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EEG-16

Radionuclide Release, Transport and Consequence Modeling for WIPP.

A Report of a Workshop Held on September 16-17, 1981.

Environmental Evaluation Group

Environmental Improvement Division

Health and Environment Department

State of New Mexico

February 1982

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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.

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.

(Continued on back cover)

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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 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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SUMMARY

The purpose of this workshop was to discuss potential mechanisms for release of radionculides from the WIPP repository years after waste emplacement and termination of institutional controls, and the resultant radiological consequences. Opportunity was also provided for the exchange of information on meaningful release and transport models, and the availability, reliability and significance of data for the parameters applicable to those models. Other than those scenarios provided in draft by the Environmental Evaluation Group (EEG) (Appendix II), there were no new breach scenarios postulated. Also there were no major objections posed to the EEG proposals or the approaches taken in these drafts.

Although there were no formal conclusions highlighted by the Conference, the EEG has concluded that the statements below provide a summary of EEG's views concerning the topics covered. These views are based upon the discussions at the Conference, the subsequent comments of the conferees, the information provided in the preceding EEG sponsored geological meeting and field trip (Ref. 2, 3), and the information contained in the EEG draft reports (Appendix II):

(1) The liquid breach and transport scenarios addressed in the FEIS reflect several conservative assumptions, and represent bounding consequences for breach and transport in the Rustler aquifers. This assumes that the extent and effect of fracture flow in the Rustler, now being studied by SNLA, will not substantially alter the parameters used in the transport models.

(2) In the discussions of uncertainties in the hydrologic parameters of the Magenta and Culebra, the two aquifers in the Rustler, it was recognized that the Culebra may be extensively fractured over the flow path to Malaga Bend. Efforts are being made to obtain additional hydrologic data to more accurately define the extent and effect of this fracture flow on the hydrologic parameters. Until more definitive data is available, there remains considerable uncertainty in the parameters used for the FEIS liquid breach and transport models.

(3) Based upon consequence modeling and using several conservative assumptions, it does not appear likely that natural events involving a brine reservoir beneath the repository would lead to a breach which would bring radionuclides to the surface. However, under certain circumstances as described in EEG-11 and EEG-15 (Appendix II), involving human intrusion and a brine reservoir under the repository, if such a breach did occur in less than 500 years, a significant quantity of the radionuclides from the waste might be brought to the surface. The potential occupational hazard of a brine reservoir during construction, and the possible threat of long-term breach if nearby reservoir is unusually large or in communication with aquifers in the area, has led EEG to the conclusion that more definitive information is needed on the age, origin, size, and possible aquifer communication of brine reservoirs.

(4) The available information on known breccia pipes, and the results of modeling and long-term consequence evaluation indicates that this form of dissolution, even if one were being formed directly beneath the repository at the present time, is adequately bounded by the FEIS scenarios. The possible transport of radionuclides to the surface as a result of a breccia pipe formation is very unlikely, becase of the nature of the collapse and transport process.

(5) Dr. Roger Anderson has postulated in the past (Ref. 12), and others have agreed, that deep dissolution involving the mechanism of brine density flow has been responsible for the removal of large quantities of salt from the Basin, and poses a serious threat to the integrity of the repository. EEG believes that the brine density flow mechanism, with removal of salt through the Delaware Mountain Group aquifers, does not represent an adequate explanation for salt dissolution in the Basin. And if wastes were transported away from the repository through the DMG, by other dissolution processes, the long transport time in these aquifers would not allow release of radioactivity to the biosphere. However, because of other potential pathways for transport of the wastes, there is a need to understand more fully the risk of deep dissolution at the WIPP site. For this reason, the EEG has recommended to DOE that additional information be

obtained in the zone of anomalous seismic reflection at the WIPP site to determine if dissolution features are present. There is also a need to know to what extent brine reservoirs may be related to deep dissolution.

(6) The possibility of human intrusion into a nuclear waste repository at some time after termination of institutional controls undoubtedly will exist for any nuclear waste repository. However, it appears that the radiological consequences of a breach occurring as a result of mining for potash or hydrocarbons at the WIPP site are bounded by the FEIS scenarios. In the unlikely event that solution mining for culinary salt should occur at WIPP, release of a fraction of the radioactivity and small doses to a large population could occur.

I. INTRODUCTION

This is a report of a workshop sponsored by the Environmental Evaluation Group (EEG) in Santa Fe, New Mexico on September 16-17, 1981. It was designed by EEG and the participants to provide a discussion of important considerations in the long-term assessment of a possible breach of the proposed Waste Isolation Pilot Plant (WIPP) repository years after decommissioning. The workshop also provided an opportunity for those having expertise and knowledge of the geology and hydrology at WIPP,or of the methods used in mathematical modeling and consequence evaluation, to review several draft reports prepared and distributed by EEG in advance of the meeting and summarized by EEG staff during the proceedings. (See the list of these reports in Appendix II.) These reports presented EEG's considerations of the more plausible long-term breach and transport events other than those which have been considered by the U.S. Department of Energy (DOE), and provided assessments of the radiological health consequences of these events. These reports are to be published by EEG after consideration of all comments submitted. This workshop and these reports were based in part on potential breach events which have been postulated by several experts, and provide a comprehensive summary of the long-term public health risks which may ensue from the emplacement of nuclear waste at WIPP.

Participants in the workshop included geologists, hydrologists, radiological physicists, modelers, and others with special expertise in the agenda topics. The complete list of attendees and the agenda may be found in Appendix III.

During the proceedings, two participants served as rapporteurs for each of the five technical sessions to provide a summary of the presentations and discussions. The rapporteur summaries are presented in Section II of the report. A discussion of those issues brought out during the proceedings which EEG considers to be important to the decisions on potential breach and transport events, or to the assessment of radiological consequences is presented in Section III.

The Environmental Evaluation Group is grateful to the participants for their contribution to the organization and conduct of the workshop, and in the very helpful review of the five draft EEG reports.

SECTION II

REPORTS OF RAPPORTEURS

HYDROLOGICAL PARAMETER UNCERTAINTIES

Prepared by

Charles Hadlock and James Channell

Presentations

Jerry Mercer (USGS) - Hydrology of Delaware Basin

Mercer described the history of hydrologic investigations in the Delaware Basin that led to the conclusion that the Magenta and Culebra aquifers in the Rustler Formation are the ones most likely to provide a pathway for transport of the waste to the biosphere if there is liquid breach. Since most of this information is well known and has been described in EEG-6 (Ref. 2) and elsewhere it will not be repeated here. However, the following observations are especially pertinent:

(1) The Bell Canyon aquifer of the Delaware Mountain Group (DMG) probably flows from the southwest toward the Capitan Reef. Hiss' potentiometric contours are the main basis for this conclusion (Ref. 1).

(2) The Santa Rosa Sandstone formation exists only under the eastern portion of the site and in Zone II there is only one to two feet of saturated sands. This aquifer is thicker to the east and is locally used by some ranchers. However, even in the eastern part of the basin the Magenta and Culebra receive greater use. Recharge is believed to be local and the saturated thickness could be increased during a wet hydrologic cycle.

(3) Since the potentiometric levels of the Magenta and Culebra aquifer are clearly different at the site, it is believed they are not hydrologically connected.

(4) Flow in the Magenta aquifer is believed to be inter-granular. Fracture flow dominates in the Culebra but is believed to behave somewhat like porous media.

In response to a question by Lokesh Chaturvedi concerning Rustler flow direction in Nash Draw, Mercer acknowledged it was complex and said he thought flow in Nash Draw was probably along the axis of the Draw.

Stanley Davis (U. of Arizona) - Statistical Variability of Porosity and Permeability in Fractured Rock

Davis showed a number of viewgraphs illustrating statistical variations of permeability and porosity in various formations. He also showed two viewgraphs of actual fracture occurrence and orientation in rocks. The four main points made were:

(1) Most permeability and porosity data follow a log-normal distribution in the center of the plot (Fig. 1). This type of distribution appears to fit most sedimentary materials, although the slope of the line will vary. However, it is not certain that the extension of the plotted lines to very low or very high probabilities (e.g. >99%) is valid. Also, it is known that the type of distribution obtained is influenced strongly by the sample dimensions (such as diameter of core or area of influence of an aquifer test) and the spacing of discontinuities (or distance between pores, joints, faults, etc.) in an aquifer.

(2) There are several uncertainties concerning fractures. Their orientation is difficult to determine from the surface and may vary with depth. Also, there is no way of directly determining apertures of fractures since removal of a core alters the natural condition.

(3) Variations of permeability with depth are significant in most formations. Thus values derived from one depth may not be valid for other depths.

(4) Because of these uncertainties it is best to try to verify transport phenomena in the field, either by use of environmental tracers or field tracer studies. Work is presently underway to develop the use of Cl-36 as an environmental tracer.

In answer to specific questions, Davis made the following observations:

(1) No general assumptions can be made concerning increasing permeability values in a certain direction in fractured media.

(2) Field observations have confirmed that direction of flow is not necessarily normal to potentiometric surface contours - it may be nearly parallel to the contours.

(3) If only four or five hydraulic conductivity data points were available he would use the geometric mean value, without much confidence. Use of tracer studies would be preferred.

Don Diego Gonzalez (Sandia) - Analysis of fracture flow in the Rustler Aquifers

Gonzalez spoke primarily about the tracer studies being conducted at the WIPP site in the Rustler aquifers. These studies are designed to estimate fracture flow and anisotropy in the Culebra aquifer. Primary and secondary porosity as well as the types of fracture porosity were discussed. Gonzalez believes the Culebra aquifer probably has double porosity (fractures filled with sediments).

The recent tracer test in the three H-6 wells (located 2.5 miles northwest of the center of the site) were discussed. Separate tracers were injected into two of the wells with pumping from the third. Tracer breakthrough occurred in five hours from one well and 43 hours from the other, and preliminary values for effective porosity are 0.8 and 20% respectively. An effective porosity of 10% was presumed in preliminary modeling efforts.

A two-well recirculation test at the H-2 wells (0.8 miles west of the center of the site) was also discussed. This test, which took 280 days for tracer recovery, resulted in estimated values of 13-17 feet for dispersivity and 17 to 18% for effective porosity.

The following points emerged during the discussion:

(1) Although not definitely established, the data suggest that flow in the Culebra aquifer from the site is to the south past well H-3 then turning southwest toward H-7 (Figure 2).
(2) The amount of fractures (and transmissivity) in the Culebra aquifer increase toward the west from the site.
(3) Although tracer tests have not been completed, Gonzalez expects results from final modeling will indicate travel times to the Pecos River that are somewhat longer than the 1,850-4,000 year times that have been generated in previous scenarios.

John Hawley (NM Bureau of Mines) - Surface Stability in the Los Medanos Area

Hawley described the evolution of surface features in the Delaware Basin during Late Tertiary and Quaternary Periods. These deposits and events are summarized in Figure 3. Hawley made the following pertinent comments:

(1) The site was near sea level about 10 million years ago. It is now about 3,000 feet above sea level and still rising. This is not just gentle tilting but includes buckling and a very complex combination of tectonics and climate changes.

(2) The site is not evolving at a steady rate. A geomorphic threshold was crossed when the Pecos River crossed the Capitan Reef. Therefore, cyclic glacial effects are now being superimposed on a changing system and there could be large effects in future glacial cycles. For example, in a new ice age more runoff could flush sediments out of the valley of the Pecos.

Lokesh Chaturvedi (NMSU, EEG) - Hydrologic Parameters and Potential Release Paths at the WIPP Site

The principal thrust of Chaturvedi's remarks can be summarized in two categories:

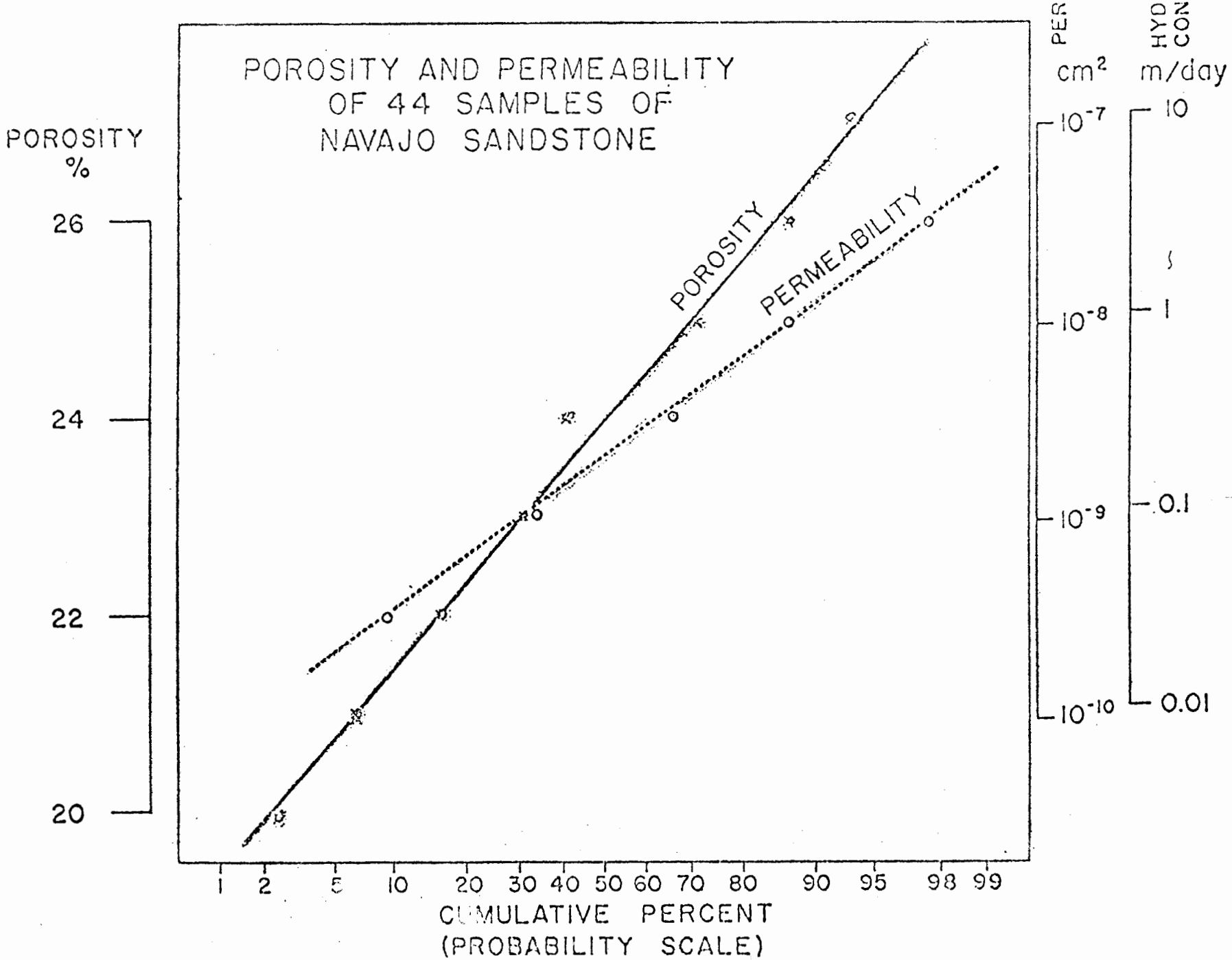
(1) The reported values of transmissivity, porosity, and hydraulic gradient in the Rustler aquifers show considerable variation. Since so few data points are available, there is no assurance that the values used in the mathematical modeling are appropriate.

(2) Adequate consideration has not been given to the possibility that the Rustler aquifers' outlets may not be at the Pecos River at Malaga Bend. Outlets closer to the WIPP site may be at the Magenta outcrop in Nash Draw or at Laguna Grande de la Sal.

Exception was taken by two persons to portions of Chaturvedi's argument. Wendell Weart said that more data (then unpublished) were available than indicated by Chaturvedi, and these were considered by Sandia and INTERA before modeling.

Weart also stated that he had never been certain that fracture permeability had been bounded. Mercer acknowledged the existence of Rustler outcrops in Nash Draw but said that extensive field investigations on his part to find evidence of water outflow had failed to reveal any, and also, that earlier hydrologic studies had failed to show any connection between the Rustler aquifers and Laguna Grande de la Sal. The statement was also made by Weart that because of the briny water at Laguna Grande de la Sal the radiological consequences would be less than at Malaga Bend. There was no evidence indicated that this conclusion was based on a detailed analysis of water usage, salt usage, or other human activity at the lake.

