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ASME (American Society of Mechanical Engineers). 1989. Quality Assurance Program Requirements for Nuclear Facilities. ASME NQA-1-1989. September 15, 1989. The American Society of Mechanical Engineers, New York, NY.

INTRODUCTION, 1 PURPOSE, p 1;
" This Standard sets forth requirements for the establishment and execution of quality assurance programs for the siting, design, construction, operation, and decommissioning of nuclear facilities. Nonmandatory guidance is provided in the Appendices."

Christensen, C.L., and Peterson, E.W. 1981. "Field-Test Programs of Borehole Plugs in Southeastern New Mexico." In The Technology of High-Level Nuclear Waste Disposal Advantages in the Science and Engineering of the Management of High-Level Nuclear Wastes, P.L. Hofmann and J.J. Breslin, eds., SAND79-1634C, DOE/TIC-4621, Vol. 1, pp. 354-369. Technical Information Center of the U.S. Department of Energy, Oak Ridge, TN.

FOREWORD, p 1;
" This paper provides an update on the Sandia Borehole Plugging Program (BHP) as reported at the October 1979 National Waste Terminal Storage (NWTS) Information Meeting, sponsored by ONWI, and included in ONWI 62. As reported in that paper, the Sandia BHP is specifically designed to support plugging activities for the proposed Waste Isolation Pilot Plant (WIPP) being considered by the U. S. Department of Energy (DOE) for the storage of defense non-heat producing transuranic (TRU) waste. This program will also provide generic information on bedded-salt formations to ONWI for inclusion in the NWTS commercial nuclear-waste repository programs. The goal of the Sandia BHP is to provide the plugging technology that will be required at the decommissioning and final closure of the WIPP facility.

At the time of the 1979 meeting, . . ."

p. 3, para 2;
" Field-testing experience with cementitious materials indicates that emplacement techniques used within the oil-field cementing industry will be adequate for repository plugging operations. Any modifications that may be required are expected to involve only minor changes; no new technology will be required."

Section VIII. SUMMARY AND CONCLUSIONS, p 25;
" The Bell Canyon Test (BCT) was conducted to evaluate candidate grout plugging mixes and plug emplacement techniques, and to asses plug performance under in-situ cured conditions. Grout plugging procedures are routinely performed in standard oil-field operations; however, quantitative measurements of plug performance are rarely obtained. the BCT was an attempt to quantify the state-of-the-art.

The experiment was performed in a 20-cm (8-inch) diameter wellbore that intercepted a natural aquifer having a shut-in pressure of 12.4 MPa (1800 psi) and a production capability of 38,000 liter/day ($10^4$ gals/day). This aquifer was located below a thick anhydrite bed (in the Castile Formation) near the site of the proposed Waste Isolation Pilot Plant (WIPP) in SENM. A 2-m (6-ft) grout plug was emplaced above the aquifer between 1368 m and 1370 m (4495 ft). By unloading the wellbore fluids from above the plug, the full 12.4 MPa pressure differential could be applied to the plug for flow testing.

Following the coring operation to deepen the wellbore, extensive logging, conditioning, and testing was conducted over a three-month period prior to plug emplacement. After plug emplacement on September 26, 1979, six test periods at forty-day intervals were scheduled to evaluate plug performance. Following the first four periods, the

plug was extended as additional 4 m (12 feet). However, tests on this extension have not been completed.

Brine-mixed grout was initially identified as the prime candidate for the plug. Laboratory samples (prepared to evaluate grout/rock interface performance), however, indicated permeability at the interface that was higher than either the grout or rock values taken separately (10-200 $\mu$darcy vs 0.1-1 $\mu$darcy). This leakage was attributed to a poor seal at the interface possibly caused by a salt residue formed during grout hydration. Hence an alternate fresh water mix was selected for the BCT plug. Routine tests (compressive strength, push-out strength, etc.) did not reflect this variation between the brine and fresh water mixes.

The plug performance was assessed using three basic techniques: fluid build-up tests (FBU), shut-in tests, and tracer transit-time tests; all testing was conducted through an "umbrella" packer emplaced 3-4 m above the plug to create a test chamber. The fluid build-up tests exhibited leakage in the tubing and packer plumbing as high as or higher than the leakage around the plug, leading to complications in the analysis. The shut-in tests and the tracer transit times worked satisfactorily.

The field data, taken together with laboratory data, suggest, that the predominant flow into the test region occurs through the cement plug/borehole interface region, with smaller contributions to total flow occurring through the wellbore damage zone, the plug core, and the surrounding undisturbed anhydrite bed.

The 2.0-m-long by 20-cm-diameter grout plug limits flow from the high-pressure (12.4 MPa) Bell Canyon aquifer to 0.6 liter/day (0.2 gal/day), a reduction factor of about $10^5$. Tracer flow studies are consistent with a flow channel having a maximum width not greater than about $2x10^{-5}$cm, in which the maximum flow velocity is approximately 1.2 m/day. This suggests that predominant flow is not through a finite number of fractures, but through a region whose microstructure approximates a porous medium. If the flow path cross-sectional area is assumed to be equal to that of the wellbore, the corresponding permeability and connected porosity would be 50 microdarcies and 1.5%, respectively. Plug performance remained consistent throughout the relatively short 4-month test period.

If the measured data are attributed to flow through a formation disturbed zone surrounding the umbrella packer(positioned approximately 4 m above the cement grout plug), then the kA value of this disturbed zone is nearly one order of magnitude less than that through the plug+formation system. If the medium surrounding the cement grout plug is similar, the predominant flow must occur through the plug or plug/wellbore interface. It is of interest to note that if the cross-sectional area of the wellbore damage region surrounding the umbrella packer is assumed equal to that of the wellbore, it must have a permeability on the order of 10 microdarcies.

Experience from conducting the BCT and analysis of the test data have allowed the following conclusions to be drawn:

While an industrial capability exists in the form of downhole passive pressure recorders or a limited system for uphole monitoring of downhole conditions, these both have serious drawbacks in field testing. The passive systems have limited resolution capability

and require recovery of the sensing system, thus terminating the test sequence. The active system, while having adequate resolution (0.1 psi), was not readily compatible with the packers that were initially used. By suitable field modifications, both systems were successfully used; however, with minor improvements, these systems could be made even more effective.

Cement-emplacement technology is generally adequate to satisfy repository plugging requirements; however, plug compatibility with the host rock must be carefully assessed for each repository site. generally accepted laboratory cement-testing techniques need to be supplemented by flow characteristics and geochemical stability.

The BCT indicated that grouts can be effective in sealing boreholes, if proper care is exercised in matching physical properties of the local rock with grout mixtures. Further, the reduction in fluid flow provided by even limited length plugs is far in excess of that required by bounding safety assessments for the WIPP.

Future plans for the next and succeeding years include continued testing of the BCT, removal of selected core sections from a three-year-old plug emplaced during the initial WIPP site evaluation program in the Potash Core test (PCT) and the establishment of a Surface Wellbore Test Bank (SWTB) for the emplacement and subsequent removal at nominal 2-, 5-, 10-, 15-, 30-year increments of in-situ cured plugs for long-term analysis. Other field tests that will address multi-component, multi-barrier plugs, in-situ diagnostic techniques in large diameter plugs leading to shaft sealing experience, and in-situ determination of formation parameters are now in the planning stage."

DOE (U.S. Department of Energy), 1980. Final Environmental Impact Statement, Waste Isolation Pilot Plant. DOE/EIS-0026, Vol. 1 and 2. U.S. Department of Energy, Washington, D.C.

Alternative 2: The authorized WIPP facility, p. 1-5;

" The authorized WIPP facility would consist of both surface and underground facilities, including a waste-handling building, an underground-personnel building to support underground construction, an administration building, four shafts to the underground area, underground openings at a single level for waste disposal and for experiments, and various support structures. There would be a storage pile for mined rock (primarily salt), an evaporation pond for runoff from the mined-rock pile, a sewage-treatment plant, a disposal area for construction spoils, and a landfill for sanitary wastes. The construction of the facility would take 4.5 years, and the plant would be designed for an operating life of about 25 years. The facility would be operational in 1987.

