future generations from drilling into the repository.

Your Department has asked the Congress for exclusive authority to prevent mining without any power to redelegate such authority but has been silent on how it would be done. How can you claim credit for the ability to prevent intrusion (as well as the authority) without providing any plans to show how it will be done?

Your letter states that your contractors have been instructed to evaluate criteria for markers and provide warnings. What progress has been demonstrated through published or unpublished work since this requirement was established 5 years ago? You correctly point out that the DOE HLW commercial repository program has done a large amount of work in this area using WIPP as an example. Since we are not aware of any difference in the technology of markers in the past decade, why not use their work?

Multiple Barriers

You stated that WIPP depends on a combination of engineered and natural barriers. To date, DOE has not selected any engineered barriers as required by the Standards. The waste is soluble, respirable, and in a carbon steel drum and the only commitment to an engineered barrier is a getter of unspecified composition and thickness to be placed above the waste. Your letter only describes plugs and seals (which DOE is not allowed to take credit as an engineered barrier in the NRC regulated repository in Nevada nor did EPA include room and shaft seals as an engineered barrier for WIPP).

Although my impression may not be totally fair, the tenor of your response suggests a commitment to the absolute minimum as expressed in the philosophy that anything beyond plugs would only be included if it were proven to be necessary through performance assessment. The intent of the Assurance Requirements was clearly spelled out by EPA in the 1985 preamble that it is not necessary to quantify the amount of benefit obtained but was to be done as an assurance of repository integrity due to the inherant uncertainties in the calculations of travel times and leach rates.

Waste Removal

You state that mined geologic repositories such as the WIPP meet the requirement for waste disposal removal with no further action. As the regulator of TRU waste at WIPP, DOE has imposed far less stringent requirements on waste removal at WIPP than the regulator of HLW disposal (NRC) has placed on DOE. Note the requirements in 10 CFR 60 for the SAR which include plans for alternate storage should retrieval prove necessary.

Sincerely,

Robert H. Neill
Director

RHN:lsb
Enclosures: 2/13/90 letter Neill, EEG to Hunt, DOE
7/31/90 letter Hunt, DOE to Neill, EEG

cc: Mr. J. Bickel, DOE-ALO
Mr. L. Duffy, DOE-Headquarters
Ms. J. Lytle, DOE-Headquarters
Mr. M. Frei, DOE-Headquarters

SUPPLEMENT 8
(Appendix IRD, DCCA)

Department of Energy
Field Office, Albuquerque
P.O. Box 5400
Albuquerque, New Mexico 87115

RECEIVED
JUN 18 1992
ENVIRONMENTAL EVALUATION GROUP

JUN 16 1992

Mr. Robert H. Neill, Director
Environmental Evaluation Group
7007 Wyoming, N. E., Suite F-2
Albuquerque, NM 87109

Dear Mr. Neill:

The Department of Energy has received your letter dated December 27, 1991, which provides the Environment Evaluation Group's review comments on DOE/WIPP 91-029, "Implementation of the Resource Disincentive in 40 CFR Part 191.14(e) at the Waste Isolation Pilot Plant" (August 1991). At the present time, we are reviewing a plan to address this complex issue. When we have completed the task of addressing this issue, we will provide you with a detailed response to your referenced letter and its accompanying "Comments."

If you have any questions regarding this transmittal, please call Tracy Loughead of my staff at 845-5977.

Sincerely,

W. John Arthur, III
Project Director
WIPP Project Integration Office

cc:
C&C File (ED9100184)
T. Loughead, WPIO
J. Kenney, EEG

LIST OF EEG REPORTS

LIST OF EEG REPORTS

EEG-1 Goad, Donna, A Compilation of Site Selection Criteria Considerations and Concerns Appearing in the Literature on the Deep Disposal of Radioactive Wastes, June 1979.

EEG-2 Review Comments on Geological Characterization Report, Waste Isolation Pilot Plant (WIPP) Site, Southeastern New Mexico SAND 78-1596, Volumes I and II, December 1978.

EEG-3 Neill, Robert H., et al, (eds.) Radiological Health Review of the Draft Environmental Impact Statement (DOE/EIS-0026-D) Waste Isolation Pilot Plant, U. S. Department of Energy, August 1979.

EEG-4 Little, Marshall S., Review Comments on the Report of the Steering Committee on Waste Acceptance Criteria for the Waste Isolation Pilot Plant, February 1980.

EEG-5 Channell, James K., Calculated Radiation Doses From Deposition of Material Released in Hypothetical Transportation Accidents Involving WIPP-Related Radioactive Wastes, November 1980.

EEG-6 Geotechnical Considerations for Radiological Hazard Assessment of WIPP. A Report of a Meeting Held on January 17-18, 1980, April 1980.

EEG-7 Chaturvedi, Lokesh, WIPP Site and Vicinity Geological Field Trip. A Report of a Field Trip to the Proposed Waste Isolation Pilot Plant Project in Southeastern New Mexico, June 16 to 18, 1980, November 1980.

EEG-8 Wofsy, Carla, The Significance of Certain Rustler Aquifer Parameters for Predicting Long-Term Radiation Doses from WIPP, September 1980.

LIST OF EEG REPORTS (CONTINUED)

EEG-9 Spiegler, Peter, An Approach to Calculating Upper Bounds on Maximum Individual Doses From the Use of Contaminated Well Water Following a WIPP Repository Breach, September 1981.

EEG-10 Radiological Health Review of the Final Environmental Impact Statement (DOE/EIS-0026) Waste Isolation Pilot Plant, U. S. Department of Energy, January 1981.

EEG-11 Channell, James K., Calculated Radiation Doses From Radionuclides Brought to the Surface if Future Drilling Intercepts the WIPP Repository and Pressurized Brine, January 1982.

EEG-12 Little, Marshall S., Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP, May 1982.

EEG-13 Spiegler, Peter., Analysis of the Potential Formation of a Breccia Chimney Beneath the WIPP Repository, May, 1982.

EEG-14 Not published.

EEG-15 Bard, Stephen T., Estimated Radiation Doses Resulting if an Exploratory Borehole Penetrates a Pressurized Brine Reservoir Assumed to Exist Below the WIPP Repository Horizon, March 1982.

EEG-16 Radionuclide Release, Transport and Consequence Modeling for WIPP. A Report of a Workshop Held on September 16-17, 1981, February 1982.

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