Figure 1


POROSITY AND PERMEABILITY
OF 44 SAMPLES OF
NAVAJO SANDSTONE
POROSITY
%
26
24
22
20
POROSITY
PERMEABILITY
PERMEABILI
cm²
10⁻⁷
10⁻⁸
10⁻⁹
10⁻¹⁰
HYDRAULIC
CONDUCTIVI
m/day
10
1
0.1
0.01
1 2 5 10 20 30 40 50 60 70 80 90 95 98 99
CUMULATIVE PERCENT
(PROBABILITY SCALE)

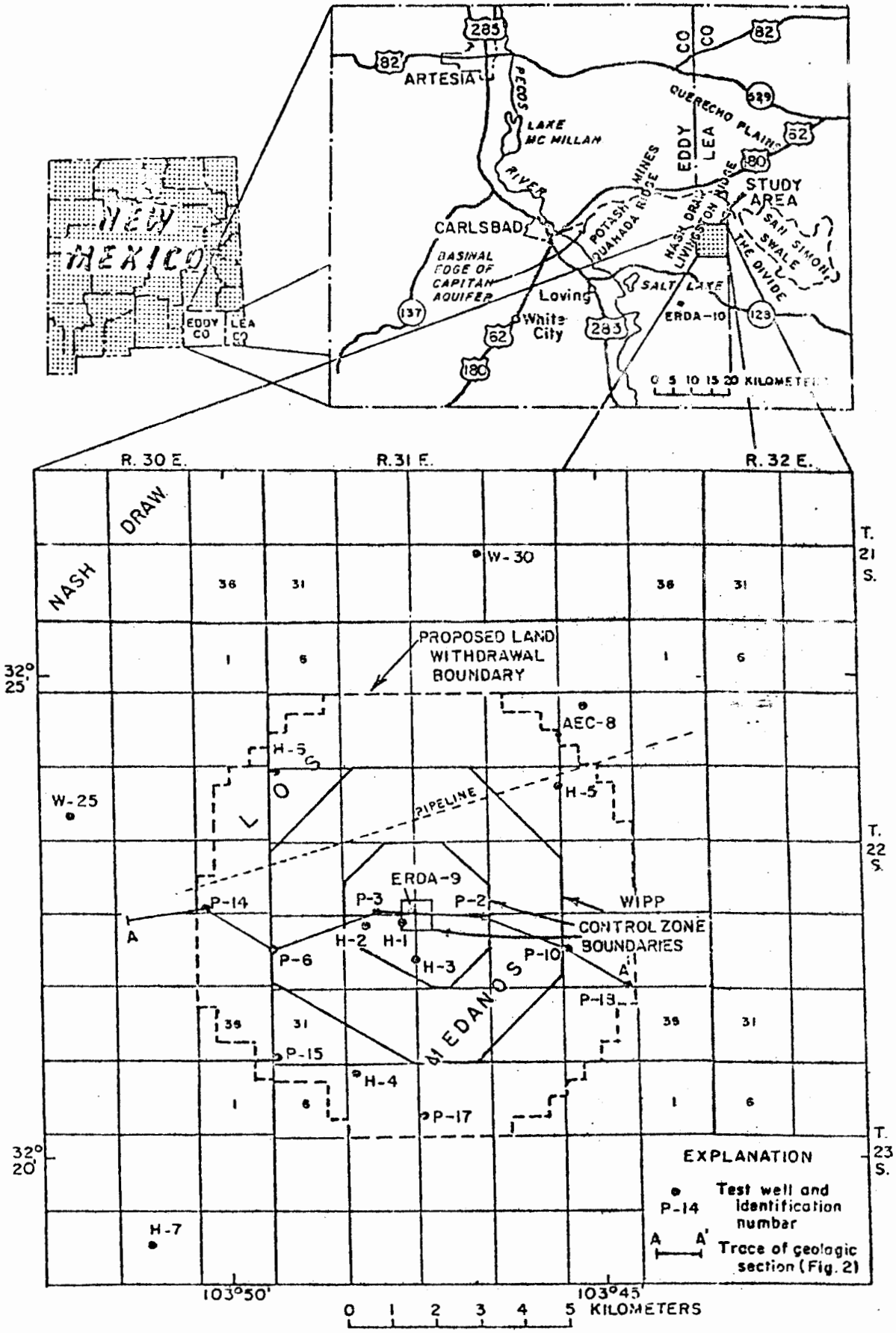


Figure 2 Location map of the WIPP study area showing hydrologic and selected geologic test holes at Los Medanos. (reproduced from New Mexico Geological Society, Special Publicatio No. 10, 1981, pp. 123-131)

Figure 3

CHART SHOWING DEPOSITS AND EVENTS IN THE WIPP SITE REGION

AGE (MY)	PERIOD	EPOCH	PROVINCIAL AGE	Volcanic Ashes	Rock-Stratigraphic Units: High Plains Section	Rock-Stratigraphic Units: Pecos Valley Section	Middle Pecos Valley Region Events and Environments	Middle Rio Grande Events and Environments	(My)
0	QUATERNARY LATE	HOLOCENE	RANCHO LABREAN		Tahoka, Double Lakes and Blackwater Draw FMS (Lake and eolian deposits	Stream Valley and dissolution basin fills	Local Effects of Late Pleistocene glaciation-major erosion & dissolution	Episodic river valley cutting and filling	0.2
			?						0.4
	QUATERNARY MIDDLE	PLEISTOCENE	IRVINGTONIAN	Pearlette "O" Δ ⊙ Bishop		Soils of Mescalero Surface	regional effects of early to middle Pleistocene Glaciation-major dissolution and valley erosion	Soils of La Mesa Surface	0.6
					TULE FM. (Lake and eolian deposits)	GATUNA FORMATION (alluvial, Lacustrine and eolian deposits)		deposition of fills in intermontane basins by major river system (the ancestral Rio Grande)	0.8
1				Cerro ↑ Toledo ↓					1.0
									1.2
	QUATERNARY EARLY			Guaje					1.4
									1.6
			?		Younger Caprock Caliche of High Plains				1.8
2	TERTIARY	PLIOCENE	BLANCAN	Pearlette "B" Δ	BLANCO FORMATION (Lacustrine eolian and alluvial deposits)		regional effects of early (Pliocence) continental glaciation and valley erosion	deposition of fills in intermontane basins and mountain valley erosion by major river system	2.0
									2.5
3									3.0
					CAPROCK CALICHE ZONE ON OBALLALA FORMATION				3.5
4								initial development of the ancestral Rio Grande	4.0
									4.5
			?						5.0
5		MIOCENE	HEMPHILLIAN		(Locally thick alluvial and eolian deposits on the High Plains) OGALLALA FORMATION (In Pecos Valley Section Locally thick alluvial, Lacustrine, eolian and Colluvial deposits in solution basins and stream valleys)		onset of major river activity dissolution of "preOgallala" rocks in Pecos Valley section of Texas and New Mexico		6.0
6									7.0
7									8.0
8									9.0
9			?						
10		LATE	CLARENDONIAN				development major river systems in Pecos-Rio Grande headwaters areas (Sangre de Cristo)		10
11									11

John W. Hawley 9/14/81

HYDROLOGICAL TRANSPORT MODELS

Prepared by

L. Chaturvedi and S. M Zand

Presentations

Dev Shukla (D'Appolonia) - Hydrologic Transport Modeling for WIPP

Shukla described the results of studies conducted by D'Appolonia Consulting Engineers, Inc. to evaluate independently the data and methods used in the long-term waste isolation assessment reported in Chapter 8 of the WIPP Safety Analysis Report (SAR), (Ref. 7). The D'Appolonia work is reported in "Modeling Verification Studies Long-Term Waste Isolation Assessment" Project No. NM78-648-701, January, 1981.

The conclusions reached by D'Appolonia are:

(1) Hydraulic conductivity data as used in the SAR for the Rustler aquifer, although defensible, are inconclusive and the basic question of the effects of fracture permeability remains unanswered.

(2) The values used for distribution coefficients in the SAR may need further study for future defense of the SAR. However, the values used in the SAR models are based on laboratory data, and reasonable variation would have little effect on the radiation consequences.

(3) The SAR regional modeling results showing the radionuclides released at Malaga Bend are reasonable. Although D'Appolonia's analysis produced a water travel time to Malaga Bend that is 2.2 times less than the one in the SAR, the net effect on the radionuclide release rate at Malaga Bend is minimal.

(4) D'Appolonia's models can reproduce the SAR waste-release rates for similar input data. However, the waste-release rates reported in the SAR for Communication Events 1 and 2 are extremely, if not

excessively, conservative considering the increase in the density of the water as a result of dissolution of the salt surrounding the TRU wastes.

(5) Sensitivity analyses performed by D'Appolonia have shown that varying the hydrogeologic and geochemical input data over reasonable ranges does not significantly alter the radionuclide release rate at Malaga Bend.

Moses Greenfield (UCLA) - Square Wave Model for Hydrologic Transport through Rustler Aquifers

Greenfield described the mathematical modeling effort he performed for EEG in 1979. His objective was to determine if the INTERA model used by DOE in the Draft EIS on the WIPP project could be approximated by simple one-dimensioal equations (Ref. 8). Greenfield's square wave model yielded total body and organ doses differing from INTERA by factors ranging from 1.1 to 11.2 (for radium-226) with a mean value of 4.2.

Perhaps the most useful outcome of Greenfield's model is that it permits one to identify the key parameters that most significantlly effect the final results. This would include the distribution coefficient for such elements as plutonium, neptunium, and thorium, and the groundwater flow velocity.

James Channell (EEG) - Sensitivity Analysis of Hydrologic Parameters in Modeling

Channell described sensitivity analyses that were performed by EEG to evaluate the effect of varying several parameters on the Pu-239 travel time from the WIPP repository to Malaga Bend of the Pecos River (Ref. 5). The highest plausible calculated concentrations of Pu-239 in the Pecos River as a result of the WIPP repository breach were calculated to be 1.7 pCi/ℓ. This concentration was derived from two different sets of assumptions involving plutonium transit times of 23,000 and 113,000 years. The allowable EPA

drinking water standard for finished drinking water is 15 pCi/ℓ. Channell emphasized the following:

(1) The scope of this evaluation was limited.

(2) The study was done before D'Appolonia's sensitivity analysis.

(3) Uncertainty associated with the source term was not considered.

(4) Concentration of other radionuclides were not calculated but generally the dose consequences would be less than that of Pu-239.

Stanley Logan (S.E. Logan and Associates, Inc.) - Influence of Dissolved Solids on Radiological Consequences

Logan described briefly his theoretical studies of the WIPP project. Starting in 1975, he studied WIPP as a HLW repository for the EPA; in 1980, he studied WIPP as a TRU waste repository for the Sandia National Laboratory in Albuquerque (SNLA). He presented the calculated consequences on the WIPP TRU waste of a liquid repository breach using two limiting criteria. Since plutonium-239 dominates the hazard index from 1,000 to 100,000 years, it was considered as the radionuclide of concern for the analysis. In the first calculation, the assumption is made that water cannot dissolve the radionuclide without also dissolving the salt. He also assumed, as was done in the FEIS, that water selectively attacks the 12 foot thickness of the salt at the repository horizon, entering with distilled water characteristics and leaving with a concentration of 350,000 mg/ℓ of salt.

The second calculation is based on the assumption that the rate of removal o the waste materials is limited by their solubility limits.

The percentage of the total repository volume which is waste is 2.4 for remotely-handled (RH) waste, and 11.5 for contact-handled (CH) waste. Considering the Pu-239 inventory of the WIPP repository as given in the FEIS for 1000 years after decommissioning, Table 1 provides a summary of the assumptions and consequences of these liquid breach events.

Logan's second calculation was based on solubility limits of a given radionuclide in a waste. He used the experimental data on leach rates for the Waste Rock Interaction Technology (WRIT) project by Brookhaven National Laboratory (BNL) and SNLA. Using the leach rate of a mixture of incinerated ash and portland cement in WIPP brine (curve 2, Figure 4), he obtained an equilibrium concentration of 6.1×10^{-7} μCi/cc for Pu-239. This is approximately 0.1 of the Radiation Concentration Guides (RCG) for discharge into surface water or groundwater in an unrestricted environment (5×10^{-6} μCi/cc). These results demonstrated the conservatism inherent in the assumption that the waste dissolves at the same rate as the salt.

Discussion

After the formal presentations, the following items were discussed:

Fracture Flow Modeling, Distribution Coefficient and Hydraulic Conductivity -- A number of participants expressed concern about the lack of proper understanding of fracture flow modeling and the sparcity of data on distribution coefficients and hydraulic conductivity.

Potability of Radionuclide-laden Brine -- A number of the participants emphasized that the radionuclide-laden brine is not potable due to high concentration of salt. Channell commented that, in the well scenario developed by EEG, use of the reverse osmosis process could improve the potability of the well water.

TABLE 1

Assumptions and Consequences of Liquid Breach

		RH	CH
Pu-239 at 1000 y			
	gm	1.2×10^{6}	6.1×10^{6}
	Ci	7.2×10^{4}	3.7×10^{5}
Salt	gm	6.9×10^{11}	3.1×10^{12}
Water required for 350,000 ppm, cc		2.0×10^{13}	8.7×10^{13}
Pu conc.,	μCi/cc	3.7×10^{-3}	4.2×10^{-3}
RCG	μCi/cc	5×10^{-6}	5×10^{-6}
Pu/RCG		730	850

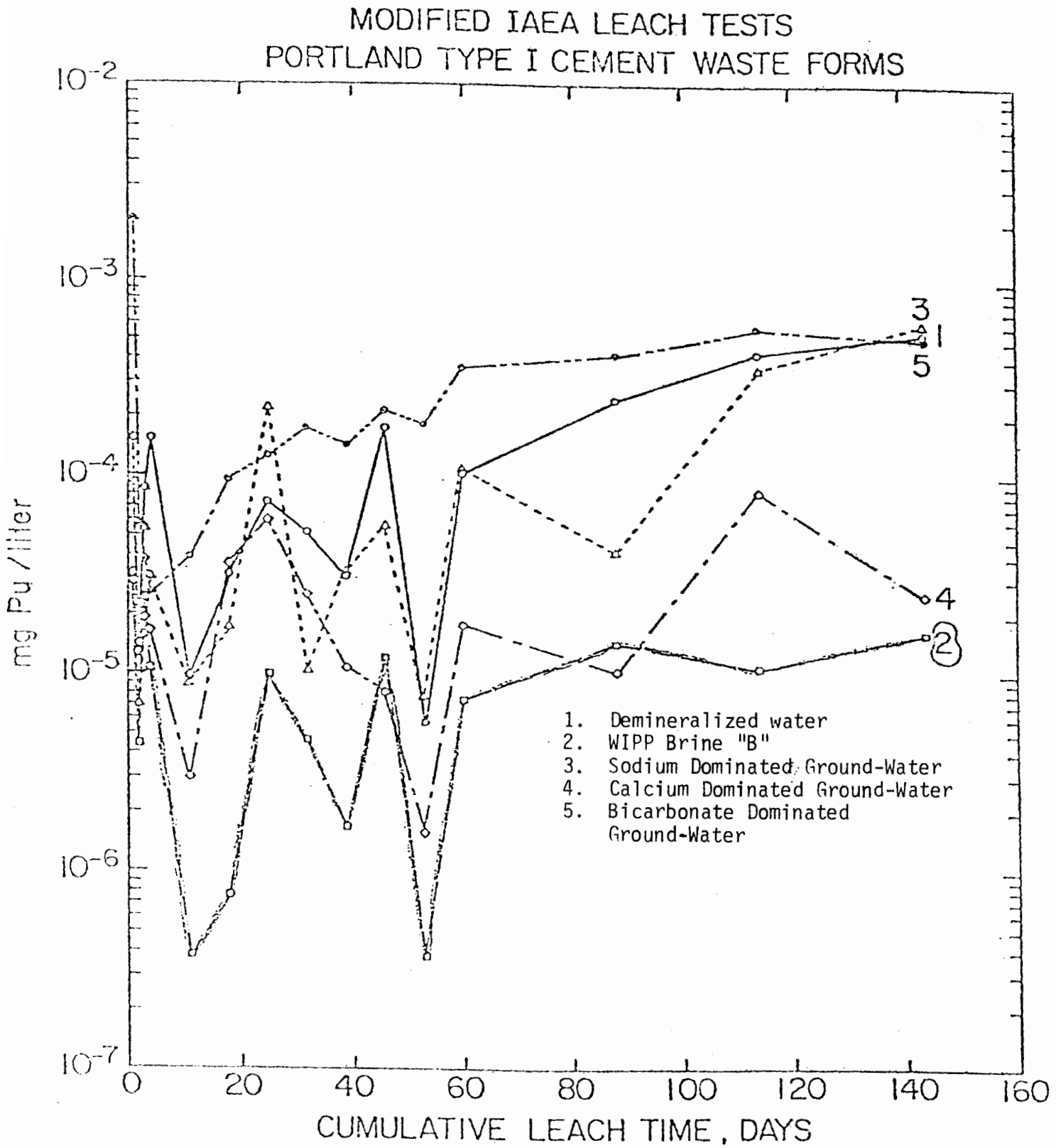


Figure 4. Mg/liter plutonium release from portland type I cement waste forms in modified IAEA testing. (BNL-28856)

DEEP SEATED DISSOLUTION MODELS

Prepared by

Moses Greenfield and Steven Bard

Presentations

Roger Anderson (UNM)- Geographical and Time Bounds of Deep Dissolution-Quantification of an Hypothesis

Anderson reviewed the geological data he believes is evidence that deep dissolution has been and perhaps continues to be active in the Permian Basin. He cited his early work in tracing salt and breccia beds where he first noted missing salt in the formations. As physical evidence of this he presented log data which showed a dissolution wedge resulting from the lateral removal of salt between the Castile and Salado formations. As further evidence of deep dissolution in the Poker Lakes and Big Sinks area, he used an isopach plot to correlate 300 feet of depression in the Rustler formation with 300 feet of a section in the lower Salado where salt was missing. Anderson also indicated a correlation between anticlinal structures in the Castile with missing salt above and subsidence of the Rustler to form a depression at the surface. He then postulated that there might be a generic association with structures in the Castile which leads to a salt removal mechanism.

Anderson emphasized that in order to remove salt a relatively porous or open fracture system is required which is not common to bedded salt. His early hypothesis was a brine density flow mechanism in which unsaturated water from below the Castile provided the driving force for salt dissolution and subsequent drainage into the DMG aquifer. In light of a number of challenges as to the magnitude of the role which brine density flow could play in the removal of salt, Anderson proposed as an alternative a biogenic mechanism which could increase porosity and lead to subsequent deep-seated salt dissolution. This utilizes the reducing potential of anaerobic bacteria in the presence of anhydrite and hydrocarbons to increase permeability and hence fluid flow. Anderson cited the presence of H_2S in brine reservoirs in addition to evidence of biogenic sulfate and sulfite in the Carlsbad Caverns as support for this theory.

Anderson summarized by emphasizing the need to account for missing salt in the formations by some logical mechanism.

Discussion

The discussion primarily focused on present rates of dissolution since this is the key factor to the time frame in which the integrity of the repository could be compromised. Anderson commented that deep dissolution was probably more active at an earlier time but that there was no way to predict present rates. He added that the limiting factors for this mechanism would be the amount of hydrocarbons and sulfur present and emphasized that the potential scale of the process could be large given the quantities present.