The development of the WIPP would occur in two distinct phases: (1) site and preliminary-design validation (SPDV), in which two deep shafts and an underground experimental area would be constructed; and (2) full construction in which the required surface and underground facilities and the remaining shafts would be built. . . .

Over its 25-year operating life, the WIPP could receive about 6.2 million cubic feet of contact-handled TRU waste and as much as 250,000 cubic feet of remotely handled TRU waste. This would account for all of the TRU waste currently held in interim storage in Idaho, two-thirds of that expected to be generated at all DOE facilities between now and 1990, and all of that expected to be produced from 1990 through 2003. In addition, the WIPP could receive about 150 cubic feet of high-level waste for experiments."

2.1.1 Decisions for Which This Environmental Impact Statement Provides Environmental Input, p. 2-2;

" This environmental impact statement (EIS), prepared in accordance with the requirements of the National Environmental Policy Act (NEPA) of 1969, provides environmental information for the following decisions:

1. What should be the strategy for the long-term management of the TRU waste stored at INEL?
2. Should the TRU waste stored at the INEL be disposed of in the first available HLW repository or in a repository for TRU waste only, such as the authorized WIPP facility?
3. Should the WIPP facility at the Los Medanos site be constructed and operated?
4. If the WIPP facility is not to be constructed at the Los Medanos site, should the site be retained to preserve the option of characterizing it as a potential site for a combined TRU-HLW repository?

If the answer to the fourth question is yes, additional NEPA documentation will be prepared prior to decisions on the qualification of the Los Medanos site as a candidate for an HLW repository. The qualification of other sites, site selection, and repository construction

and operation will also require NEPA documentation (DOE, 1980a)."

2.1.2 Contents of This Environmental Impact Statement, p. 2-3, para. 6;

" Structure

This document consists of two parts. The first part consists of chapters 2 through 4. It begins with a description of the national program for the management of radioactive waste and the WIPP project (Chapter 2). Chapter 3 formulates four alternative plans for the disposal of the TRU waste now stored at the INEL. Chapter 4 analyses the environmental impacts of these four alternatives.

The second part of this document presents the environmental impacts of the authorized alternative. It describes the waste to be received at the WIPP (Chapter 5); the methods and the environmental impacts of transporting the waste (Chapter 6); the environment of the Los Medanos site in southeastern New Mexico (Chapter 7); and the design of the facility (Chapter 8). These data are the basis for a detailed analysis of the environmental impacts induced by its construction and operation (Chapter 9). Because the WIPP is designed to keep the waste isolated far into the future, Chapter 9 discusses environmental impacts both in the short term, during the operating life of the repository, and in the long term, for hundreds of thousands of years into the future."

DOE (U.S. Department of Energy), 1990a. Final Supplement Environmental Impact Statement, Waste Isolation Pilot Plant. DOE/EIS-0026-FS. U.S. Department of Energy, Office of Environmental Restoration and Waste Management, Washington, D.C. Available from NTIS as DE90005774.

Section 3.1.1 Changes to the Proposed Action and New Information or Circumstances, p 3-2;

" This subsection describes specific proposed changes not covered in the 1980 FEIS, and new circumstances and information that have developed since 1980. These changes have been factored into the impact analyses in this final SEIS.

o Clarifying that the WIPP may eventually include permanent emplacement of post-1970 TRU waste from the 10 DOE generator facilities listed in Table 3.1. According to the 1981 Record of Decision, the WIPP was to initially dispose of waste in retrievable storage at the Idaho National Engineering Laboratory. After this waste was emplaced at the WIPP, the WIPP would then be available to dispose of TRU waste from ". . . other defense waste generating facilities, . . ." which were not specified by name.

The 1980 FEIS focused on the total inventory of 6.2 million cubic feet of CH TRU waste and 250,000 cubic feet of RH TRU waste expected to be received at the WIPP over its 25-year operating life. In 1980 this amount included all of the CH and RH waste in retrievable storage at the Idaho National Engineering Laboratory, two-thirds of the estimated waste to be generated at all DOE facilities between 1980 and 1990, and all TRU waste to be generated at all facilities between 1990 and 2003.

The DOE still proposes that the phased development of the WIPP proceed for the permanent emplacement of 6.2 million cubic feet of CH and 250,000 cubic feet of RH waste. This SEIS clarifies that the waste may eventually come directly from the 10 DOE generator facilities listed in Table 3.1. By analyzing the impacts of transportation and emplacement of post-1970 waste from all 10 DOE generator facilities, this SEIS updates the FEIS analyses of the environmental impacts of transporting to and emplacing in the WIPP only post-1970 TRU waste from Idaho National Engineering Laboratory and Rocky Flats Plant."

p. 3-4;

" Changes in volume of the TRU waste inventory. In 1980, it was contemplated that approximately 6.2 million $ft^3$ of CH and 250,000 $ft^3$ of RH TRU waste would be available for disposal at the WIPP. The WIPP as designed would be able to accommodate this volume of TRU waste. Recent estimates indicate that approximately 5.6 million $ft^3$ of CH TRU and 95,000 $ft^3$ of RH TRU waste are in retrievable storage at 6 generator/storage facilities or would be newly generated at these facilities and by an additional 4 facilities through the year 2013, the projected operating life of the WIPP (Tables 3.1 and 3.2). This lesser volume is currently estimated because of an improvement in recordkeeping and inventory sampling, a change in the definition of TRU waste (Appendix B), changes to the WIPP Waste Acceptance Criteria (WAC) (Subsection 2.3 and Appendix A), and expected facility process modifications that would result in waste minimization and volume reduction (e.g., Rocky Flats Plant supercompacter).

This SEIS, however, assesses the impacts of the WIPP using the volume limits of 6.2 million $ft^3$ of CH TRU and 250,000 $ft^3$ of RH TRU waste to set an upper limit on the potential impacts of filling the WIPP repository to its design capacity. The WIPP design capacity is sufficient to encompass TRU waste generated from new or planned defense-related facilities through the year 2013 (e.g., Special Isotope Separation Facility and the proposed Modular High Temperature Gas Cooled Reactor at the Idaho National Engineering Laboratory). Thus, the impacts associated with transporting, receiving, and permanently emplacing waste from all 10 facilities is conservatively "bounded" by the SEIS analysis."

DOE (U.S. Department of Energy), 1990b. Final Safety Analysis Report. WP02-9, Rev. 0. May 1990. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

PREFACE

"**Background**

This Final Safety Analysis Report (FSAR) has been prepared for the Waste Isolation Pilot Plant (WIPP) in order to satisfy the commitments made in the Working Agreement for Consultation and Cooperation(Article III, Section C and Article IV, Section K, known as the Working Agreement) between the State of New Mexico and the U.S. department of energy (DOE) and the requirements of Order DOE 5481.1B,Safety Analysis and Review System.

The objectives of the Safety Analysis Preparation and Review process, as specified in Order DOE 5481.1B, ensure that:

1. Potential hazards are systematically identified;

2. Potential consequences are analyzed;

3. Reasonable measures to eliminate, control or mitigate the hazards have been taken, including, where applicable, compliance with commitments made in environmental assessments and impact statements;

4. There is documented management authorization of the DOE operation based upon an objective assessment of the safety analysis.

Specific hazards that are analyzed include credible natural hazards such as flood, weather (tornado, wind, etc.) and earthquake; and credible man made hazards such as fire, explosion, radiation, and mining hazards. Mitigating measures include facility design and construction, operational controls, and administrative limits.

This FSAR represents a statement and commitment by the DOE that the WIPP facility can be operated safely and at minimum risk, if operated in accordance with this FSAR. Consequently, this FSAR has been prepared to document that a systematic analysis of the potential hazards associated with operating the WIPP facility has been performed (objective 1 of Order DOE 5481.1B); that potential consequences have been analyzed (objective 2 of Order DOE 5481.1B); and that reasonable measures have been taken to eliminate, control, or mitigate the hazards (objective 3 of Order DOE 5481.1B). In addition, this FSAR documents the implementation of commitments made in the environmental impact statement regarding the mitigation of adverse impacts to the environment (objective 3 of Order DOE 5481.1B)."