Robert Neill asked if new data resulting from the proposed deepening of ERDA-6 and WIPP-12 might provide some definitive information on biogenic dissolution. This provoked further discussion on the difficulty of estimating the extent and rates of subsurface dissolution.

Davis estimated from some brief calculations that if this process were active presently at the rate of 1 cm/year over a 100 Km front that the H_2S gas emanating from the ground surface would be noticeable to the senses. Davis commented that it would be interesting to examine the sulfur isotopes in the system to observe if fractionation has occurred, which would lend some support to the importance of biogenic dissolution.

Dennis Powers (Sandia) - Bounds and Rates of Deep-dissolution

Powers' opening remarks referred to Sandia's programs which may provide further information as to the nature, origin and possibly the age of the disturbed zone. This will include data generated from the deepening of ERDA-6 and WIPP-12 in addition to ongoing studies of the mechanism and mechanics of deformation with an emphasis on differential densities of materials.

Using current knowledge of the DMG hydrology, Powers showed that salt dissolution is proceeding very slowly and does not support Anderson's brine density flow theory as the primary mechanism for the formation of the disturbed zone.

Discussion

Alison Monroe of SWRI, Albuquerque inquired how the deepening of ERDA-6 and WIPP-12 could help resolve the missing salt strata dilemma. Powers indicated that analyses of dissolution residues in core samples in addition to other interpretive data could provide some helpful information. These data may also be helpful in providing evidence of whether the disturbed zone is the result of dissolution or mechanical deformation. Stan Davis noted that a Kr-81 dating technique soon to become available will provide a valuable tool for determining ages in the range of 1 million years.

D'Arcy A. Shock (NAS) - Dissolution Mechanics

Shock illustrated the complexities of the dissolution process by using a graph to show the solubility of $CaSO_4$ in brine as a function of NaCl concentration in the brining solution and the temperature. He emphasized with this data that any NaCl mining in the presence of gypsum, and anhydrites, results in a saturated solution of $CaSO_4$ and creates a problem in the solution mining of pure NaCl.

Shock described the results of laboratory experiments he had performed to observe the dissolution mechanics in solution mining, in which salt is removed preferentially from the sides and top of a cavity (Fig. 5). He indicated that the driving mechanism for this process is the gravity density gradient at the solution-salt interface. This is illustrated quantitatively in Figure 6 as a function of temperature and percent NaCl in solution.

Shock concluded by speculating on the dissolution scenarios considered for the WIPP repository. He dismissed as unlikely the production of a conduit from the DMG due to the absence of a potentiometric driving force. Regarding solution mining for NaCl, he emphasized that since effective mining practices rely upon horizontal solutioning, the vertical distances required at WIPP would make this an impractical method for NaCl extraction.

Discussion

Neill asked if the transport rate of salt by the DMG aquifer could be measured. Shock indicated it would be a very difficult if not an impossible rate to determine.

S. M. Zand (EEG) - Potential Effects of Dissolution of Evaporites on Repository Integrity

Zand's presentation in its entirety is a draft report listed in Appendix II and was distributed to the participants of the Workshop prior to the presentation. He discussed the possible interrelationships of dissolution processes in the Delaware Basin with the formation of breccia pipes, brine reservoirs, regional dissolution and regional land subsidence. He briefly mentioned the surficial effects of shallow dissolution, citing Nash Draw which is five miles west of the WIPP boundary, and San Simon Swale, 20 miles to the east, as prominent features of this process. Zand's primary emphasis, however, was on deep dissolution and its potential for compromising the integrity of the WIPP repository.

He treated deep dissolution under two categories (a) local or point source dissolution, and (b) regional or blanket dissolution. The controversy regarding deep-dissolution at the proposed WIPP facility was discussed. This included Anderson's brine density flow hypothesis advanced as the primary mechanism for deep dissolution, and counter arguments and supportive data by George Bachman and others refuting the significance of this mechanism for past and future salt removal.

Zand believed that the potential radiological consequences resulting from dissolution have, for the most part, been represented by the scenarios considered in the FEIS and those scenarios presently being addressed by the EEG. However, he cautioned that the present models need further investigations as to their applicability to fracture flow. He also indicated that at the present rate of deep and shallow dissolution, it would require time several orders of magnitude greater than the half-life of Pu-239 before the repository is breached by water.

Zand summarized by discussing some of the uncertainties associated with predictive modeling in the Culebra and Magenta aquifers in the Rustler Formation.

Discussion

Chaturvedi asked Zand to further clarify his dissolution model concerning the DMG aquifer. Zand emphasized that assuming simple homogeneous granular flow and existing DMG salt concentration, dissolution would occur vertically in the Castile at the rate of 1.8 meters per million years. Neill asked Powers how this compared to his model. Although the units were not comparable, Powers indicated that based upon his assumptions the entire Basin could be dissolved in two billion years.

Richard Snyder questioned Zand's model of deep dissolution as not being realistic since the only confirmed breccia pipes are associated with the Reef and not the Basin. Zand recognized this but stated that he was proposing only a hypothetical situation in order to estimate dissolution rates.

Peter Davies (Stanford University) - Mechanics and Rates of Formation of Breccia Pipes

Davies discussed the mechanics and rates of salt bed deformation resulting from the removal of salt from the base of a formation. He said that salt deformation is strongly dependent upon strain rates (Fig. 7). At low levels of stress and over long periods of time a steady state ductile flow prevails. At higher strain rates there is some ductile flow but also strain hardening which results in brittle collapse. He interpreted this to mean that the ability of a formation to resist loading decreases with increasing deformation and that commonly associated with this type of failure is the development of a ruptured or fractured surface. Davies illustrated this with a schematic diagram showing a possible sequence of events occurring in the formation of a breccia pipe (Fig. 8). As dissolution continues from below, a cavity develops which collapses upon reaching some unstable size. In considering this scenario, he pointed out that as the salt is removed from the base of the formation the overlying salt will respond essentially instantaneously to the

deformation. And considering that dissolution occurs over hundreds and thousands of years, it would seem unlikely that a cavern would form large enough to result in a catastrophic collapse unless some unusual conditions were present. Davies speculated that breccia pipe development involving salt is a combination of ductile subsidence followed by brittle collapse of the salt.

He presented slides of geological cross-sections through the breccia pipe (Hill C) in the Mississippi Potash Mine illustrating broad downbedding and areas of thickening and thinning. He indicated with sections of anhydrite and halite clasts that differences in solubility could lead to brittle collapses in some sections while ductile subsidence occurred in others.

Davies presented a ductile subsidence model using Fourier series analysis to calculate velocity fields. An important boundary condition was the salt dissolution rate at the base of the bedded salt formation. The model predicted the structural formation of a funnel shaped breccia pipe.

Davies stated that there is no evidence of a breccia pipe at the WIPP site but indicated with a series of slides that the Marker Bed-124 depression north of the site contains structural features which would be expected to be associated with ductile subsidence and that dissolution appears to be a physically and geologically reasonable explanation for the origin of this depression.

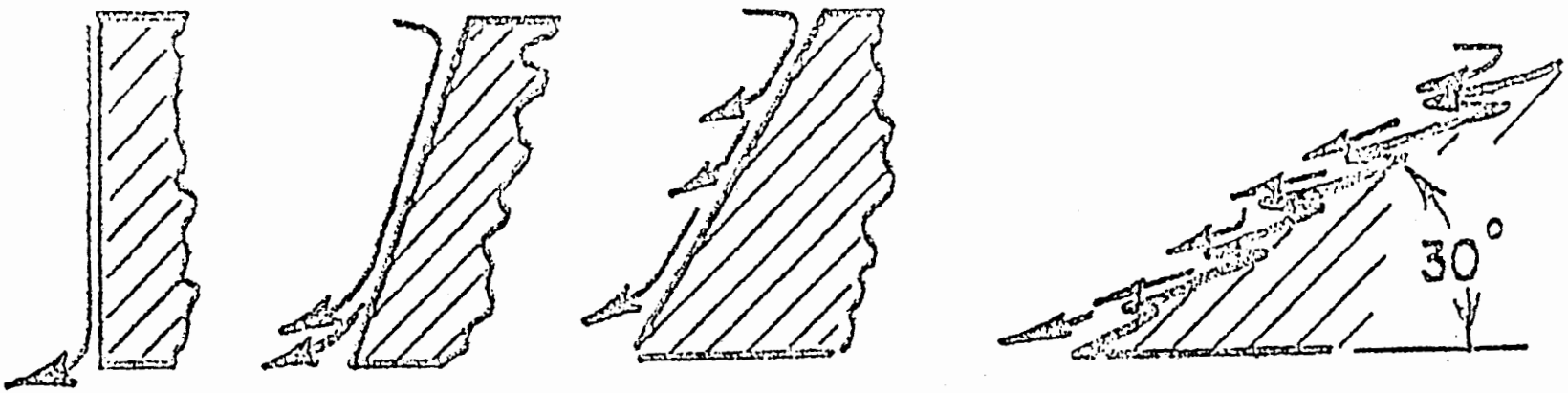
In closing, Davies indicated that the radiological impact of ductile subsidence at the WIPP site would be much less severe than that of a brittle collapse but he did not have a clear concept of what that impact might be.

Discussion

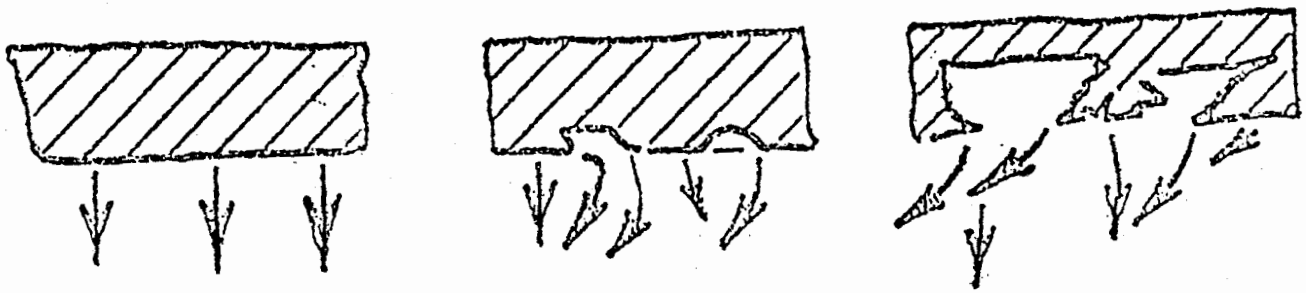
Powers indicated that more recent data is available which might necessitate changes in Davies model. Davies responded to inquiries regarding the capability of his model to incorporate a number of input parameters. He also discussed his plans to couple the ductile subsidence model to a brittle collapse model.

DISSOLUTION MECHANISMS
(PURE SALT)

SIDE MECHANISM



TOP



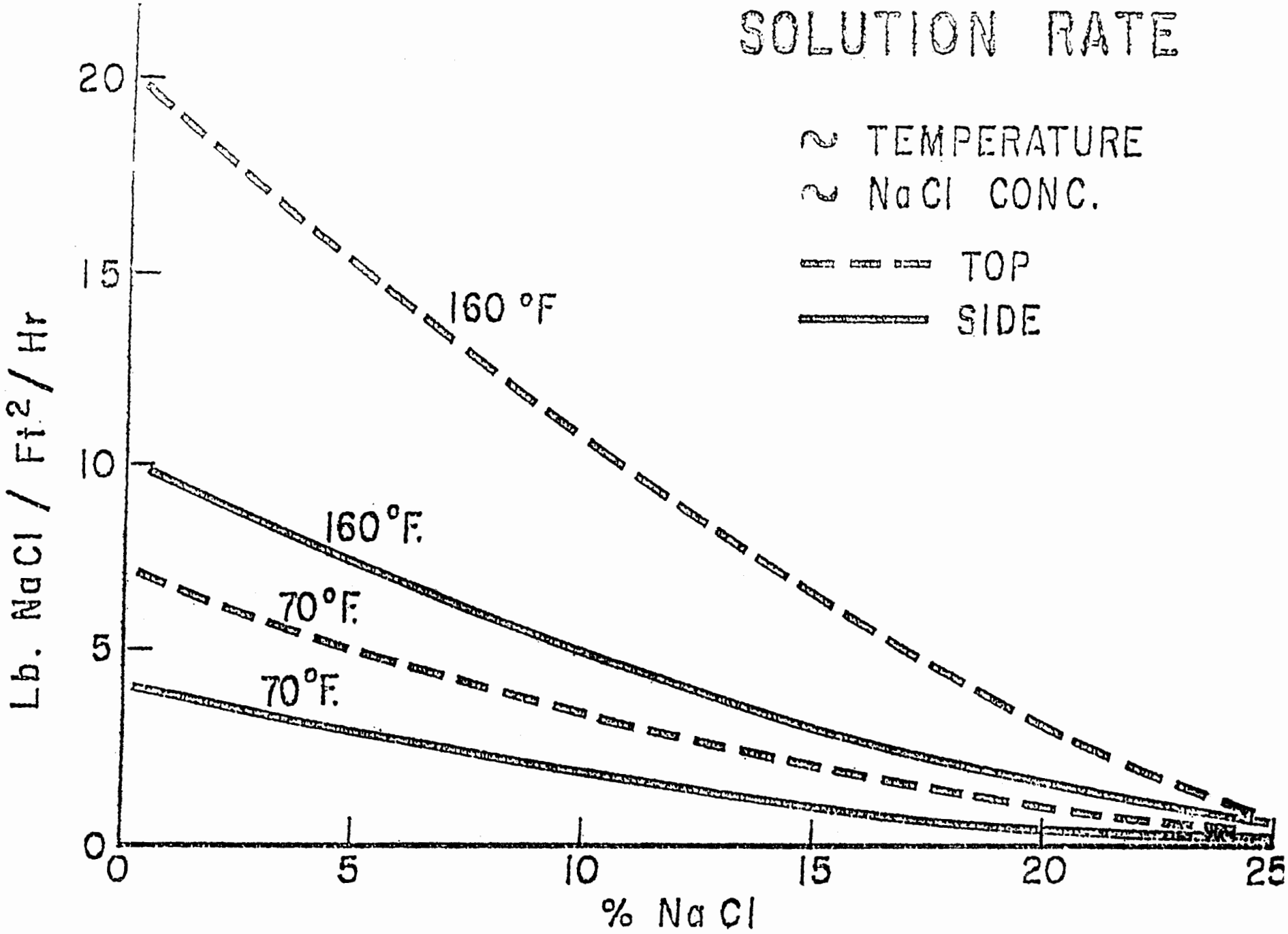

SOLUTION RATE
~ TEMPERATURE
~ NaCl CONC.
TOP
SIDE
160 °F
160°F.
70°F.
70°F.
Lb. NaCl / Ft²/ Hr
% NaCl
0
5
10
15
20
25

Figure 6

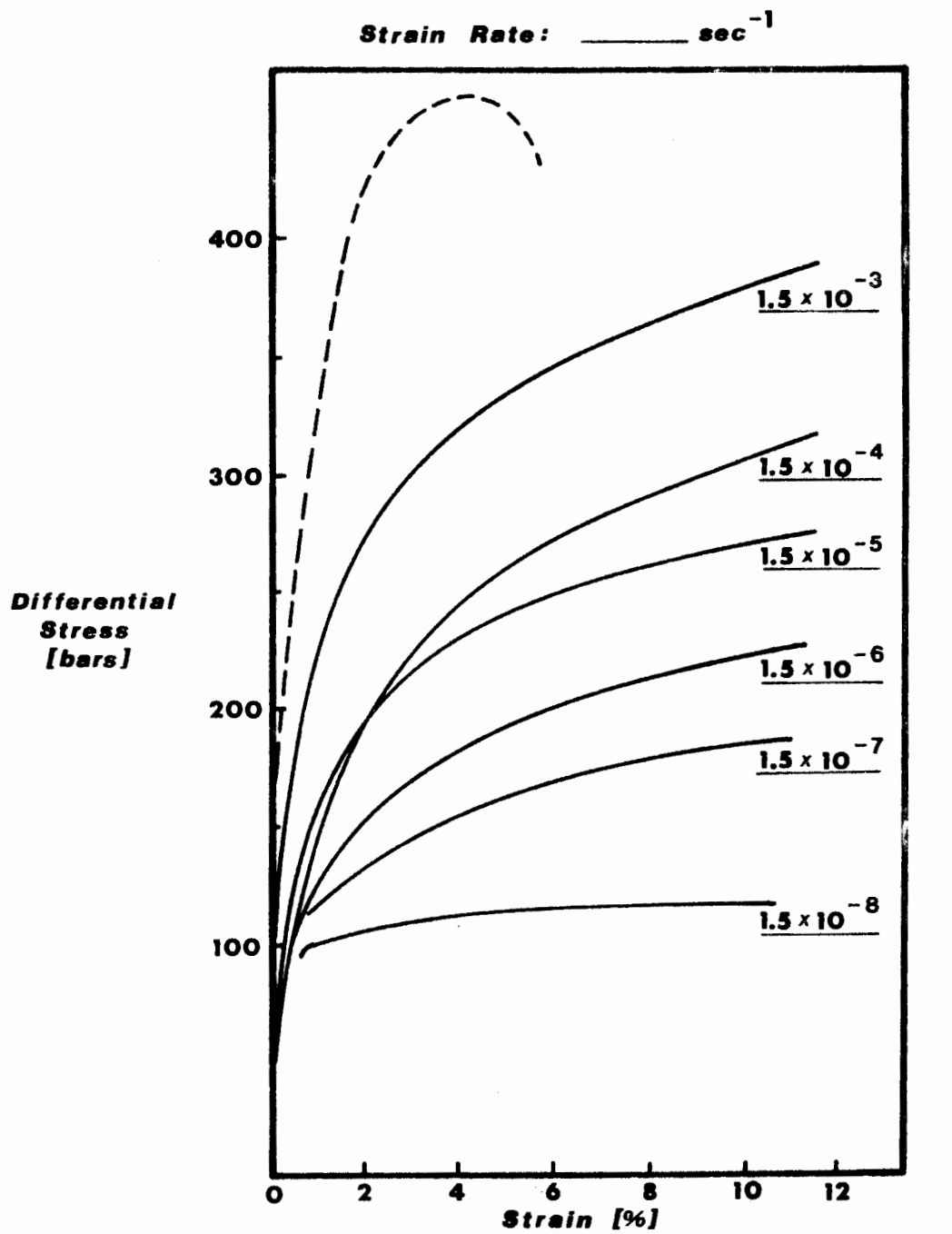

Halite Deformation:
Effect of Strain Rate
[after Heard, 1972]
Strain Rate: _____ sec^{-1}
Differential Stress [bars]
400
300
200
100
1.5 x 10^{-3}
1.5 x 10^{-4}
1.5 x 10^{-5}
1.5 x 10^{-6}
1.5 x 10^{-7}
1.5 x 10^{-8}
0
2
4
6
8
10
12
Strain [%]

Figure 7

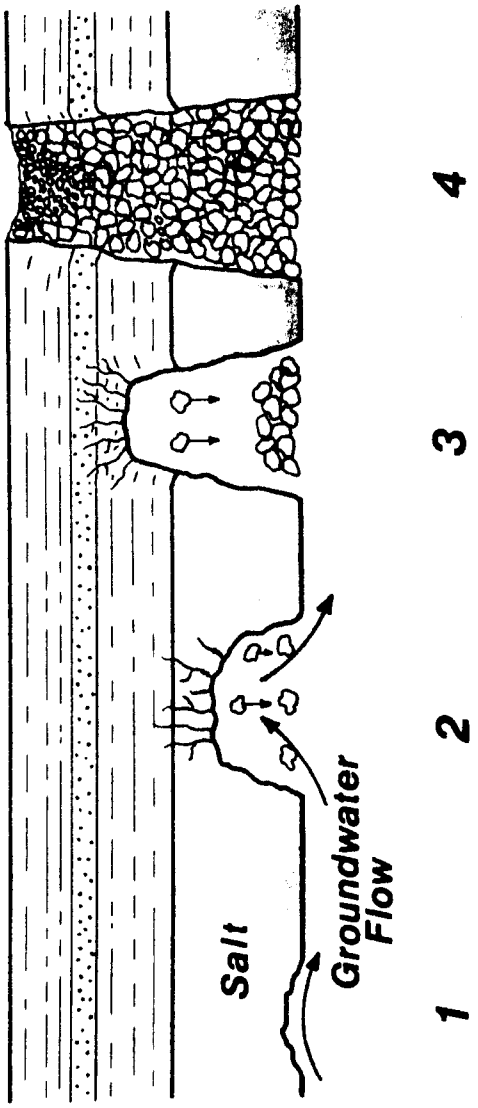


Figure 8

DEEP DISSOLUTION SCENARIO DOSAGE ESTIMATES

Prepared by

Peter Davies and Marshall S. Little

Presentations

Peter Spiegler (EEG) - Breccia Pipe Scenarios

Spiegler discussed his report (Appendix II) which provides an analysis of the potential formation of a breccia pipe beneath the WIPP repository. He referred to the two known breccia pipes at Hills A and C about 14 miles northwest of the WIPP site over the Capitan Reef, and said that one of the objectives of his paper was to examine the possibility and consequences of a breccia pipe forming under the WIPP site. He recalled that the Final Environmental Impact Statement (FEIS) and the WIPP Safety Analysis Report (SAR) had concluded that Scenario 1 bounded the potential consequences of a breccia pipe under the WIPP site. This scenario involves a liquid breach with water coming up from the DMG, dissolving the waste and transporting the radionuclides to Malaga Bend via the Rustler aquifer. Some have objected to that pathway contending that a breccia pipe could bring radioactivity directly to the surface.

Spiegler referred to the work of Stanton on the mechanism of breccia pipe formation (Ref. 10). Stanton has suggested that a breccia pipe could form either by dissolving soluble rock to form a large cavern which then collapses upon reaching a critcal size (Process a), or by a more gradual subsidence and flowage of salt following the dissolution of the soluble rock (Process b). Spiegler discussed the two processes (Fig. 9). In Process a, the lower aquifer removes salt at a rate faster than the creep rate of salt. A large cavern can be formed. Upon reaching a critical size, the cavern collapses. In Process b, the creep rate of salt is greater than the dissolution rate of salt by the aquifer. Brecciation occurs above the salt bed, and does not involve formation of a cavern, because the salt flows downward to replace the dissolved rock at a rate faster than the rate of dissolution.

Coring data on Hill C has indicated that this breccia pipe resulted from a catastrophic collapse as described by Process a (Ref. 11), and would have required a cavity of 570,000 cubic meters. Based on calculations shown in Appendix A of Spiegler's paper, he has concluded that such a cavity could not form at the Salado-Castile interface. This is based on the results of free convection and mass transfer calculations. Appendix B of Spiegler's paper provides detailed calculations which show that a large cavern also could not form at the interface between the Castile and the DMG, because the salt flowage from the Castile would be at a greater rate than the dissolution. Therefore it is Spiegler's view that only Process b could occur in the vicinity of the WIPP site.

Process b would involve a gradual subsidence, and the contaminated brine would be transported to the biosphere through the DMG aquifer. Based on the parameters of the DMG, Spiegler believed that this process and transport would take such a long period of time that radioactive decay would reduce the radioactivity to very low levels. However, Spiegler has examined the consequences of a catastrophic collapse event (Process a) at the WIPP site if it did occur. Based on the size of Hill A and C, he has assumed that no more than 1/10 of the total repository area would be involved in such a collapse. As the transuranic nuclides move up the porous chimney to the surface, Spiegler notes that the clay material in the intervening formations would retard the radionuclides to such an extent that the water reaching the surface would contain concentrations of plutonium which would be less than the permissible release concentrations of the Nuclear Regulatory Commission in the Code of Federal Regulations, 10 CFR 20. Calculations of this result are provided in Appendix C of Spiegler's paper.

Spiegler also examined the collapse structures at Bell Lake Sink and San Simon Sink. Using the estimated size of these sinks and their estimated age and assuming the existence of a dissolution wedge, he calculated their average dissolution rates. The Bell Lake Sink dissolution wedge would require an additional 36 million years to reach the repository, while the San Simon Sink, dissolution wedge would require about 4.4 million years to reach the repository.

Discussion

In the discussion following Spiegler's presentation, it was brought out that in a collapse event under the WIPP site, water would not move to the surface since the DMG head is not adequate to reach the surface. Spiegler pointed out that since some breccia pipes remain porous, it is proper to assume that water can move up and down in a manner analagous to natural convection.

Davies did not believe that Anderson, in his brine density flow model, conceived of a fracture all the way through the Castile to the Salado. It would be more likely that salt in the Castile would be dissolved first. Also, Davis's analysis of the data on Hill C did not suggest to him that this breccia necessarily resulted from a catastrophic collapse. Powers said that the core of Hill A was more suggestive of a chaotic collapse than Hill C. Weart added that in collapse structures resulting from known chaotic collapse events, it has been found that some of the breccia material do not show evidence of chaotic collapse.

Craig Frederickson (Technical Support Contractor, DOE) -- Applicability of FEIS and SAR scenarios to potential geological breaching associated with deep dissolution, beccia pipes and brine reservoirs

Frederickson reviewed the scenarios presented in the FEIS and the SAR, and discussed the types of geologic or human intrusion events which could lead to such liquid breach and transport scenarios. In reviewing the source term for these scenarios he emphasized that the CH-TRU waste predominated in the radiation consequences because of the decay of the fission products in the RH-TRU over the first few hundred years (Figure 10). Frederickson presented a description of the first scenario, which involves the water from the DMG moving up through the repository dissolving the waste and transporting the radionuclides to the Rustler and then to the biosphere (Fig. 11). This type of breach could originate as a result of drilling by someone not knowledgeable of the repository, and the communication extending down into the DMG. A natural fracture, or a breccia pipe could also establish such a liquid communication. Neither the FEIS nor the SAR considered the probabilities of these events. Frederickson pointed out that a number of conservative assumptions were used in calculating the radiation consequences. The effect

of the density, which limits the upward movement of brine, was not considered (Fig. 12). Actually it is likely that the more dense brine resulting from the dissolution of the salt and the repository would tend to diminish the flow toward the Rustler, or at least reduce the rate by a factor of about four. It is possible that the flow would be down toward the DMG rather than up to the Rustler. The Rustler, however, gives the fastest travel time to the biosphere. A straight line path also was assumed rather than a more circuitous path which is more likely and would take longer. The lowest recorded flow rate of the Pecos was used in calculating the dilution of the water into the Pecos from the Rustler. Thus, a number of conservative assumptions were used in calculating the radiation consequences.

In Event 2, Rustler water moves down a man-made, or natural U tube connection to the repository and back up the down stream end of the U tube (Fig. 12). Such a connection could result from drill holes, abandoned potash mines, or some natural events. This scenario also involves conservative assumptions similar to Event 1.

Communication Event 3 (Fig. 14) involves the gradual diffusion of dissolved waste in brine up to the Rustler. This could occur from some type of mining activity, perhaps many boreholes resulting in a fractured system.

In all three events, the waste is transported through the Rustler to Malaga Bend.

The resultant 50 year dose commitments from 1 year exposure via several possible pathways resulting from these scenarios were presented. The pathways included swimming in the Pecos, consumption of the water, consumption of farm products grown on land irrigated by the Pecos, and fish from the Pecos. These routes of exposure were examined for infants, children, teens, and adults. The resultant doses were found to be only a small fraction of background due mainly to the long travel time from the repository to the Pecos (Table 2).

The effect of a well located three miles from ERDA 9 was also considered as a discharge point from the contaminated brine in the Rustler. This study also included several very conservative assumptions. To provide well water of rea-

sonably acceptable total dissolved solids (TDS), it was necessary to choose a well location off the center line of the brine plume flowpath in the Rustler, to yield a TDS of 20,000 mg/ℓ. It was then desalinated to 5000 mg/ℓ for consumption. Actually, three discharge points were examined as shown in Fig. 15. This event was considered very improbable by Frederickson because consumption of the very high TDS water in the Rustler is not likely. The resultant doses also were found to be quite small and only a fraction of natural background (Table 3).

Several other possible outlets were examined for the Rustler water coming from the repository, but these were considered either unlikely or bounded by the results of release at Malaga Bend. Frederickson added that a sensitivity analysis also was carried out to examine the effect of large but plausible changes in the hydraulic parameters. (Fig. 16)

Frederickson pointed out that the dose results at Malaga Bend were due primarily to radium-226, a decay product of uranium. He added that the concentrations of radium resulting from these breach events were much smaller than the normal concentration of radium in several natural waters in the U.S., and therefore he concluded that the radiological consequences of these breach events would not have a significant effect. In response to questions, he believed the four liquid breach scenarios of the SAR bound the possible consequences of a brine reservoir causing a breach, although he has not actually performed such an analysis.

Table 2

MAXIMUM TOTAL BODY AND CRITICAL ORGAN DOSE COMMITMENTS (MREM)(1)

LIQUID BREACH AND TRANSPORT

	Skin (Teen) (2)	Bone (Child)	Liver (Teen)	Total Body (Child)	Kidney (Adult)
Event 1	3.1E-5(3)	2.1E-2	2.5E-5	1.1E-2 (0.0073)(4)	7.1E-4
Event-2	2.4E-5	1.6E-2	1.9E-5	8.3E-3 (0.0055)	5.5E-4
Event 3	6.1E-9	4.2E-6	4.9E-9	2.1E-6 (0.000001)	1.4E-7

(1) 50 year dose commitment resulting from one year intake.

(2) Notation within parenthesis indicate age specific group yielding maximum exposure.

(3) 3.1E-5 = 3.1×10^{-5}

(4) Values in parentheses are percentages of normal background.

Table 3

MAXIMUM INDIVIDUAL DOSE COMMITMENT
COMMUNICATION EVENT 1 (mrem)(1)
(LOCAL WELL OUTLET RESULTS)

INDIVIDUAL	ORGAN				
	Skin	Bone	Liver	Total Body	Kidney
Adult	----(3)	1.3	2.7E-5(2)	0.90	5.4E-3
Teenager	----(3)	1.2	3.3E-5	0.88	4.5E-3
Child	----(3)	1.7	5.5E-5	1.3	3.6E-3
Infant	----(3)	1.3	9.4E-5	1.0	2.3E-3

(1) 50 year dose commitment resulting from one year intake; maximum dose commitment occurs approximately 400,000 years after event initiation.
(2) 2.7E-5 = 2.7 x 10(-5)
(3) Pathway leading to skin dose not present.

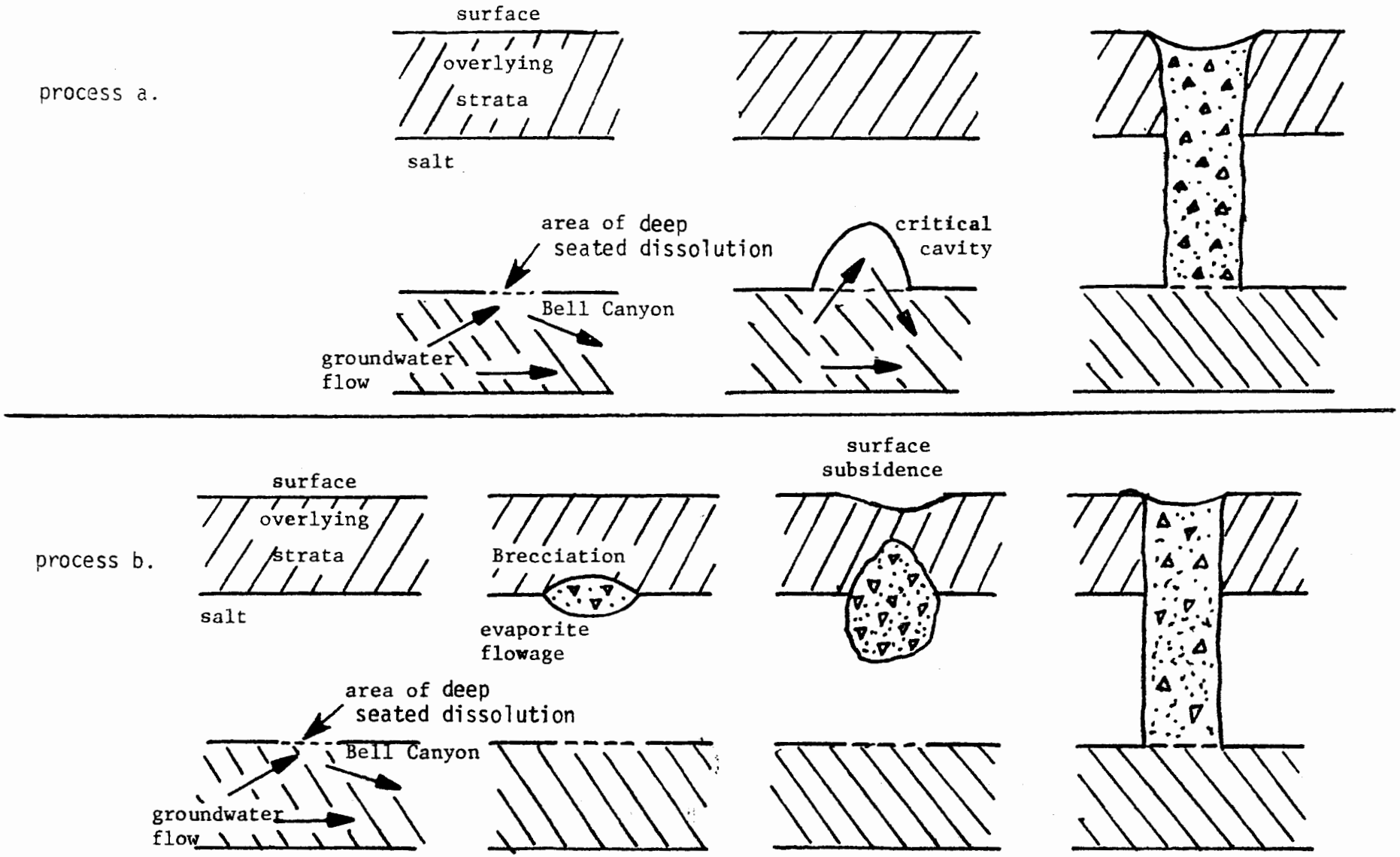
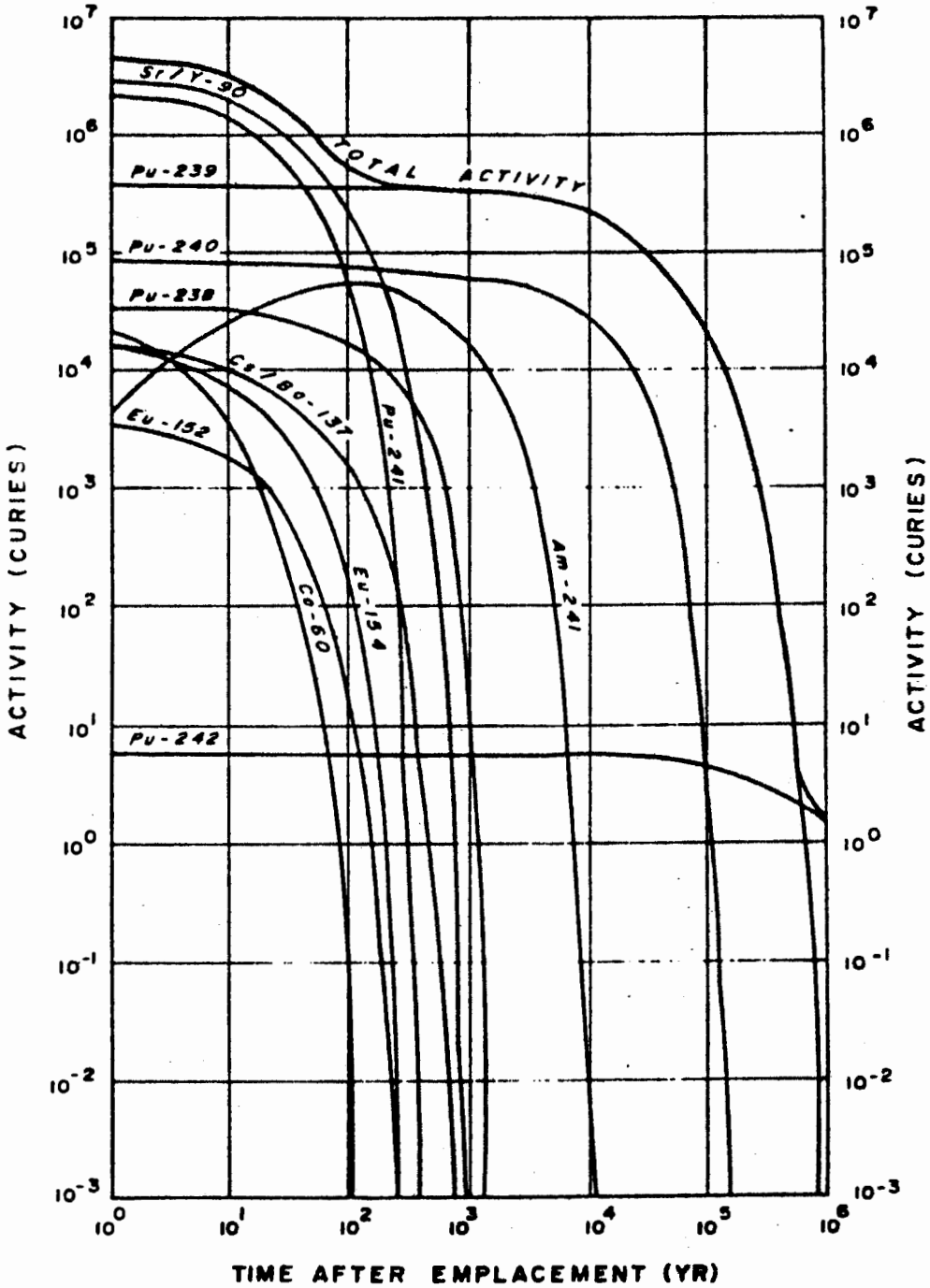


Figure 9. Sequential Events in the Formation of a Breccia Pipe



NOTE:

Activities assume 6 million cubic feet of CH-TRU waste and 250,000 cubic feet of RH-TRU waste. Figure considers decay of emplaced radionuclides only.