Section 1.1 INTRODUCTION; p 1.1-1. para 3;
" In addition, this FSAR has been prepared in accordance with Article III of the 1981 Consultation and Cooperation Agreement (C&C Agreement) between the DOE and the State of New Mexico and, as such, represents the most comprehensive document concerning the WIPP facility both in general terms and specifically as related to public health and safety."

Section 1A.1.1.1 Earthquakes, p 1A.1-2;
" Seismic risk analysis has defined a conservative DBE for the WIPP facility with a maximum ground acceleration of 3.2 in/$s^2$ (0.1g) horizontally and vertically, with 10 maximum stress cycles, and based on a 1000-year recurrence interval. This maximum acceleration is used in analysis and design of surface confinement facilities and equipment. Response spectrum analysis was contacted using structural mode shapes and frequencies for two principal horizontal directions, and modal responses (shear, moments,stresses, deflection, accelerations) were combined to assess the contribution to loading from seismic sources.
Seismic overturning moment was used to compute foundation reactions and account for vertical earthquake effects. . . . "

DOE (U.S. Department of Energy). 1995. Safety Analysis Report. DOE/WIPP-95-2065, Rev. 0, November 30, 1995. Carlsbad Area Office, Carlsbad, NM.

Facility Background and Mission, p. 1-4;

" The United States Department of Energy (DOE) was authorized by Public Law 96-164[1] to provide a research and development facility for demonstrating the safe permanent disposal of transuranic (TRU) wastes from national defense activities and programs of the United States exempted from regulations by the U.S. Nuclear Regulatory Commission (NRC). The Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico near Carlsbad, was constructed to determine the efficacy of an underground repository for disposal of TRU wastes.

In accordance with the 1981 and 1990 Records of Decision (ROD),[2,3] the development of the WIPP was to proceed with a phased approach. Development of the WIPP began with a siting phase, during which several sites were evaluated and the present site selected based on extensive geotechnical research, supplemented by testing.

The site and preliminary design validation (SPDV) followed the siting phase, during which two shafts were constructed, an underground testing area was excavated, and various geologic, hydrologic, and other geotechnical features were investigated. The construction phase followed the SPDV phase during which surface structures for receiving waste were built and underground excavations were completed for waste emplacement. . . ."

p. 1-5, para 1;

" This Safety Analysis Report (SAR) documents the safety analyses that develop and evaluate the adequacy of the WIPP CH TRU safety bases necessary to ensure the safety of workers, the public, and the environment from the hazards posed by WIPP waste handling and emplacement operations during the disposal phase and hazards associated with the decommissioning and decontamination phase.

The analyses of the hazards associated with the long-term (10,000 year) disposal of TRU and TRU mixed waste, and demonstration of compliance with the requirements of 40 CFR 191, Subpart B[4] and 40 CFR 268.6[6] will be addresses in detail in the WIPP Final Certification Application scheduled for submittal in October 1996 (40 CFR 191) and the No-Migration Variance Petition (40 CFR 268.6) scheduled for submittal in June 1996. Section 5.4, Long-Term Waste Isolation Assessment summarizes the current status of the assessment. Section 5.4 will be updated upon completion of the long-term assessment demonstration (currently scheduled for the FY-97 Annual Update)."

2.5 Meteorology, 2.5.1 Recent Climatic Conditions, p. 2-51;

" Current climatic conditions are provided to allow for the assessment of impacts of these factors on the disposal unit and the site. The WIPP facility does not rely on climatic conditions to control waste migration; however, meteorological information is used in the evaluation of the air pathway during operation of the facility."

2.5 Meteorology, 2.5.1.2 Regional Meteorological Conditions for Design and Operating Bases, 2.5.1.2.1 Heavy Precipitation, p. 2-51;

" The maximum 24-hour rainfall at Roswell was 5.65 inches in November 1901.[2] The maximum 24-hour snowfall in Roswell was 15.3 inches in December 1960. The greatest snowfall during a 1-month period was 23.3 inches in February 1905.[3]."

3.2.4 Water Level (Surface Flood) Design, p. 3-17;

" Flood elevations for the Pecos River and the vicinity of the WIPP facility are described in Chapter 2. The WIPP facility nominal grade elevation is more than 400 ft above the probable maximum flood (PMF) level of the Pecos River, and the WIPP facility is separated from the river by about 14 mi of gradually rising land. Since there are no perennial or intermittent streams near the WIPP facility that have the potential for sustained flooding of the site, neither buoyancy nor static water forces due to flood elevations shall be considered in the WIPP facility design.

3.2.4.1 Phenomena Considered in Design Load Calculations

Phenomena such as flood currents or wind-induced waves shall not apply because the grades for the WIPP facility structures are more than 400 ft above the PMF level on the Pecos River, and none of the local drainage ways has the potential for sustained flooding of the WIPP facility.

3.2.4.2 Flood Force Application

As stated above, the WIPP facility structures are above the PMF level and are not subjected to flood loadings.

3.2.4.3 Flood Protection

Protection against the PMF level on the Pecos River shall not be required for WIPP facility SSCs. Protection from flooding, caused by locally intense precipitation, is described in Chapter 2.

An accidental rupture of the fire water tanks may result in a local flood around the tanks, and provisions shall be made so that any liquid released does not cause a flood of sufficient depth to endanger equipment or systems. Static and dynamic fluid pressures resulting from a tank rupture shall be considered in the design of structures where applicable. Water storage tanks shall be located outside of buildings so that water released from them does not flood Design Class II SSCs, and floor drainage systems shall accommodate any water from other small tanks or piping systems within the buildings."

DOI (Department of the Interior). 1995a. 43 CFR Part 3160, Onshore Oil and Gas Operations, Federal and Indian Oil and Gas Leases Drilling Operations. Subpart 3162, Requirements for Operating Rights, Owners and Operators. Subpart 3162.3-4, Well Abandonment. 43 CFR Chapter 2. October 9, 1995. 53 Federal Register 22 847, June 17, 1988. Bureau of Land Management, Washington, D.C.

3162.3-4 Well abandonment:

" (a) The operator shall promptly plug and abandon, in accordance with a plan first approved in writing or prescribed by the authorized officer, each newly completed or recompleted well in which oil or gas is not encountered in paying quantities or which, after being completed as a producing well, is demonstrated to the satisfaction of the authorized officer to be no longer capable of producing oil or gas in paying quantities, unless the authorized officer shall approve the use of the well as a service well for injection to recover additional oil or gas or for subsurface disposal of produced water. In the case of a newly drilled or recompleted well, the approval to abandon may be written or oral with written confirmation.

(b) Completion of a well as plugged and abandoned may also include conditioning the well as water supply source for lease operations or for use by the surface owner or appropriate Government Agency, when authorized by the authorized officer. All costs over and above the normal plugging and abandonment expense will be paid by the party accepting the water well.

(c) No well may be temporarily abandoned for more than 30 days without the prior approval of the authorized officer. The authorized officer may authorize a delay in the permanent abandonment of a well for a period of 12 months. When justified by the operator, the authorized officer may authorize additional delays, no one of which may exceed an additional 12 months. Upon the removal of drilling or producing equipment from the site of a well which is to be permanently abandoned, the surface of the lands disturbed in connection with the conduct of operations shall be reclaimed in accordance with a plan first approved or prescribed by the authorized officer."

DOI (Department of the Interior). 1995b. 43 CFR Part 3593, Boreholes and Samples. Subpart 3593.1, Core and Testhole Cores, Samples, Cuttings. 43 CFR Chapter 2, October 9, 1995. 53 Federal Register 22 847, June 17, 1988. Bureau of Land Management, Washington, D.C.