Fig. 10 **RADIOACTIVE DECAY OF EMPLACED NUCLIDES**

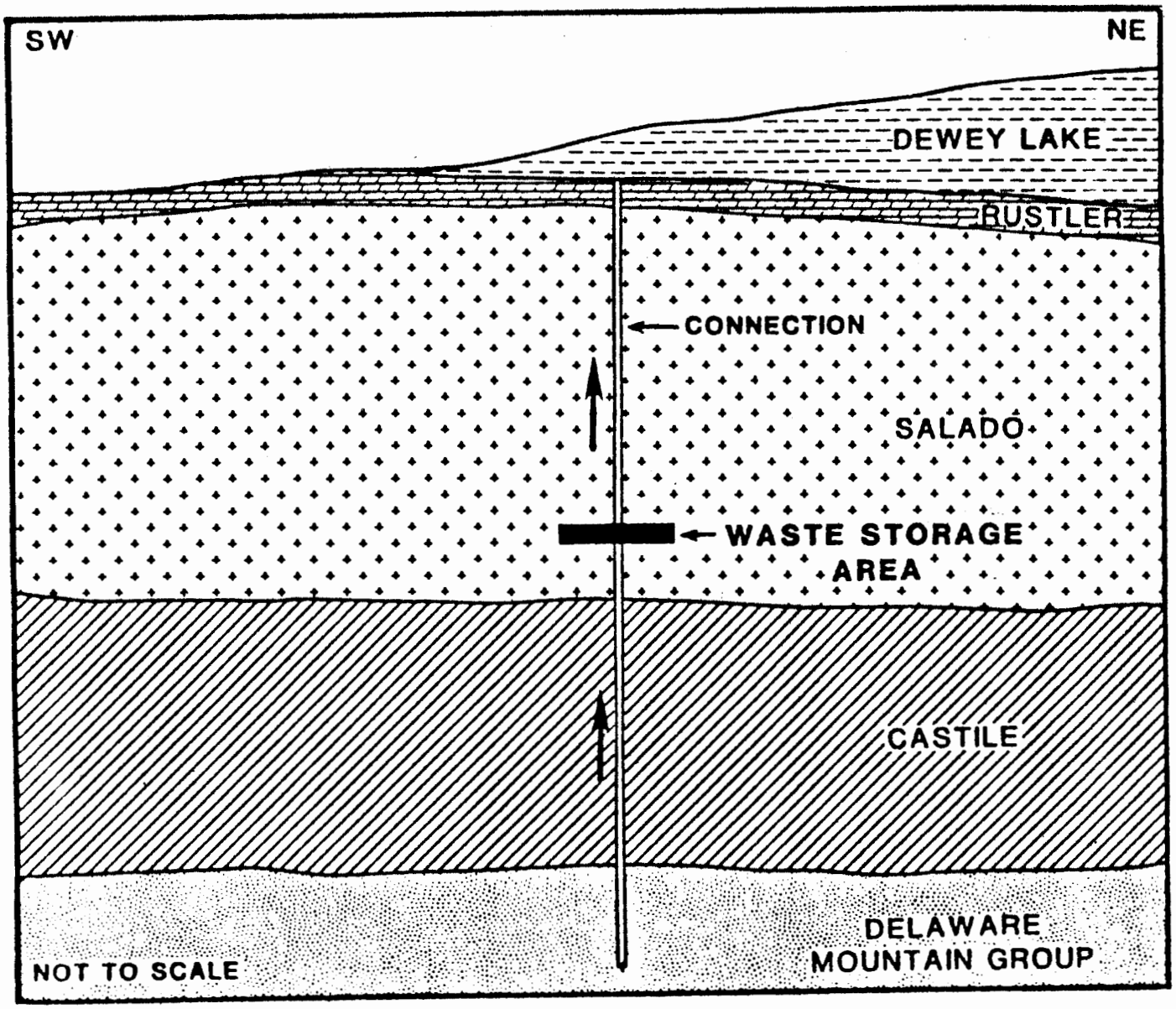


Figure 11 **COMMUNICATION EVENT 1**
(TWO AQUIFER COMMUNICATION)

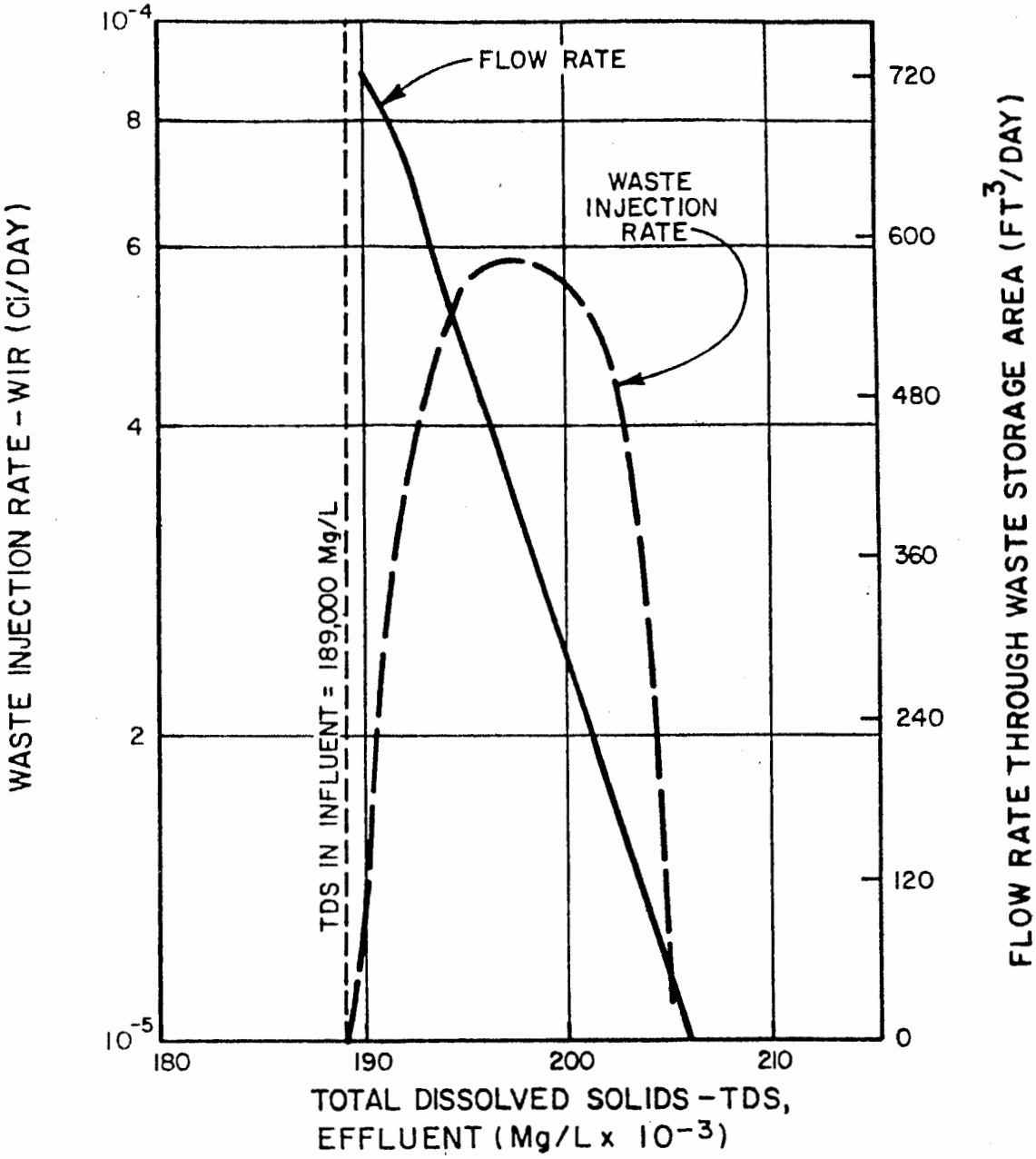


Figure 12 FLOW RATE AND WIR VS. TDS

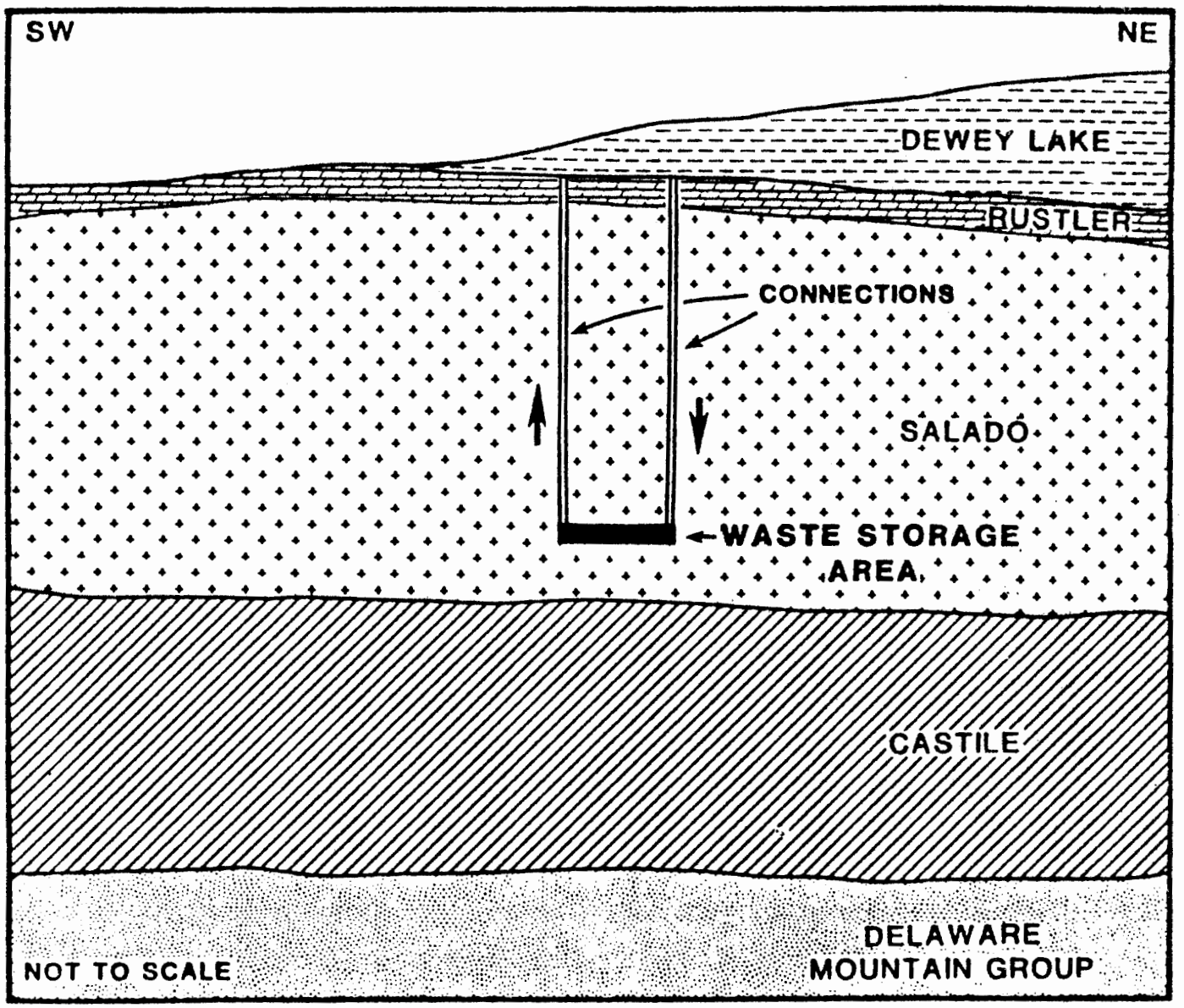


Figure 13 **COMMUNICATION EVENT 2 (SINGLE AQUIFER COMMUNICATION)**

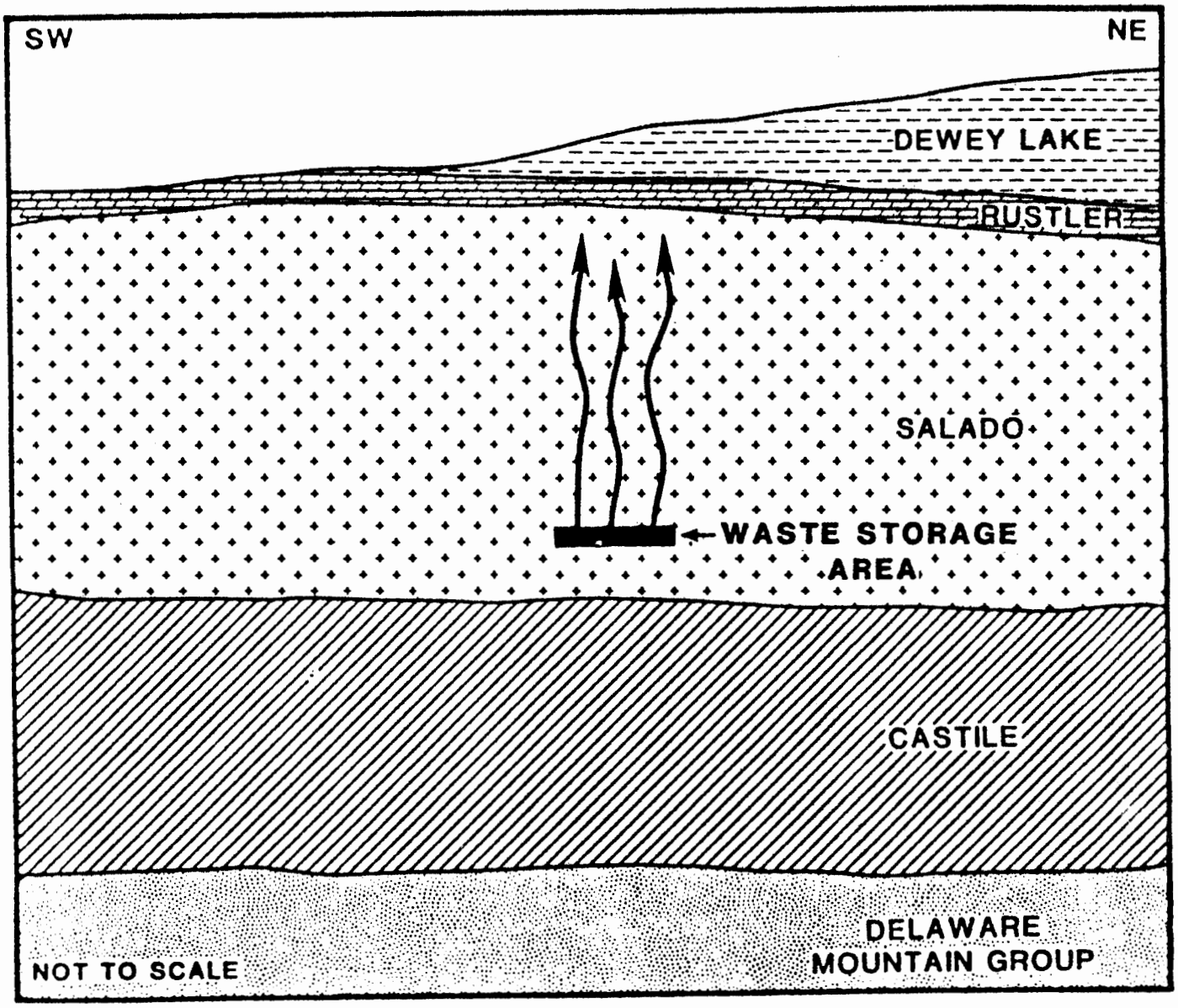


Figure 14 **COMMUNICATION EVENT 3 (DIFFUSION PATHWAY)**

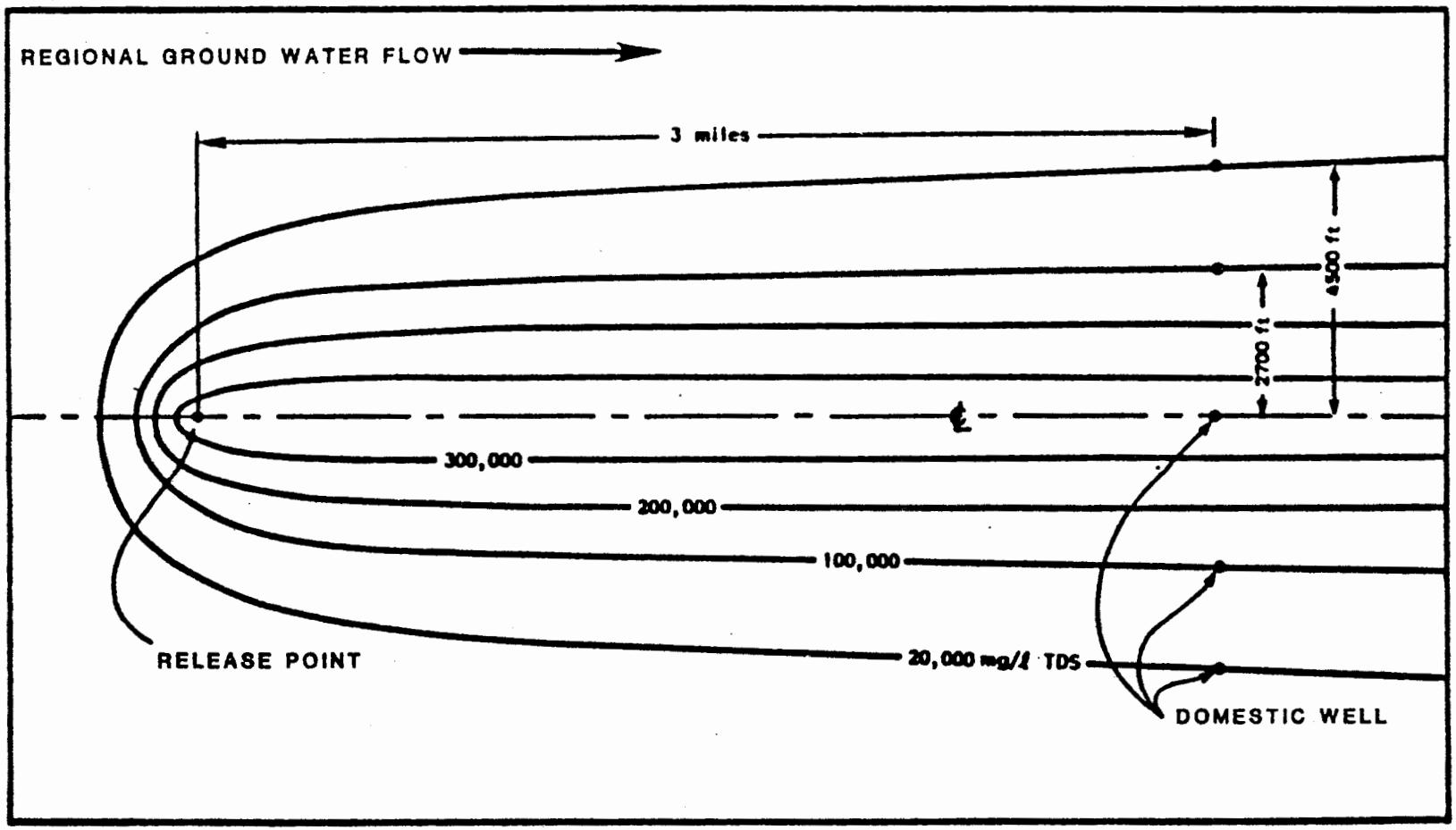


Figure 15 Locations of a domestic well situated 3 miles downgradient of release point. Total dissolved solids isopleths at steady-state are used to locate the off-axis well location.

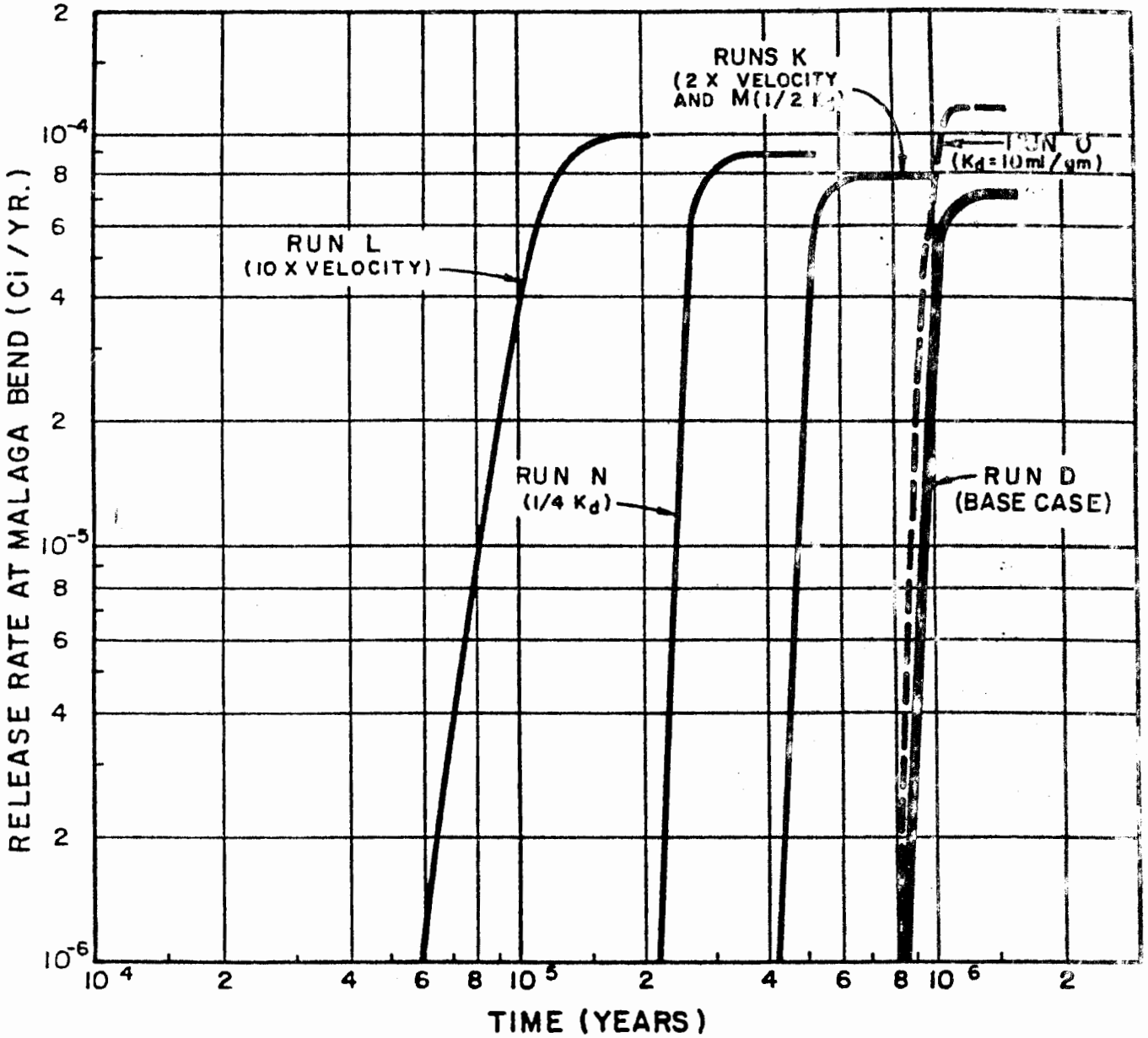


Figure 16 **SENSITIVITY OF RESULTS TO KEY PARAMETERS**

HUMAN INTRUSION SCENARIO DOSAGE ESTIMATES

Prepared by

Stanley Logan and Peter Spiegler

Presentations

James Channell (EEG) - Brine Reservoir Scenario

In describing his draft report (Appendix II), Channell first pointed out that his scenario is as much a human intrusion as a brine reservoir scenario. The scenario is as follows: Brine flows up to the waste storage area when an exploratory borehole penetrates the repository and an underlying brine reservoir. The borehole is capped but the established communication eventually allows the repository to be flooded. The brine slowly leaches radioactivity and becomes contaminated. The assumed leaching rates are 10^{-4}/yr for actinides and 1.2×10^{-3}/yr for Cesium. The Sr-90 is leached within 25 years. The brine is pressurized by 1) gases generated from the decomposition of organics in the waste and 2) creep of salt. A second borehole years later again intercepts the repository and because of pressurization, contaminated brine flows to the surface where it is collected in an evaporation pond. Important assumptions in the scenario are as follows:

(1) Institutional control over the site is lost after 100 years.
(2) Drillers are unaware of the repository and fail to recognize the radiological hazard.
(3) There is a residence in the downwind direction.
(4) There is a brine reservoir under the site.
(5) The brine reservoir and the waste storage area of the repository are intercepted by the first borehole.
(6) The pressure in the brine reservoir is such that the upward flowing brine fills all the available void space in the repository.
(7) A second borehole years later intercepts the repository resulting in copious amounts of brine flowing to the surface.

The scenario would have to occur within a few centuries after closure because the organics in the waste are expected to decompose rapidly following closure of the repository. The creep of salt would compact the waste to zero porosity over a very long time span, in which case such a scenario could not occur.

Channell summarized the dose calculations as presented in Table 4. Channell did not consider the ingestion pathway as significant but expressed concern about the inhalation pathway, due to resuspension of salt particles, because the doses are higher and once the radioactivity is brought to the surface, it remains as a perpetual source.

Channell then discussed the probabilities of the seven assumptions and summarized the probablility analysis of events as presented in Table 5. Channell discussed in detail the proposed EPA high level waste standards and pointed out that the calculated probability value of exceeding the standards, 4.5×10^{-5}, is half of the recommended allowable value in the standards, 1 $\times 10^{-4}$.

In conclusion, Channell reiterated his concern about inhalation doses and because of this concern recommended a more refined analysis of the probability of bringing the waste to the surface.

Discussion

Shock asked whether in this type of scenario Sr-90 was the radionuclide of concern. Channell answered that Sr-90 was the radionuclide of concern for the ingestion pathway while Pu was the radionuclide of concern for the inhalation pathway.

Anderson asked what would happen to the scenario if the entire repository (all Zone II of the WIPP site) were considered filled with HLW. Several participants contributed the following answers:

(1) HLW does not have a greater Pu-concentration than TRU waste;
(2) HLW will be vitrified, a solid form with low leach rates; and
(3) HLW will be packaged in cannisters that will withstand corrosion for 1000 years.

There were several questions regarding the assumptions: For example, what is the amount of brine that fills the repository and what amount of brine would come to the surface? Channell answered that about 1 1/2 million barrels of brine were necessary to fill the repository and less than 1% of the brine would come to the surface.

Weart questioned the probability values for encountering a brine reservoir at the site. He emphasized that the boreholes where brine was encountered are grouped east and northeast of the site. The boreholes are not distributed randomly. He suggested that the inhalation calculation should use resuspension data of Pu obtained at the Nevada Test Site. These resuspension values are much lower than previously assumed data. Frederickson expressed doubts about the resuspension rate of recrystalized salt and the dissolving of nuclides.

Stephen Bard (EEG)-Brine Reservoir Scenario

In presenting his draft report (Appendix II), Bard discussed the encounter of brine reservoirs near the WIPP site using Figure 17.* He pointed out that over a 40 year span, brine had been encountered in nine of 60 boreholes and that in eight of the nine encounters, brine flowed to the surface. These eight encounters were located over an arc east to north of the site. The ninth encounter is southwest of the site. Bard emphasized Weart's contention that the brine reservoirs are geologically associated with anticlines and that there are no anticlinal structures beneath the WIPP site. However, because this contention is not accepted by all geologists, EEG takes the position that a brine reservoir could occur under the WIPP site.

Bard then described a scenario in which an exploratory gas or oil well borehole penetrates the repository and intercepts a pressurized brine reservoir in the Castile formation below the repository. The borehole has a diameter of 10 inches and penetrates either one RH- or three CH- waste containers. The pressurized brine brings cored wastes to the surface where it is then distributed uniformly over 20 acres.

Bard presented calculated bone doses to rig personnel for repository breach occurring at times of 100, 400 and 1000 years post-closure. These are shown in Table 6. The inhalation doses are due to resuspended particles while the direct exposures are due to standing on contaminated ground. The drilling crew is assumed to work on the contaminated ground surface for eight hours per day for 250 days. Bard also discussed the inhalation doses as a function of contaminated area. The data are presented in Figure 18.

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*On November 22, 1981, a brine reservoir was discovered during the deepening of WIPP-12, a hole located about 1.5 miles north of ERDA-9 (just north of Zone II). The brine was encountered in the upper part of the Castile.

Discussions:

The questions dealt mainly with the sequence of events of such scenarios. Snyder pointed out that these scenarios fail to reflect realistic activities going on at a drilling rig. He questioned the logic for keeping the rig at the site for so long and the logic for having a person stand next to the mud pond for so long.

Marshall S. Little (EEG) - Solution Mining Scenario

In presenting his report (Appendix II), Little first reviewed the five DOE scenarios of the FEIS and pointed out that none of them fitted a solution mining scenario. He also pointed out that the DOE does not consider a breach of the repository from solution mining of halite as credible. Conceding that solution mining of halite is not envisioned currently because of lack of water and chemical industries in the area, Little emphasized that the scenario should be considered in the long-term because climatic and social changes may render these deposits attractive.

Little discussed the potash at the WIPP site and presented Table 7 as a summary of the potash resources and reserves. Resources are considered to be minerals that are currently or potentially of economic value; this includes seams that are thicker than 4 feet and contain sylvite or langbeinite with 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 silvite or langbeinite with a potassium oxide richness greater than 13% or 9% respectively. The total surface value of the reserves at the WIPP site is estimated at about 1.2 billion dollars. Little pointed out that 83% of reserves are located in Zone IV and that there is some speculation that Zone IV might not be included in the WIPP project at some time in the future, and therefore these reserves would be available. Most of the potash in any of the zones is considered by DOE to be recoverable without risk to the repository because potash mining is very efficient and the seams are at least 400 feet above the repository horizon.

In the halite mining scenario, Little makes the following assumptions: 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 in the repository 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 substantial collapse of the overlying formations.

The calculated doses due to an annual consumption of 1800 gm of contaminated salt are shown in Table 8. Little also estimated the 50-year population dose commitment at 0.9 million person-rem, assuming 1/24 of the salt for food is derived from the solution mining event, which is equivalent to 0.06% of natural background.

Little summarized the estimated natural gas reserves within the WIPP using Table 9. He pointed out that most of the gas reserves are in Zone IV and that they could be recovered by slanted drilling. Possible breach of the repository through such drilling is believed to be bounded by the direct drilling scenario in the FEIS.

Discussion

Neill pointed out that the scenario dealt only with culinary applications of salt and that other applications might also be important. Snyder said that salt from Carlsbad is used to feed cattle and a meat pathway might be worth looking into. Georgia Yuan questioned the logic of most mining scenarios. Scenarios usually read as follows: Man is curious and starts exploration of underground. After an encounter with radioactivity is confirmed through analysis, the mine is abandoned. The investment in the mine may not permit the abandoning of the mine and other courses of action should be considered.

Neill asked about the current status of solution mining in the U.S. Little pointed out that at present there is no solution mining in the Delaware Basin. Shock said that solution mining is linked with the chemical industry and therefore solution mining is encountered along the Gulf of Mexico coast because of the availability of chemical industries. The cost of transporting salt from the Delaware Basin to the Gulf of Mexico coast is greater than the mining cost.

Weart expressed doubt about a mining scenario because the cost of mining is a strong function of mining depth. Paul Archer pointed out that in exploring the Permian Basin, ONWI encountered only one small, shallow brining operation in Texas.

Craig Federickson Technical Support Contractor, DOE - Human Intrusion Scenarios

Frederickson discussed human intrusion scenarios. He described a scenario for mineral and hydrocarbon exploration involving drilling through the repository. Chip samples were assumed to be examined at a distance of 1 m for a period of 1 hour. The mud pond dries followed by resuspension and downwind transport to an off-site farm. The resulting dose to the well site geologist and for 1 year off-site exposure are summarized in Table 10.

General Discussion

The discussion dealt mainly with the use of probabilities of human intrusion scenarios. Hadlock offered three advantages for including probabilities in such scenarios:

(1) The decision to proceed with WIPP following the SPDV phase will be based on broad conclusions. Probability numbers would be considered because numbers are convincing. Detailed analyses would be excluded.
(2) EPA is basing its standards on probabilistic analyses.
(3) A probabilistic analysis is the only way to characterize the variability and uncertainty of systems.

Chaturvedi pointed out that WIPP-14 was drilled to explore the MB124 depression which Davies considers to be a possible location for a buried breccia pipe. The location of WIPP-14 was chosen by SNLA on the basis of results from a detailed gravity survey, seismic reflection profiles, and a topographic depression. WIPP-14 was located about 2000 feet east of the center of MP 124 depression as seen in well F-92. Powers said that the results of WIPP-14 showed normal stratigraphy. Chaturvedi suggested that perhaps the results of WIPP-14 would provide a basis for Powers and Weart to comment on the presentation of Davies, but they indicated that they would prefer to study Davies' work further before commenting.