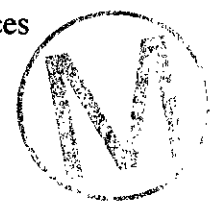
3593.1, Core and test hole cores, samples, cuttings:

" (a) The operator/lessee shall submit promptly to the authorized officer a signed copy of records of all core or test holes made on the lands covered by the lease, license or permit. The records shall be a form that will allow the position and direction of the holes to be located on a map. The records shall include a log of all strata penetrated and conditions encountered, such as water, gas or unusual conditions. Copies of analysis of all samples shall be transmitted to the authorized officer as soon as obtained or as requested by the authorized officer. The operator/lessee shall furnish the authorized officer a detailed lithologic log of each drill hole and all other in-hole surveys or other logs produced. The core from test holes shall be retained by the operator/lessee for 1 year or such other period as may be directed by the authorized officer, and shall be available for inspection by the authorized officer. The authorized officer may cut such cores and receive samples as appropriate. Upon the request of the authorized officer, the operator/lessee shall furnish samples of strata, drill cuttings, and mill products.

(b) Surface drill holes for development or holes for prospecting shall be abandoned to the satisfaction of the authorized officer by cementing and/or casing or by other methods approved in advance by the authorized officer and in a manner to protect the surface and not endanger any present or future underground operation or any deposit of oil, gas, other mineral substances or aquifer.

(c) Logs and analyses of development holes shall not be required unless specifically requested by the authorized officer. Drill holes may be converted to surveillance wells for the purpose of determining the effect of subsequent operations upon the quantity, quality of pressure of ground water or mine gases. Such conversion may be required by the authorized officer or requested by the operator/lessee and approved by the authorized officer. Prior to the termination of the lease, license or permit term, all surveillance wells shall be reclaimed unless the surface owner assumes responsibility for reclamation of such surveillance wells. The transfer of liability for reclamation shall be approved in writing by the authorized officer.

(d) When drilling on lands with potential for encountering high pressure oil, gas or geothermal formations, drilling equipment shall be equipped with blowout control devices acceptable to the authorized officer."



EPA (U.S. Environmental Protection Agency), 1993. 40 CFR Part 191 Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes; Final Rule. Federal Register, Volume 58, No. 242, pp. 66398-66416, December 20, 1993, Office of Radiation and Indoor Air, Washington, D.C. WPO 39133.

PREAMBLE: SUMMARY;

" The U.S. Environmental Protection Agency (EPA) is promulgating amendments to the environmental standards for the disposal of spent nuclear fuel, high-level and transuranic wastes (40 CFR 191.15 and Subpart C).

EPA originally promulgated these standards in 1985 pursuant to the Agency's authorities and responsibilities under the Nuclear Waste Policy Act of 1982, as amended, the Atomic Energy Act of 1954, as amended, and §2(a)(6) of Reorganization Plan No. 3 of 1970 (5 USC app. 1). In 1987, following a legal challenge, the U.S. Court of Appeals for the First Circuit (hereinafter referred to as 'the First Circuit' or ' the court') remanded subpart B of the 1985 standards to the Agency for further consideration. *Natural Resources Defense Council, Inc. v. United States Environmental Protection Agency*, 824 F.2d 1258 (1st Cir. 1987). Recently enacted legislation, (Pub. L. 102-579) known as the Waste Isolation Pilot Plant Land Withdrawal Act (WIPP LWA), however, reinstates the 1985 disposal standards except 'the 3 aspects of §§191.15 and 191.16 of such [standards] that were subject of the remand ordered' by the First Circuit. The WIPP LWA directs EPA to expedite issuance of final disposal standards and specifies that such regulations shall not be applicable to the characterization, licensing, construction, operation, or closure of any site required to be characterized under §113(a) of Public Law 97-425, the Nuclear Waste Policy Act of 1982.

Today's action represents the Agency's response to this legislation and to the issues raised by the court pertaining to individual and ground-water protection requirements. After considering the relevant comments received on the February 10, 1993 proposed rulemaking, the Agency has taken this final action in the form of amendments to parts 191 of title 40 of the Code of Federal Regulations. In so doing, EPA has not revised any of the regulations reinstated by the WIPP LWA.

DATES: These amendments will become effective on January 19, 1994. These amendments will be promulgated for purposes of judicial review at 1 p.m. eastern standard time on December 20, 1993."

50 FR 38085, col 2;

" §191.12 Definitions.

Unless otherwise indicated in this Subpart, all terms shall have the same meaning as in Subpart A of this Part.

(a) "Disposal system" means any combination of engineered and natural barriers that isolate spent nuclear fuel or radioactive waste after disposal.

50 FR 38086, col. 2;

" §191.14 Assurance requirements.

To provide the confidence needed for long-term compliance with the requirements of 191.13, disposal of spent nuclear fuel or high-level or transuranic waste shall be conducted in accordance with the following provisions, except that these provisions do not apply to facilities regulated by the Commission (see 10 CFR Part 60 for comparable provisions applicable to facilities regulated by the Commission):"

. . .

" (b) Disposal systems shall be monitored after disposal to detect substantial and detrimental deviations from expected performance. This monitoring shall be done with techniques that do not jeopardize the isolation of the wastes and shall be conducted until there are no significant concerns to be addressed by further monitoring."

. . .

(d) Disposal systems shall use different types of barriers to isolate the wastes from the accessible environment. Both engineered and natural barriers shall be included."

EPA (U.S. Environmental Protection Agency), 1996. 40 CFR Part 194: Criteria for the Certification and Re-Certification of the Waste Isolation Pilot Plant's Compliance with the 40 CFR Part 191 Disposal Regulations; Final Rule. Federal Register, Vol. 61, No. 28, pp. 5224-5245, February 9, 1996. Office of Radiation and Indoor Air, Washington, D.C. In NWM Library as KF70.A35.C751 1996 (Reference).

SUMMARY, p. 5224, col. 1;

" The Environmental Protection Agency (EPA) is promulgating criteria for determining if the Waste Isolation Pilot Plant (WIPP) will comply with EPA's environmental radiation protection standards for the disposal of radioactive waste. If the Administrator of the EPA determines that the WIPP will comply with the standards for disposal, then the Administrator will issue to the Secretary of Energy a certification of compliance which will allow the emplacement of transuranic waste in the WIPP to begin, provided that all other statutory requirements have been met. If a certification is issued, EPA will also use this final rule to determine if the WIPP has remained in compliance with EPA's environmental radiation protection standards, once every five years after the initial receipt of waste for disposal at the WIPP. This rulemaking was mandated by the WIPP Land Withdrawal Act of 1992. EFFECTIVE DATE: These regulations are effective April 9, 1996."

§194.14 Content of compliance certification application, p. 5238, col. 2;

" Any compliance application shall include:

. . .

(b) A description of the design of the disposal system including:

(1) Information on materials of construction including, but not limited to: Geologic media, structural materials, engineered barriers, general arrangement, and approximate dimensions; and

(2) Computer codes and standards that have been applied to the design and construction of the disposal system."

State of New Mexico, Oil Conservation Division, Energy, Mineral, and Natural Resources Department. 1988. Order R-111-P, Potash Areas of Eddy and Lea Counties, NM. Case 9316, Revision to Order R-111-P, April 21, 1988. Santa Fe, NM.

F. PLUGGING AND ABANDONMENT OF WELLS;

" (1) All wells heretofore and hereafter drilled within the Potash Area shall be plugged in a manner and in accordance with the general rules or field rules established by the Division that will provide a solid cement plug through the salt section and any water-bearing horizon and prevent liquids or gases from entering the hole above or below the salt section.

(2) The fluid used to mix the cement shall be saturated with the salts common to the salt section penetrated and with suitable proportions but not more than three (3) percent of calcium chloride by weight of cement being considered the desired mixture whenever possible."

State of New Mexico, Oil Conservation Division, Energy, Minerals, and Natural Resources Department. 1991. Rule 202, Plugging and Permanent Abandonment, March 1, 1991. Santa Fe, NM.

RULE 202. - PLUGGING AND PERMANENT ABANDONMENT:

" A. NOTICE OF PLUGGING

(1) Notice of intention to plug must be filed with the Division on Form C-103, Sundry Notices and Reports on Wells, by the operator prior to the commencement of plugging operations, which notice must provide all of the information required by Rule 1103 including operator and well identification and proposed procedures for plugging said well, and in addition the operator shall provide a well-bore diagram showing the proposed plugging procedure. Twenty-four hours notice shall be given prior to commencing any plugging operations. In the case of a newly drilled dry hole, the operator may obtain verbal approval from the appropriate District Supervisor or his representative of the method of plugging and time operations are to begin. Written notice in accordance with this rule shall be filed with the Division ten (10) days after such verbal approval has been given.

B. PLUGGING

(1) Before any well is abandoned, it shall be plugged in a manner which will permanently confine all oil, gas and water in the separate strata in which they are originally found. This may be accomplished by using mud-laden fluid, cement and plugs singly or in combination as approved by the Division on the notice of intention to plug.

(2) The operator shall mark the exact location of plugged and abandoned wells with a steel marker not less than four inches (4") in diameter set in cement and extending at least four feet (4') above mean ground level. The operator name, lease name and well number and location, including unit letter, section, township and range, shall be welded, stamped or otherwise permanently engraved into the metal of the marker.

(3) As soon as practical but no later than one year after completion of plugging operations, the operator shall:

(a) fill all pits;
(b) level the location;
(c) remove deadmen and all other junk; and
(d) take such other measures as are necessary or required by the Division to restore the location to a safe and clean condition.

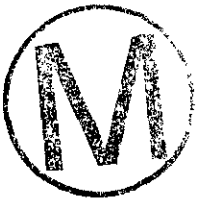
(4) Upon completion of plugging and clean up restoration operations as required, the operator shall contact the appropriate district office to arrange for an inspection of the well and location.

C. Reports

(1) The operator shall file Form C-105, Well Completion or Recompletion Report and Log as provided in Rule 1105.

(2) Within thirty (30) days after completing all required restoration work, the operator shall file with the Division, in TRIPLICATE, a record of the work done on Form C-103 as provided in Rule 1103.

(3) The Division shall not approve the record of plugging or release any bonds until all necessary reports have been file and the location has been inspected and approved by the Division."



State of New Mexico, State Engineer's Office. 1995. Article 4, Well Drillers' Licensing-Construction, Repair, and Plugging of Wells: Articles 4-14, Shallow Wells Construction Repair Plugging, and 4-20.2, Abandonment-Plugging. Santa Fe, NM.

Article 4-14, Shallow Wells-Construction-Repair-Plugging:
" The State Engineer has not adopted any general specifications for the construction, repair, or plugging of non-artesian or shallow wells. Any specific requirements and provisions made by the State Engineer shall be set forth in the permit. Application for Permit to Repair is required for all repair work, cleaning, scaling, deepening, modification of casing, or other work requiring the use of a well rig. Any specific requirements or conditions governing the repair will be set out in the approval of the permit. If plugging is required (Article 2-13), shallow wells shall be plugged by filling to the ground surface or, if the casing is not to be removed, by welding a steel plate or cap to the casing."

Article 4-20.2, Abandonment-Plugging:
" In the event that the test or exploratory well is to be abandoned, the State Engineer shall be notified. Such well shall be plugged in accordance with Article 4-19.1 so that the fluids will be permanently confined to the specific strata in which they were originally encountered."

U.S. Congress, 1992. Waste Isolation Pilot Plant Land Withdrawal Act, Public Law 102-579, October 1992, 102nd Congress, Washington, D.C.

An Act
To withdraw land for the Waste Isolation Pilot Plant, and for other purposes.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,

"SEC.7.DISPOSAL OPERATIONS.

(a)TRANSURANIC WASTE LIMITATIONS.--

(1) REM LIMITS FOR REMOTE-HANDLED TRANSURANIC WASTE.--

(A) 1,000 REMS PER HOUR.--No transuranic waste received at WIPP may have a surface dose rate in excess of 1,000 rems per hour.

(B) 100 REMS PER HOUR.--No more than 5 percent by volume of the remote-handled transuranic waste received at WIPP may have a surface dose rate in excess of 100 rems per hour.

(2) CURIE LIMITS FOR REMOTE-HANDLED TRANSURANIC WASTE.--

(A) CURIES PER LITER.--Remote-handled transuranic waste received at WIPP shall not exceed 23 curies per liter maximum activity level (averaged over the volume of the canister).

(B) TOTAL CURIES.--The total curies of the remote-handled transuranic waste received at WIPP shall not exceed 5,100,000 curies.

(3) CAPACITY OF WIPP.--The total capacity of WIPP by volume is 6.2 million cubic feet of transuranic waste."

# BIBLIOGRAPHY DOCUMENTS

Beauheim, R.L., Saulnier, Jr., G.J., and Avis, J.D. 1991. Interpretation of Brine-Permeability Tests of the Salado Formation at the Waste Isolation Pilot Plant Site: First Interim Report. SAND90-0083. Sandia National Laboratories, Albuquerque, NM.

ABSTRACT, p i;

" Pressure-pulse tests have been performed in bedded evaporites of the Salado Formation at the Waste Isolation Pilot Plant (WIPP) site to evaluate the hydraulic properties controlling brine flow through the Salado. Hydraulic conductivities ranging from about $10^{-14}$ to $10^{-11}$ m/s (permeabilities of about $10^{-21}$ to $10^{-18}$ $m^2$) have been interpreted from nine tests conducted on five stratigraphic intervals within eleven meters of the WIPP underground excavations. Tests of a pure halite layer showed no measurable permeability. Pore pressures in the stratigraphic intervals range from about 0.5 to 93. MPa. An anhydrite interbed (Marker Bed 139) appears to be one or more orders of magnitude more permeable than the surrounding halite. Hydraulic conductivities appear to increase, and pore pressures decrease, with increasing proximity to the excavations. These effects are particularly evident within two or three meters of the excavations. Two tests indicated the presence of apparent zero-flow boundaries about two to three meters from the boreholes. The other tests revealed no apparent boundaries within the radii of influence of the tests, which were calculated to range from about four to thirty-five meters from the test holes. The data are sufficient to determine if brine flow through evaporites results from Darcy-like flow driven by pressure gradients within naturally interconnected porosity or from shear deformation around excavations connecting previously isolated pores, thereby providing pathways for fluids at or near lithostatic pressure to be driven towards the low-pressure excavations. Future testing will be performed at greater distances from the excavations to evaluate hydraulic properties and processes beyond the range of excavation effects.

Bechtel National. 1986. Quarterly Geotechnical Field Data Report. DOE/WIPP-221. U.S. Department of Energy, Carlsbad, NM.

FOREWORD, p iii;

" The purpose of the Quarterly Geotechnical Field Data Reports is to meet the U.S. Department of Energy intent to provide geotechnical and related information from WIPP underground activities to interested persons or groups in a timely manner. This Quarterly Geotechnical Field Data Report (GFDR) presents information obtained from the geotechnical studies at the WIPP site underground facilities from April 1 through June 30, 1985, as well as all previous data collected from the geomechanical instruments. During this period, the geotechnical activities at the site included maintaining and repairing instruments and monitoring previously installed geomechanical instruments in shafts, underground drifts, and test rooms. The data presented in this GFDR reflect the update of continuing measurements and monitoring. Also continuing and included in this report are preliminary geotechnical and structural analyses and interpretations of the data.

The GFDR is organized into two principle parts. The first part, Geotechnical Field Data, . . ."

Borns, D.J., 1985. Marker Bed 139: A Study of Drillcore from a Systematic Array. SAND85-0023. Sandia National Laboratories, Albuquerque, NM.

ABSTRACT, p 3;

" In southeastern New Mexico, Marker Bed 139 (referred to in this report as MB139) is one of 45 numbered siliceous or sulfatic units within the Salado Formation of the northern Delaware Basin. MB139 is divided into five zones. Zones I and V are the upper and lower contact zones, respectively. Zone II is a syndepositionally deformed subunit of polyhalitic anhydrite. Zone III is mixed anhydrite and polyhalitic anhydrite, a distinctive pale-green and pink, with subhorizontal fractures. Zone IV consists of interlayered halite and anhydrite without the overprint of polyhalite.