Table 4. CALCULATED BONE DOSES
(50-YEAR DOSE COMMITMENT FROM ONE YEARS INTAKE)

Pathway	Tc + 125y	Tc + 400y
	Rem	
Workers		
Inhalation	13.	120.
External	0.45	0.84
Resident		
Inhalation	1.3	12.
Ingestion	2.1	0.03
	Person-rem	
Area Population	24.	220.

Tc = time of closure

Table 5. ESTIMATED PROBABILITIES

Event	Probability During Repository Lifetime
Some Waste will come to the Surface	2.5×10^{-4}
Area Population dose Commitment in Table 1 will occur	5.0×10^{-5}
Exceeding Draft EPA Standards for release of radioactivity to environment	4.5×10^{-5}
Residence Inhalation dose committment in Table 1 will occur	5.0×10^{-7}
Residence Ingestion dose commitment in Table 1	5.0×10^{-8}

Table 6. DOSE ESTIMATES

	50 years dose commitment, mrem			
	100 yrs	400 yrs	1000 yrs	Background
Inhalation				
CH-	400	380	330	4000
RH-	70	-	-	
Direct Exposure	Annual dose equivalent, mrem/yr			
CH-	20	15	10	150
RH-	150	5		

Table 7. 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

Table 8. FIFTY YEAR DOSE COMMITMENT FROM ONE YEAR'S INGESTION OF SALT

Nuclide	Concentration PCi/gm of salt	Dose (50 yr.) Commitment Factor (mrem per Pci)	Whole Body Dose (mrem)
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.
Sr90 + d	1.9 + 1	9.4 - 4	32.
Cs137 + d	1.4 - 1	3.6 - 5	.009
			72.

Table 9. 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%)

* Table adapted from Table 9-19 of the WIPP FEIS.

** BCF = billion cubic feet.

Table 10. FIFTY YEAR DOSE COMMITMENT FROM GEOLOGIC EXPLORATION DRILLING

	Well Site Geologist (mrem)	Offsite (mrem)
Lung		2.1 - 1
Bone		1.5 - 4
Total Body	2.2 - 2 (1 hour)	6.1 - 6

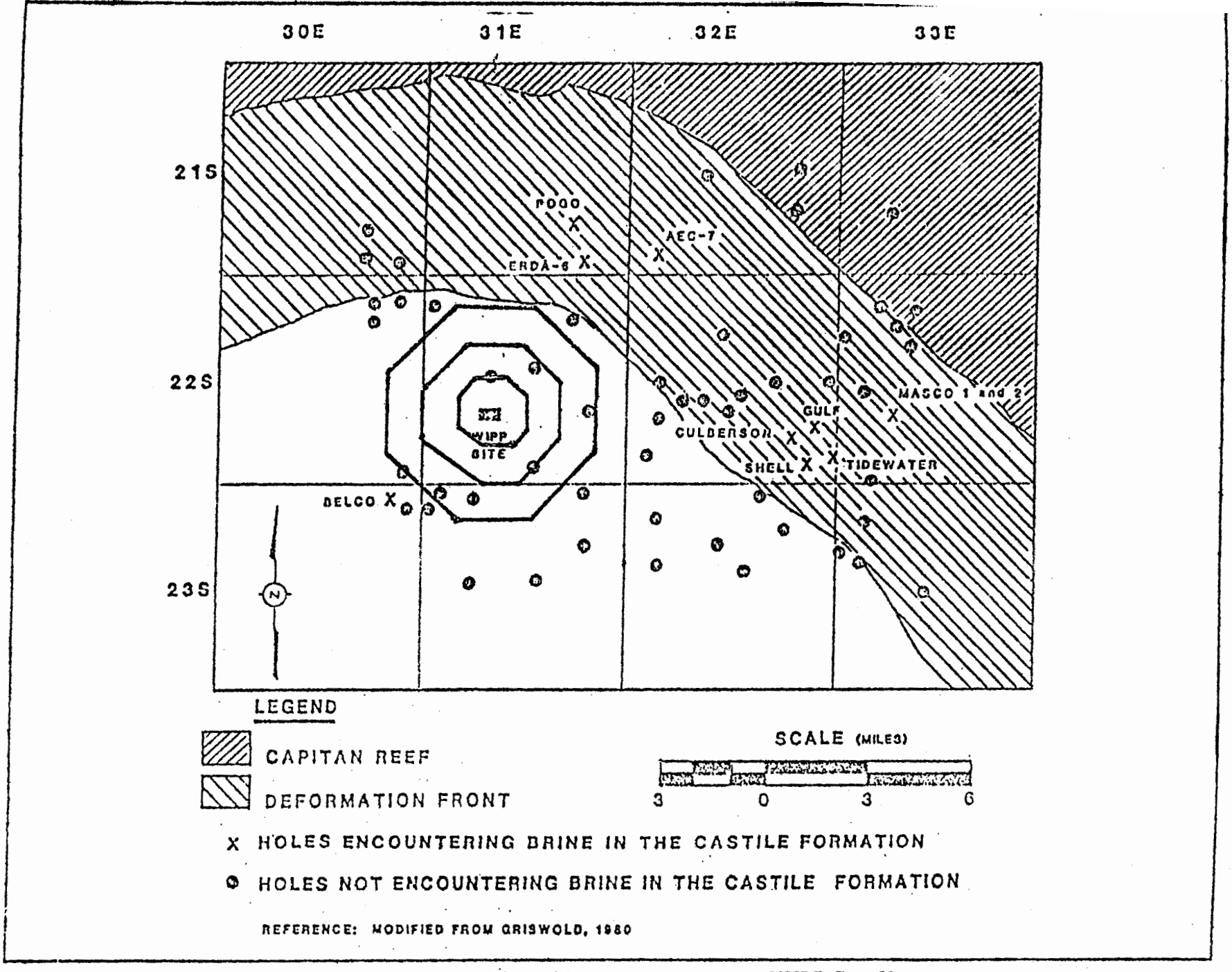


Figure 17 Location Map of Deep Boreholes in WIPP Site Vicinity

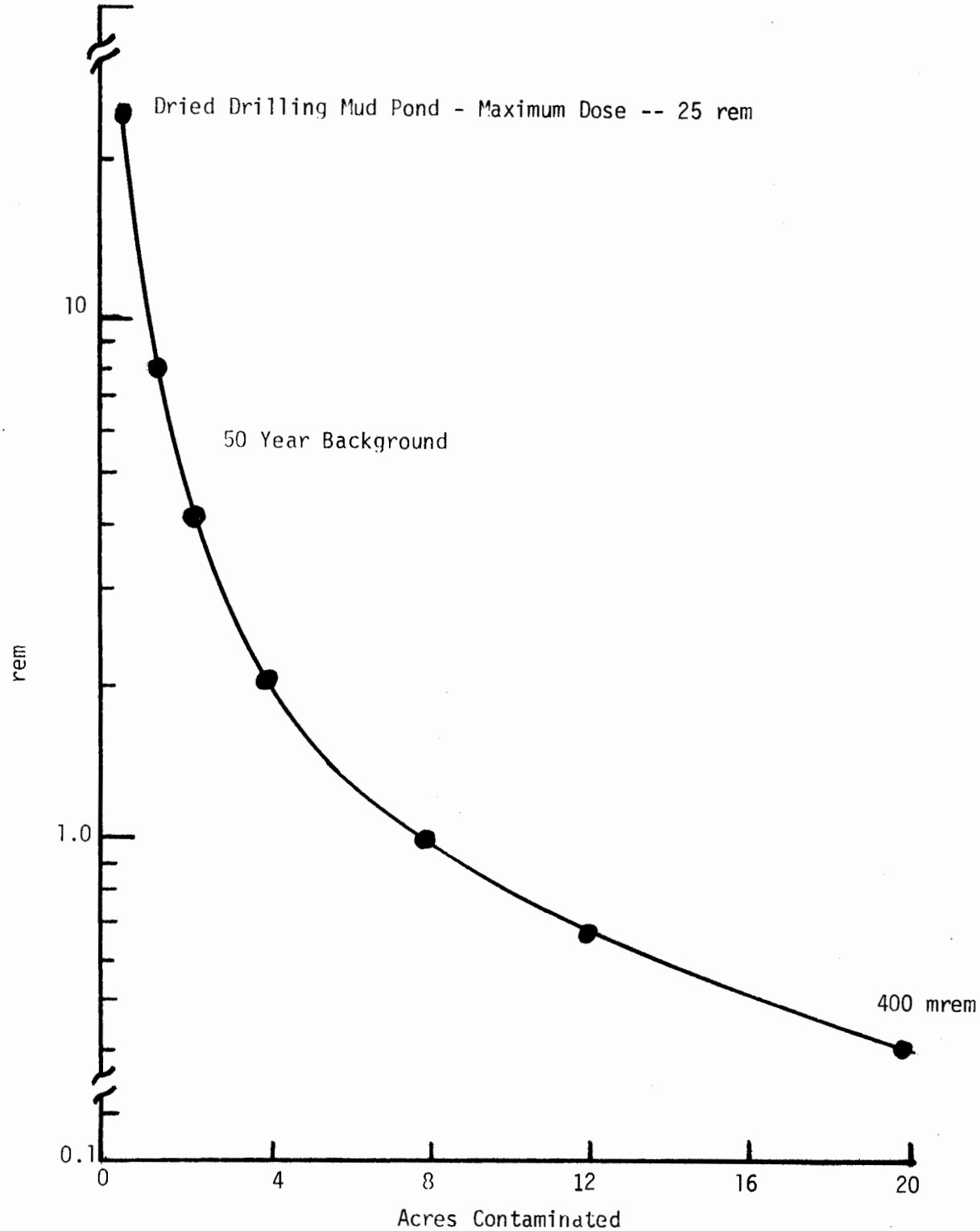


Figure 18 Fifty Year Bone Dose Commitment From One Years Inhalation as a Function of Acres of Land Surface Contaminated (rem/50 years)

SECTION III

DISCUSSION OF ISSUES

III. DISCUSSION OF ISSUES

This section provides a summary of the major issues discussed at the meeting which, in the opinion of EEG, are important in the quantitative assessment of the long-term safety of the WIPP repository. The discussion of these issues occurred in one or more of the scheduled technical sessions.

Two previous meetings held by EEG were designed to review the available background information on the geology and hydrology of the WIPP site and surrounding area, and the relevance of such information to potential breach scenarios. The first meeting was held in Albuquerque, New Mexico on January 17-18, 1980, and provided an opportunity to discuss differing opinions on the major geological questions concerning the site (Ref. 2). The second meeting was a three day field trip to the WIPP site on June 16-18, 1980, to see some of the evidence cited for different interpretations on the geologic condition in the Basin, and to further discuss their importance (Ref. 3).

During these meetings, there were expressions of concern by some of the participants with respect to geological anomalies and dissolution processes occurring or which have occurred in the Basin. Evidence was presented that some of the anomalies may threaten the long-term integrity of the repository. This conference therefore was organized to discuss the potential mechanisms for release of radionuclides from the repository and the potential impacts on the public health and safety.

Planned Radioactive Inventory

The mission of the proposed repository is to permanently store defense transuranic waste. There also will be high level material temporarily emplaced at WIPP for experimental purposes, which will be removed at the conclusion of the experiments. Until such time as this mission changes, the quantification of the long-term risks associated with the repository must be based on only the inventory of the transuranic material to be permanently emplaced.

In Neill's opening presentation, he reviewed the rate of decay of the transuranics and the small fraction of fission products which will be permanently stored at WIPP to illustrate the approximate length of time that the

repository would constitute a potential risk in the event of a breach and radionuclide transportation to the biosphere. For example, after about 1000 years, the fission products will have decayed to essentially stable nuclides, and only the longer-lived actinides will remain. Because of this decay of the shorter-lived material, Pu-239 becomes a more and more significant contributor to the total inventory (Fig. 19).

The Adequacy of the Geologic Barriers

Neill also reviewed some of the general plans with respect to the design of the repository, its approximate location and size in the Delaware Basin and its relationship to the stratigraphy and to the water-bearing zones at the site (Fig. 20). Some of the geologic anomalies, including dissolution processes which have been active in the basin and which may pose threats to the repository include brine reservoirs, breccia pipes, and deep dissolution processes. These may involve the dissolution of the deeper layers of salt and possibly of the nuclear waste, as well as the subsequent transport of this contaminated brine either directly to the surface at the site, or through underground aquifers to the surface at a point some distance from the site, such as Malaga Bend. It has been recognized that there are controversies over the extent of these processes, the degree to which they are active today or in the future, and the degree to which they may affect the repository. A multidisciplinary approach is necessary, therefore, to attempt to resolve these controversies, or possibly to reach a reasonable consensus on a consequence analysis.

Weart discussed the important perspectives relevant to the potentials for breaching. For example, the characteristics of the site will determine the natural barriers to a potential breach, and their suitability must be based upon the judgement of knowledgeable individuals. Such judgement will include the assessment of the potential changes which may occur at the site thousands of years into the future. In the course of this assessment, it is necessary to assume the worst of the plausible conditions which may occur and which may lead to a breach, and then to calculate the radiological consequences of such breach events.

Weart noted that in the safety analysis for WIPP which was prepared for the Environmental Impact Statement, it was necessary to make extremely conservative assumptions concerning the hydrologic breach and transport parameters, because all of the more accurate site-specific data were not yet available. The original selection of the Delaware Basin for WIPP was based on the decision in the early seventies by Oak Ridge National Laboratory that the Basin seemed superior to the other salt basins in the United States for a nuclear waste repository. Since then, Sandia has examined several sites in the Basin, and concluded that the present site is adequate. Weart did not believe that Sandia's objective should be to find "the best" site, but rather to provide technical assurance that whatever site is selected is an adequate one. Sandia's confidence in the adequacy of the present site is based upon a considerable amount of data from the oil industry, the potash mining industry, universities, Federal agencies, and data collected by Sandia.

In arriving at the criteria for a site, Weart explained that site selection criteria was extremely conservative to minimize the potential consequences of a breach, but should not be construed as "absolute concepts," because as more data become available, it may prove the selection was overly conservative. For example, the proximity of boreholes was originally established as "no closer than 2 miles," but with improved technology in the sealing of boreholes, there is now more confidence that this criterion was unduly restrictive, and that one mile is sufficient.

Snyder reviewed the relationship of the various disciplines in characterizing a site and evaluating the possible geologic anomalies. For example, it has been demonstrated at the WIPP site that the geophysical data do not always agree with the geologic findings. The early seismic data suggested a NW/SE trending fault running directly through the center of the site, but four drill holes, which were drilled over the supposed fault line, have shown that no such fault exists. Also in an effort to determine whether geophysical data could positively identify a breccia pipe, there have been seismic gravity and resistivity surveys over the known breccia pipes at Hills A, B, C, D, and the

Weaver pipe, all near the Capitan Reef, north of the site. The Weaver Pipe had a gravity and resistivity low. Hills A, B, and C did not indicate any anomaly in the gravity survey; Hill A had a resistivity low; Hill B only a very slight anomaly in the resistivity survey. Hill C had a pronounced resistivity low. Hill D had neither a gravity nor a resistivity low. Thus one can not usually identify geological anomalies, such as faults and breccia pipes on the basis of geophysical data alone.

Uncertainties in Modeling Parameters

There were several presentations and considerable discussion devoted to the uncertainties in the parameters used for modeling breach of the repository and transport of the waste to the biosphere. The effect of uncertainties in the hydrologic parameters associated with transport in the Rustler aquifers has been examined by both D'Appolonia (Ref. 4) and EEG (Ref. 5). The analysis by D'Appolonia was able to reproduce the release rates at Malega Bend reported in the WIPP Safety Analysis Report (Ref. 7), and suggested that the assumptions used for Communication Events 1 and 2 were probably excessively conservative. Both of these analyses also showed that varying the input parameters over a wide range did not significantly alter the radionuclide release rates at Malaga Bend. There remains, however, the possibility that other transportation modes, or release pathways, to the biosphere may exist, or that fracture flow in the Rustler could substantially alter the travel time.

Mercer and others expressed considerable confidence in the data on the Delaware Mountain Group aquifers, and he believed that the Santa Rosa Sandstone is too far east of the repository to consider as a transport medium for breached waste at WIPP.

Flow in the Magenta aquifer of the Rustler aquifers is believed to be intergranular, whereas fracture flow dominates in the Culebra. The flow in the Culebra from the site appears to be initially south then southwest toward Malaga Bend. Although Rustler outcrops exist to the west in Nash Draw, extensive field investigations by US Geologic Survey have not indicated evidence of outflow at these outcrops. Mercer believed that they may represent recharge

areas. Also Mercer reported that hydrologic studies have failed to show any connection between the Rustler aquifers and Laguna Grande de la Sal.

There is insufficient data to assess the impact of fracture flow in the Culebra on the transportation modeling and consequence analyses. The orientation of fractures is difficult to determine, and may vary with depth. The direction of flow in a fractured medium is not necessarily normal to potentiometric surface contours, therefore extensive tracer studies over the probable transportation path would seem necessary. Tracer studies are being carried out by Sandia in an attempt to improve the understanding of the flow in the Culebra. The data available to date suggest that the initial assumption of 10% porosity used in the consequence modeling presented in the Final Environmental Impact Statement was conservative. The data from the H-2 wells suggest a dispersivity of 17 feet and a porosity of 18%. A porosity of 10% was assumed in the FEIS (Ref. 6).

Davis and Mercer agreed that the direction of flow in a fractured media is not necessarily normal to potentiometric surface contours, and no general assumptions can be made concerning increasing permeability values in a given direction based on spacing between potentiometric contours. They believed that further tracer studies may provide the additional confidence needed.

There was general agreement that considerable uncertainty exists in the distribution coefficients for the radionuclides of WIPP waste. These are based on laboratory studies of powdered and solid rock from portions of Magenta and Culebra. There was consistency between the Kd results of the powdered and solid materials, but it has been demonstrated that the Kd values obtained were sensitive to many variables. There seemed to be general agreement that actinides are substantually retarded by the rock, but questions were raised about the significance of laboratory Kd's in fractured rock. Weart said that there are no plans to do in situ studies of Kd's at WIPP, because it is likely that such studies would require extremely long time periods - even over short distances.