This sequence was transitional between submarine and subaerial. The anhydritic units of MB139 formed in salt-pan or mudflat environments or both. Undulations observed along the upper contact of MB139 are interpreted to result from traction deposits or from reworking of the upper portion of the marker bed during the transition from anhydrite to halite deposition. Zones II and III exhibit soft-sediment deformation and later traces of dewatering; e.g., formation of stylolites. Such deformation is not observed in the halite above MB139 or in Zone V and the halite units below MB139.

A distinctive set of subhorizontal fractures occurs in MB139 in mid-Zone III and, to some extent, in Zone IV. These fractures are partially infilled with halite and polyhalite. Brine occurrences at the mined facility horizon at the Waste Isolation Pilot Plant may be related to these fractures. The fractures formed either in response to stress cycles that were functions of sedimentation and erosion, or in response to deformation in the underlying Castile Formation. The subhorizontal orientation, dominant in the sampling to date, is more consistent with the interplay between stress and sedimentation cycles."

Borns, D.J., and Stormont, J.C. 1988. An Interim Report on Excavation Effect Studies at the Waste Isolation Pilot Plant: The Delineation of the Disturbed Rock Zone. SAND87-1375. Sandia National Laboratories, Albuquerque, NM.

ABSTRACT, p i;

" For nuclear waste repositories with both long operational periods (50 yr) and long performance assessment periods (10 000 yr), the Disturbed Rock Zone (the zone of rock in which the mechanical and hydrologic properties have changed in response to excavation; abbreviated as DRZ) is important to both operational (e.g., slab or fracture failure of the excavation) and long term performance (e.g., seal system performance and fluid transport). At the Waste Isolation Pilot Plant (WIPP), the DRZ has been characterized with three approaches: visual observation; geophysical methods; and permeability measurements. Visual observations in drillholes indicate that fluids and fractures are common in the host rock of the underground facility. Geophysical studies have utilized radar, electromagnetic (EM), and direct current (DC) electromagnetic methods. Radar has been useful, but the penetration is limited by the water content and the bedded nature of the host rock. The EM method was able to detect a fourfold increase in resistivity from 1 to 5 m into the rock. This trend reflects a fourfold increase in the moisture content from near the excavation (0.5 to 1% by weight) to 5 m into the host rock (2 to 3% by weight). The DC method has been able to detect zones of moisture around the excavation. Numerous gas permeability measurements indicate that beyond 2 m from an excavation halite and interbeds (anhydrite and clay) allow very low gas flow (calculated permeabilities $<$ 1 microdarcy for gas flow tests and $<$ 0.01 microdarcy for brine-based permeability tests). Within 2 m of the excavation, very high flow rates ($10^4$ SCCM) were measured. All three approaches have defined a DRZ at the WIPP extending laterally throughout the excavation and varying in depth from 1 to 5 m, according to the size and age of the opening."

Borns, D.J., and Stormont, J.C. 1989. The Delineation of the Disturbed Rock Zone Surrounding Excavations in Salt. Rock Mechanics as a Guide for Efficient Utilization of Natural Resources, Proceedings of the 30th US Symposium on Rock Mechanics, June 19-22, 1989, A.W. Khair, ed., SAND88-2230c, pp. 353-360, A.A. Balkema, Brookfield, VT.

ABSTRACT, p 353;

" At the Waste Isolation Pilot Plant (WIPP) in southeastern New Mexico, the Disturbed Rock Zone (DRZ, the zone of rock in which the mechanical and hydrologic properties have changed in response to excavation) has been characterized with visual observations, geophysical methods, and gas-flow measurements. The visual observations, geophysics, and gas-flow tests have defined a DRZ at the WIPP extending laterally throughout the excavation and varying in depth from 1 to 5 m. Desaturation and microfracturing has occurred to some degree within the zone. The dilation that results from the microfracturing in the DRZ provides a component of the observed closure."

Chan, K.S., Bodner, S.R., Fossum, A.F., and Munson, D.E. 1992. A Constitutive Model for Inelastic Flow and Damage Evolution in Solids Under Triaxial Compression. Mechanics of Materials, SAND92-0546J, Vol. 14, No. 1, pp. 1-14.

ABSTRACT, p 1;

" A constitutive model for describing time-dependent, pressure-sensitive inelastic flow and damage evolution in crystalline solids under non-hydrostatic compression has been developed on the basis that the relevant damage and dislocation flow processes both contribute to the overall inelastic strain rate. A damage-based kinetic equation is first formulated using the work-conjugate approach and the continuum damage concept. That relation is then added to the dislocation-based kinetic equation of a multi-mechanism deformation (M-D) model to obtain the macroscopic inelastic strain rate. The proposed kinetic relation for the overall inelastic strain rate is shown to be derivable from a flow potential. The kinetic equation indicates plastic dilitancy under triaxial compression when the damage term is activated, and leads to plastic incompressibility when inelastic straining is primarily provided by dislocation flow mechanisms. The dependence of creep rate and plastic dilitancy on confining pressure shown by model calculations for rock salt is in accord with experimental observations."

COE (U.S. Army Corps of Engineers). 1985. Federal Engineering Operating Procedures for Construction of the Waste Isolation Pilot Plant.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

DOE (U.S. Department of Energy) 1986. Waste Isolation Pilot Plant Design Validation Final Report. DOE/WIPP 86-010. U.S. Department of Energy, Carlsbad, NM.

EXECUTIVE SUMMARY, INTRODUCTION, p 1;

" The Waste Isolation Pilot Plant (WIPP) is being developed by the U. S. Department of Energy (DOE) as a research and development facility to demonstrate the safe disposal of radioactive waste from U. S. defense programs. The facility is located in southeastern New Mexico, about 25 miles east of the city of Carlsbad. Underground development is at a depth of about 2,150 feet in thick deposits of bedded salt. The facility operation will include in situ experiments addressing technical issues for defense waste programs and storage of defense related contact-handled (CH) and remote-handled (RH) transuranic (TRU) waste.

In 1979, the DOE established a Site and Preliminary Design Validation (SPDV) Program to provide additional confidence in the siting and design of the WIPP facility. On July 1, 1981, the DOE entered into an agreement with the State of New Mexico whereby the DOE would perform certain work to validate the reference design of the WIPP underground openings. The results of the site validation portion of the program are presented in the report titled Results of Site Validation Experiments, Volumes I and II, TME document 3177, dated March 1983. The results of the preliminary design validation portion of the program are presented in the report Waste Isolation Pilot Plant Preliminary Design Validation Report, dated March 30, 1983.

Design validation of the WIPP is defined as the process by which the reference design of the underground openings is confirmed by determining the compatibility of the design criteria, design bases and reference design configurations using site specific information. The design validation process consists of an assessment of the condition and behavior of shafts, drifts and a full-sized, four-room test panel excavated during the SPDV Program and full WIPP construction. Based on this assessment of these excavations, and on predictions of their future behavior, any modifications to the design criteria, design bases or design configurations required to achieve a validated reference design will be developed. In addition, the validated reference design may be modified in the future as still more data and experience are gained during a 5-year demonstration period (period during which all waste must be retrievable) and permanent storage operations.

The WIPP Preliminary Design Validation Report was an interim report prepared as part of the overall validation of the WIPP underground opening reference design. The WIPP Design Validation Final Report contains additional information gathered after completion of the SPDV Program. This information has been analyzed and evaluated to complete the design validation process for the WIPP.

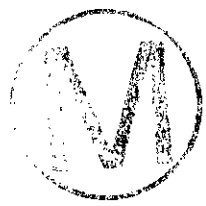
Four types of information were gathered for the WIPP Design Validation Final Report:

(1) observations of the behavior of the underground openings;
(2) descriptions of the geologic conditions encountered during underground construction;
(3) descriptions of core samples from instrumentation and other holes in the roof

and floor of the underground openings; and

(4) data from installed geomechanical instrumentation.

The design validation process provides for the collection, analysis and evaluation of in situ data. This process is designed to permit determination of the need to modify elements of the underground opening reference design so that construction and operation of the full facility can proceed in a timely, safe, environmentally acceptable and cost effective manner. Observation and instrumentation data have been collected and evaluated for each of the underground design elements. Tables I through VI at the end of this summary present the evaluation results for the design criteria, design bases and design configurations of the shafts and horizontal openings. . . ."



DOE (U.S. Department of Energy). 1988. Geotechnical Field Data Report and Analysis Report. DOE/WIPP 87-017. U.S. Department of Energy, Carlsbad, NM.

FOREWORD AND ACKNOWLEDGEMENTS;

" The Geotechnical Field Data and Analysis Report (GFDAR) is prepared to provide a timely assessment of the geotechnical status of the Waste Isolation Pilot Plant (WIPP). During the period of shaft sinking and construction of the principle underground access and experimental areas, reporting was on a quarterly basis. Because geotechnical responses of existing underground facilities have slowed to nearly steady-state and excavation of the waste storage panels will take place more slowly and over an extended period, reporting in the coming years will be on an annual cycle. Data collected before June 30 of the year of the report will be presented and analyzed. This report presents and analyzes all data collected between July 31, 1986, and June 30, 1987.

The two-volume format of the GFDAR was selected to meet the needs of several audiences. Volume I focuses on the performance of the various underground facilities including the three shafts, shaft stations, access drifts, test rooms, and waste storage areas. It provides a direct evaluation of the geotechnical aspects of performance in the context of the relevant design criteria. In addition, it provides, where possible, projections of the future performance of these facilities. The results of stratigraphic mapping and the occurrence of gas and brine are also documented. The depth and breadth of analysis for the different underground facilities varies according to the types and quantities of data that are available, and the complexity of the recorded geotechnical responses. The anticipated audience of this volume is primarily Project and external personnel who are interested in engineering aspects of facility performance.

Volume II constitutes the principle documentation and presentation of data and techniques used to acquire the data, the performance history of the instrumentation, and the complete set of data from each of the underground facilities. In addition, it presents the results of geologic logging, stratigraphic mapping, and mapping and evaluation of excavation-induced fractures. This volume has as its anticipated audience those Project personnel who need to perform data analyses beyond those provided in Volume I, and external personnel who may choose to perform other analyses and evaluations for their own purposes. Data tapes will be made available at nominal cost upon request to the U. S. Department of Energy (DOE) . . ."

DOE (U.S. Department of Energy). 1995. "Waste Isolation Pilot Plant Seal System Design Report," DOE/WIPP-95-3117. Carlsbad, NM.

ABSTRACT, p. iii;

" This report documents the Waste Isolation Pilot Plant shaft sealing system design. The seals are designed to limit the release of radionuclides and hazardous constituents from an underground nuclear waste repository in salt. Design concepts documents in this report will form the basis for no-migration variance petition modeling. In addition, these concepts are the basis for detailed sealing system design development and evaluations that will be completed in 1996 in support of the planned Compliance Certification Application. The report describes the geologic and hydrologic setting for the seals, presents qualitative and quantitative design guidance, describes the design, documents the sealing materials and their properties, and discusses evaluations of sealing system performance. The design uses a variety of common materials that have very low permeability, demonstrated technologies for construction processes, multiple components to perform each intended function, and the entire length of the shafts to effect a seal system that will meet the performance requirements. For the permanent or long-term seal that resists both gas and brine flow, more than 500 ft of highly compacted crushed salt is used in series with more than 400 ft of clay barriers. The design retards gas flow in the short term using a combination or a rigid concrete barrier (enhanced by an asphalt waterstop) and a compacted clay barrier approximately 100 ft high. Short-term brine flow down the shaft is limited by a clay barrier within the overlying formation and by a combination of more than 500 ft of asphalt, clay, and concrete barriers within the salt."

DOE (U.S. Department of Energy). 1995. Conceptual Design for Operational Phase Panel Closure Systems. DOE/WIPP-95-2057, U.S. Department of Energy, Carlsbad Area Office, Carlsbad, NM.

EXECUTIVE SUMMARY, p ES-i;

" The Waste Isolation Pilot Plant (WIPP), a U.S. Department of Energy (DOE) research facility located near Carlsbad, New Mexico, was established to demonstrate the safe disposal of defense-generated transuranic (TRU) waste. The WIPP repository is approximately 2,150 feet (ft) (655 meters [m]) below the surface in bedded salt. The WIPP facility includes a northern experimental area, a shaft-pillar area, and a waste-disposal area. The waste disposal area is comprised of panels, each of which consists of seven rooms and two access panel entries (Figure ES-1).

Following completion of waste emplacement in each panel, ventilation will be established in the next panel to be used and the panel containing the waste will be closed. The DOE will seek approval for 'partial closure' of each of the panels as they are sequentially filled with waste on a panel-by-panel basis. Partial closure is the process of rendering a part of the underground repository inactive and closed according to the approved facility closure plans.

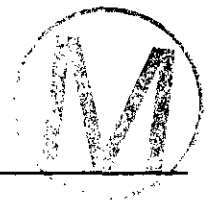
The plan covers administrative procedures deemed necessary by the U. S. Environmental Protection Agency (EPA) to provide assurance that individual panel closures are being achieved according to the New Mexico Administrative Code (NMAC) Resource Conservation and Recovery Act (RCRA) permit and as a condition of this permit. The partial closure plan will address requirements for future monitoring that are deemed necessary for the post closure period.

A review of existing literature on panel closure systems including the applicable design criteria for closure systems during the anticipated operational life of the facility of 35 years, was conducted. The literature review included panel barrier concepts and field testing as developed by the ONWI high-level waste program, the SNL WIPP Repository Sealing Program, and other panel barrier concepts. This information was reviewed because of it's application to showing compliance to quantitative flow standards during underground operations. The results of the literature review were presented to summarize previous panel barrier designs, and their application to WIPP. In addition, information on the disturbed rock zone (DRZ) (extent and permeability enhancement), potential fracturing of the Anhydrite MB139, and interface zone properties directly relevant to developing a conceptual design for panel closure systems is presented.

This report considers engineering designs such that the migration mass flow rate of hazardous constituents at the WIPP point of compliance will not exceed the environmental migration mass flow rate limit established for specific volatile organic compounds (VOCs) during the operational period. The performance criteria considers the point of compliance for the release of VOCs as the 16-section land withdrawal boundary. . . ."

ERDA (Energy Research and Development Administration). 1976. Management Guideline and Project Executive Assistance, Construction Management Plan.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.



Fernandez, J.A., Hinkebein, T.E., and Case, J.B. 1989. Selected Analyses to Evaluate the Effect of the Exploratory Shafts on Repository Performance at Yucca Mountain. SAND85-0598, Sandia National Laboratories, Albuquerque, NM.

ABSTRACT, p. 3;

" This report presents a number of analyses to determine whether the construction of two shafts associated with the exploratory shaft facility can significantly influence the long-term isolation capabilities of a high-level nuclear waste repository at Yucca Mountain, on and adjacent to the Nevada Test Site. Both shafts are planned to be located predominantly in fractured, welded tuff within the unsaturated zone. The calculational effort, using analytical solutions, focuses primarily on the potential influence of the shaft liner and the zone of increased rock damage around the shaft (termed in this paper the modified permeability zone, MPZ). Two mechanisms are considered in determining whether the MPZ can significantly enhance radionuclide releases. These mechanisms include water flow entering the exploratory shafts from both realistic and improbable scenarios and airflow exiting the shaft as a result of convective and barometric forces. The influence of the liner on the performance of the repository is determined by evaluating the potential chemical interaction between ground water and the concrete liner and the subsequent potential for precipitates to deposit within the MPZ and the shaft fill. It is concluded from these calculations and the current knowledge of the hydrology of the unsaturated zone at Yucca Mountain that the presence of the shafts and the associated MPZ and shaft liner do not significantly impact the long-term isolation capability of the repository. This conclusion is reached because both exploratory shafts will be collared in bedrock above and laterally away from the flood channel. This location makes it unlikely that significant amounts of water will enter the shaft even if a probable maximum flood occurs. Additionally, airflow out of the shaft can be controlled effectively by emplacement of shaft fill, and deposition of solids from the interaction of the shaft liner with the ground water is a localized phenomenon and should not significantly decrease the drainage capability of the rock at the base of the shaft. This report also (1) describes methods to remove the liner, to restore the MPZ, to emplace a seal, and to restore the exploratory shaft pad area in the event that future analyses suggest that further reduction of shaft inflow is necessary and (2) evaluates the impact on the sorption of the Calico Hills zeolites if the decision is made to sink the shaft into the Calico Hills unit."