Models for Breach and Transport

Several participants referred to the models used for breach and transport as

reported in the FEIS and SAR (Refs. 6, 7). There seemed to be general agreement that the assumptions used for the hydrologic breach events reported in the SAR were probably excessively conservative in assuming that the waste dissolved at the same rate as the salt, and in neglecting the effects of density changes between the saturated and unsaturated solutions.

For models which lead to transport of the contaminated brine through the Delaware Mountain Group aquifers, it is likely that the transport time would be sufficiently long to allow decay of virtually all of the radionuclides.

The effect on transport in the Rustler aquifers has been examined by varying the hydrologic parameters over wide ranges (Refs. 4, 5), and by assuming that the contaminated brine is brought to the biosphere either by a well (with the well located on the transport path about 3 miles from the repository), or by release into the Pecos at Malaga Bend (Refs. 6, 9). The results of these studies have demonstrated that the radiological consequences are acceptable if the Rustler is assumed to be relatively homogeneous or if the fractures which are known to exist, are filled with sediments.

The U.S. Department of Energy (DOE) has analyzed only one breach scenario which brings the waste to the surface at the site. This event involves an exploratory drill hole penetrating the waste storage area and intercepting waste containers. A fraction of the radioactive waste in the containers is brought directly to the surface (Chapter 8 of Ref. 7).

The Environmental Evaluation Group (EEG) has analyzed and presented at the meeting several long-term breach scenarios which lead to transport of some of the waste to the surface at the site. The detailed reports of these analyses were distributed to the participants in advance of the meeting, and are listed in the Appendix. The specific events considered include the following:

1. A breccia pipe forming under the repository and, over an extended time period enlarging through dissolution and collapse until it reaches the surface.
2. An exploratory drill hole penetrating through the repository and through waste containers to a pressurized brine reservoir assumed to be below the repository horizon. This leads to brine bringing a

fraction of the waste to the surface where it is uniformly distributed in the brine pond.

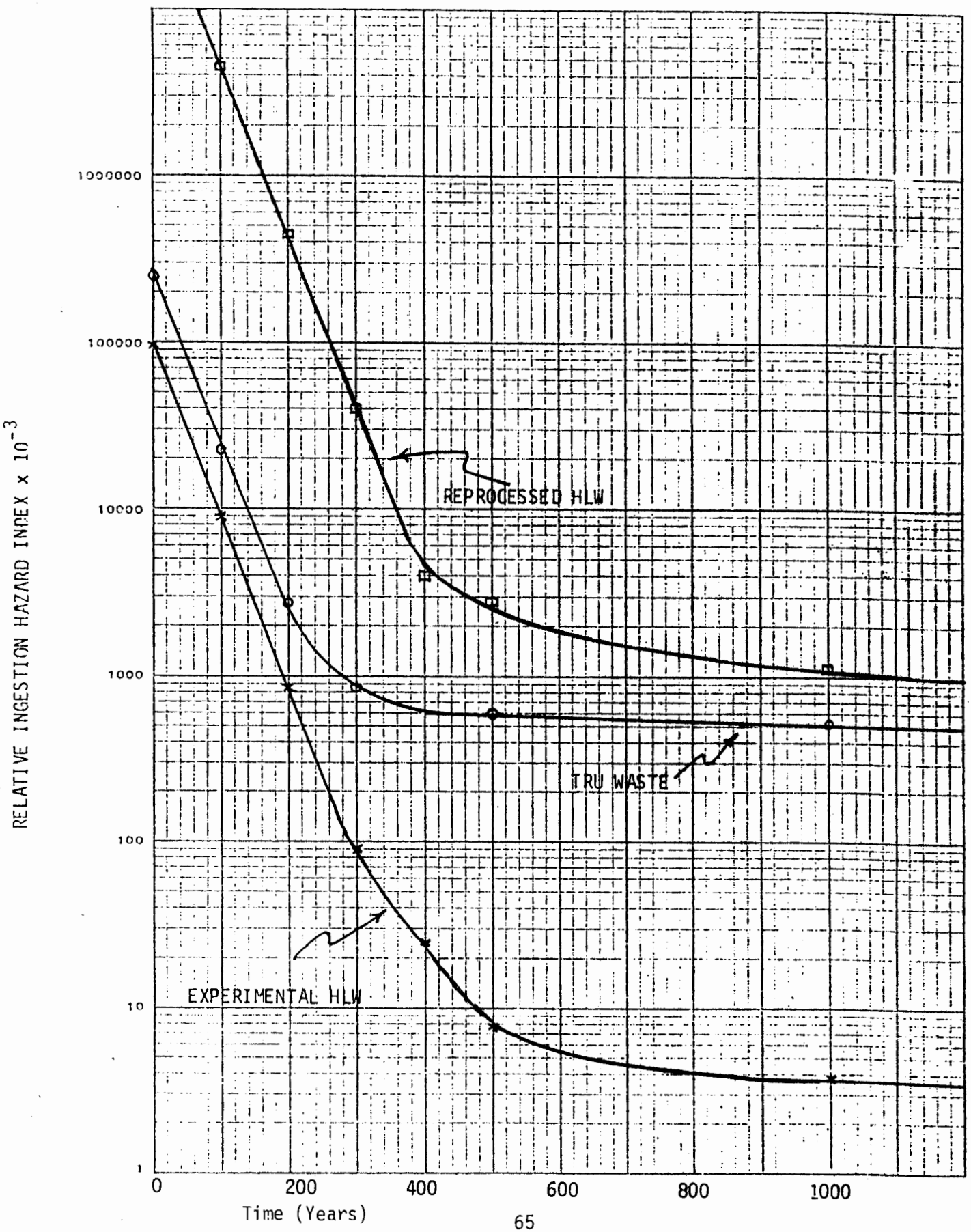
3. Two exploratory drill holes penetrate the repository over two separate time periods. The first hole extneds into a pressurized brine reservoir which is then capped near the surface. This allows brine to move into the salt backfilled repository where a fraction of the waste slowly leaches into the brine. The second hole is drilled years later, penetrates the brine-filled repository allowing the pressurized and contaminated brine to flow to the surface.

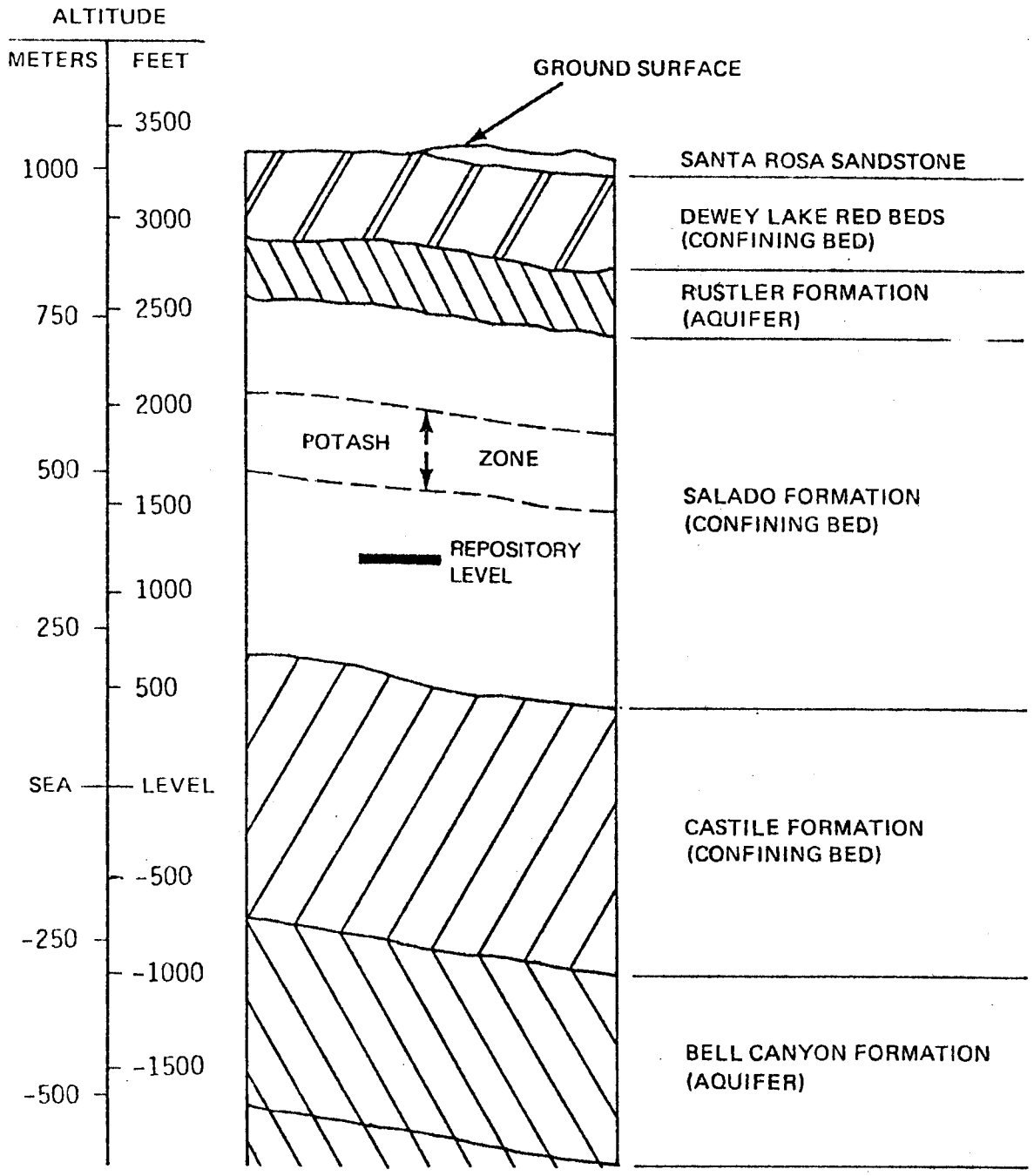
4. Solution mining of salt occurs over the repository horizon. A portion of the resultant solution intercepts the repository, dissolves the waste at the same rate as the salt, and the contaminated brine is then dried, without processing and a fraction is consumed by the population.

Roger Anderson discussed a biogenic mechanism which could lead to increased porosity and subsequent dissolution of the salt in the Salado. He believed that there is evidence that such a process is presently occurring at the Castile horizon in the northern portion of Zone III of the WIPP site, and that this process could ultimately breach the repository and transport waste to the biosphere. He offered no suggestions as to the source or pathway of the water for such dissolution and transport. It would be difficult to quantitatively assess this breach mechanism and its consequences.

RELATIVE TOXICITY OF TRU, EXPERIMENTAL HLW
& REPROCESSED HLW IN 100 ACRES OF REPOSITORY

Figure 19





NOTE:
FOR DETAILED DISCUSSIONS OF SITE GEOLOGY AND SUBSURFACE HYDROLOGY, SEE CHAPTER 2

Figure 20. Schematic Representation of the WIPP Site Stratigraphy (From Figure 8.1-3 of Ref. 7)

SECTION IV

REFERENCES

IV. REFERENCES

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APPENDIX

I. Pre-Meeting Correspondence

II. List of EEG Draft Reports

III. List of Attendees

IV. Agenda

APPENDIX I

PRE-MEETING CORRESPONDENCE

July 13, 1981

I

Dear I :

The purpose of this letter is to solicit your thoughts and suggestions on a proposed 2 day meeting to review estimates of radiation risk associated with various geological anomalies involved in breach and leach scenarios for WIPP. The intent is to bring modelers and geotechnical experts together to achieve a consensus on the long term radiological consequences of waste being brought to the surface by either naturally occuring geological processes or man-made intrusions stemming from mineral exploration or extraction.

I would appreciate any suggestions you may have on either speakers, structure, or content of meeting. This is an important meeting in endeavoring to come up with some agreement on the significance of various anomalies that have been of concern at the WIPP site and the consequences of their occurrence.

Sincerely,

Robert H. Neill
Director

RHN:lgr

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August 14, 1981

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Dear [1] :

Enclosed please note the August 12 draft of the planned workshop on Radionuclide Release, Transport and Consequences for WIPP. We believe this to be an important meeting to assess the significance of various geological anomalies that have been of concern at the WIPP site and the consequences of their occurrence. Any comments or thoughts on content or additional speakers would be appreciated. We are looking forward to your active participation and will keep you posted with more detailed information as soon as available.

The meeting will be held at La Fonda and information on transportation and hotel rates will be sent out next week.

Best personal regards.

Robert H. Neill
Director

RHN:eg

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August 18, 1981

[1]
Dear [1]:

We are looking forward to your participation in the September 16 and 17 "Radionuclide Release, Transport and Consequence Modeling for WIPP" workshop here in Santa Fe.

We have mailed a flyer to you on La Fonda, the hotel where the meeting is being held. They have quoted room rates of $55/Single, $65/Double. Other downtown hotels within a five minute walk have quoted the following rates.

La Posada (505) 983-6351 $39/Single, $44/Double	Hilton Inn (505) 988-2811 $55/Single, $70/Double
Inn of the Governors (505) 982-4333 $28/Single, $40/Double	Desert Inn (505) 982-1851 $40/Single, $56/Double

Please identify yourself as an EEG participant at La Fonda, La Posada and Inn of the Governors. The Desert Inn gives "government" discount.

Please call Ms. Peggy Tyler if you need any assistance.

Sincerely,

Robert H. Neill
Director

RHN:eg
Enclosure

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APPENDIX II

REPORTS DISTRIBUTED
AT
MEETING

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

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

3. EEG-12 Little, Marshall S. Potential Release Scenario and Radiological Consequence Evaluation of Mineral Resources at WIPP (Draft).

4. EEG-13 Spiegler, Peter. Analysis of the Potential Formation of a Breccia Chimney beneath the WIPP Repository (Draft).

5. EEG-14 Zand, Siavosh M. Dissolution of Evaporites and Its Possible Impact on the Integrity of the Waste Isolation Pilot Plant (WIPP) Repository (Draft).

6. 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 (Draft).

APPENDIX III

Revised List of attendees - September 16/17, 1981

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APPENDIX IV
AGENDA

RADIONUCLIDE RELEASE, TRANSPORT AND CONSEQUENCE MODELING FOR WIPP

A Workshop of Invited Scientists and Engineers

September 16-17, 1981

Santa Fe, New Mexico

Workshop on Radionuclide Release, Transport and Consequence Modeling for WIPP

Agenda

Mr. Robert H. Neill, Chairman

Wednesday, September 16, 1981

8:15 am . Thomas E. Baca, Director, Environmental Improvement Division, Health and Environment Department - Welcome

8:25 am . Robert H. Neill, EEG - Introduction

Session I - Goals and Perspectives

8:40 am . Wendell Weart, Sandia - Perspectives on WIPP

9:00 am . Richard Snyder, U.S. Geological Survey - A geologist's view of WIPP

Session II - Hydrological Parameter Uncertainties

Jim Channell and Charles Hadlock (Rappoteurs)

9:15 am . Jerry Mercer, U.S. Geological Survey - Hydrology of Delaware Basin

9:45 am Coffee

10:00 am . Stanley Davis, University of Arizona - Statistical variability of porosity and permeability in fractured rock

10:30 am . Don Diego Gonzales, Sandia - Analysis of fracture flow in the Rustler aquifers

11:00 am . Lokesh Chaturvedi, New Mexico State University -- Hydrologic parameters and potential release paths at the WIPP site

11:30 am - Lunch

1:00 pm . John Hawley, N.M. Bureau of Mines -- Surface stability in the Los Medanos Area

Session III - Hydrological Transport Models

Marc Zand and Lokesh Chaturvedi (Rappoteurs)

1:30 pm . Joseph Register, D'APPOLONIA - Hydrologic Transport Modeling for WIPP

2:00 pm . Moses Greenfield, UCLA - Square Wave Model for Hydrologic Transport Through Rustler Aquifers

2:30 pm . James Channell, EEG - Sensitivity Analysis of Hydrologic Parameters in Modeling

3:00 pm . Coffee

3:15 pm . Stanley Logan, Consultant - Influence of dissolved solids on radiological consequences.

3:45 pm - Discussion on first day's presentations

5:00 pm - Recess

Thursday, September 17, 1981

Session IV - Deep Seated Dissolution Model

Steve Bard and Moses Greenfield (Rappoteurs)

8:15 am . Roger Y. Anderson, UNM - Geographical and Time Bounds of Deep Dissolution - Quantification of an Hypothesis

8:45 am . Dennis Powers, Sandia - Bounds and Rates of Deep Dissolution

9:15 am . Coffee

9:30 am . D'Arcy A. Shock - Dissolution Mechanics

10:00 am . Marc Zand, EEG - Potential effects of dissolution of evaporites on repository integrity

10:30 am . Peter Davies, Stanford University - Mechanics and rates of formation of breccia pipes

Session V - Deep Dissolution Scenario Dosage Estimates

Marshall Little and Peter Davies (Rappoteurs)

11:00 am . Peter Spiegler, EEG - Breccia Pipe Scenarios

11:30 am . Craig Frederickson, TSC - Applicability of FEIS and SAR scenarios to potential geological breaching associated with deep dissolution, breccia pipes and brine reservoirs

12:00 Lunch

Session VI - Human Intrusion Scenario Dosage Estimates

Peter Spiegler and Stan Logan (Rappoteurs)

1:30 pm . James Channell, EEG - Brine Reservoir Scenario

2:00 pm . Steve Bard, EEG - Brine Reservoir Scenario

2:30 pm . Coffee

2:45 pm . Marshall Little, EEG - Solution Mining Scenario

3:15 pm . Craig Frederickson, TSC - Human Intrusion Scenarios

3:45 pm . Discussion on second day's presentations

4:45 pm Closing Remarks

5:00 pm Adjournment

Environmental Evaluation Group

Reports

(Continued From Front Cover)

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 (Draft).

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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 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.