Griswold, G.B., 1977. Site Selection and Evaluation Studies of the Waste Isolation Pilot Plant (WIPP), Los Medaños, Eddy County, NM. SAND77-0946. Sandia National Laboratories, Albuquerque, NM.

ABSTRACT, p. 3;

" Bedded-salt deposits of the Salado Formation have been selected for evaluation for a proposed Waste Isolation Pilot Plant (WIPP) to be located in Eddy County, NM, ~26 mi east of Carlsbad. Site selection and evaluation studies that included geologic mapping, geophysical surveys, drilling, and resource appraisal were conducted over and under the prospective location. The lower portion of the Salado meets essential criteria for waste isolation. Beds chosen for waste storage lie 2074-2730 ft below the surface. High-purity salt exists at these depths, and the geologic structure revealed by geophysical surveys indicates that these beds are essentially flat. Additional geophysical surveys are now under way. The initial interpretation of the new data indicates that more structure may exist in the salt beds in the northern portion of the site area. Full evaluation of potentially commercial deposits of potash and natural gas within the WIPP site will be reported by separate studies, as will be the hydrologic details of the region."

Nowak, E.J., and McTigue, D.F. 1987. Interim Results of Brine Transport Studies in the Waste Isolation Pilot Plant. SAND87-0880. Sandia National Laboratories, Albuquerque, NM.

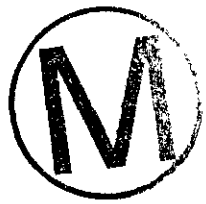
ABSTRACT, p i;

" It is important to have quantitative predictions of brine movement in a radioactive waste repository for performance assessment and for seal design evaluations. Experiments to quantify brine transport to boreholes in multi-heater, full scale tests simulating high level waste repository environments have been under way in the bedded salt of the Waste Isolation Pilot Plant (WIPP) since April, 1985. Water vapor released to the test boreholes has been collected in flowing nitrogen and weighed periodically. Before heating, water was collected during several days from four test boreholes at rates in the range of 5 to 15 g/day. This result highlights the need for an isothermal model for brine movement in the WIPP host rock salt. After heating began, the water collection rates rose to a peak, decreased, and then remained nearly constant for several hundred days. Subsequently, trends to decreasing rates have been observed. Cumulative quantities of water were 4.3 kg at 441 days from each of two boreholes in Room A1 (with a 470 W heater in each borehole) and 36 to 38 kg at 600 days from each of the two boreholes in Room B (with a 1500 W heater in each borehole). After the early transients, approximately 8 g/day/borehole were collected in Room A1, and 50 to 80 g/day/borehole were collected in Room B. These are much larger brine inflow rates than were observed during heated brine migration tests in the domal salt of the Asse mine in the Federal Republic of Germany. Results from in situ brine transport tests in domal salt are not necessarily applicable to bedded salt.

A preliminary analysis of the results was begun with a highly idealized fluid flow model for porous media. Our water collection data for unheated boreholes agreed reasonably well with the brine inflows that were calculated with this model. Agreement was attained using permeability and porosity values that are generally consistent with measured WIPP host rock properties. It was also shown that the WIPP experiments are well within the transient stage of this model. However, the temperature dependence of viscosity, when used in this model, is inadequate to account for the large water collection rates in the heated boreholes. Further model development and additional experiments are needed to understand brine movement in the WIPP, with and without sources of heat. Parametric studies of time, scale, and salt composition are needed. Measurements of pore pressure at intervals within a few meters of WIPP excavations were shown by the model analyses to be important for testing mechanistic hypotheses concerning brine transport. WIPP hydrologic and disturbed zone characterization studies can also contribute to our mechanistic understanding of brine transport to WIPP excavations."

ORNL (Oak Ridge National Laboratory). 1973. Site Selection Factors for the Embedded Salt Pilot Plant. ORNL-TM-4219. Oak Ridge National Laboratory, Oak Ridge, TN.

ABSTRACT, p 1;
" Because of the nature of radioactive waste disposal in geologic formations, the selection of suitable sites is a unique exercise totally different from that for any other type of facility. This compilation of the various factors which must be taken into consideration was assembled as an aid in the selection and confirmation of a site for the Bedded Salt Pilot Plant. As might be expected, most of these factors are related to geologic characteristics, which are discussed under the headings of: (1) stratigraphy, (2) structure, (3) hydrology, and (4) mineral resources. Other factors concerned with geography and facility design and operation are also included."



Pfeifle, T.W. and Brodsky, N.S. 1991. Swelling Pressure Water Uptake and Permeability of 70/30 Crushed Salt Bentonite. SAND91-7070. Sandia National Laboratories, Albuquerque, NM.

ABSTRACT, p i;

" Two experiments were conducted on specimens consisting of 70 percent by dry weight crushed salt and 30 percent by dry weight bentonite. The experiments included fifteen tests and were designed to measure the swell pressures induced by the introduction of saturated Brine A, a high Magnesium-content brine, and to measure permeability. Specimens of three dry densities were used: 1,600 $kg \bullet m^{-3}$, 1,800 $kg \bullet m^{-3}$, and 2,100 $kg \bullet m^{-3}$. Experiments were conducted in an oedometer which is a stiff pressure vessel designed to maintain specimens at constant volume. Ten durations ranged from 3 to 112 days.

When specimens were put into contact with brine, their swelling was inhibited by the oedometer, and the pressures that were required to restrict swelling were recorded. The mean peak pressures increased with density and were 0.5 MPa, 1.1 MPa, and 6.5 MPa for densities of 1,600 $kg \bullet m^{-3}$, 1,800 $kg \bullet m^{-3}$, and 2,100 $kg \bullet m^{-3}$, respectively. For tests at 1,600 $kg \bullet m^{-3}$ and 1,800 $kg \bullet m^{-3}$, the pressures peaked and then decayed to residual values. These residual values also increased with density and had mean values of 0.15 MPa and 0.37 MPa for densities of 1,600 $kg \bullet m^{-3}$ and 1,800 $kg \bullet m^{-3}$, respectively. The pressure never decayed for test at 2,100 $kg \bullet m^{-3}$ even though one test ran for 112 days.

Permeability measurements were made on specimens with densities of 1,600 $kg \bullet m^{-3}$ and 1,800 $kg \bullet m^{-3}$ using the constant hydraulic head, steady-state flow method. Flow was never established for the 2,100 $kg \bullet m^{-3}$ specimens. Including recent data, permeability changed approximately two orders of magnitude (from $1 \times 10^{-15} m^2$ to $1 \times 10^{-17} m^2$) as density increased from 1,600 $kg \bullet m^{-3}$ to 1,950 $kg \bullet m^{-3}$. Moisture content and distribution measurements were made on all specimens post-test. On the average, all specimens reached saturation; however, moisture content distributions were nonuniform in many specimens."

Sandia National Laboratories. 1992. Preliminary Performance Assessment for the Waste Isolation Pilot Plant, December 1992, Volume 3: Model Parameters. SAND92-0700/3, Sandia National Laboratories, WIPP Performance Assessment Division, Albuquerque, NM.

Volume 1: ABSTRACT, p i;

" Before disposing of transuranic wastes in the Waste Isolation Pilot Plant (WIPP), the United States Department of energy (DOE) must evaluate compliance with applicable long-term regulations of the United States Environmental Protection Agency (EPA). Sandia National Laboratories is conducting iterative performance assessments of the WIPP for the DOE to provide interim guidance while preparing for final compliance evaluations.

This volume contains an overview of WIPP performance assessment and a preliminary comparison with the long-term requirements of the *Environmental Radiation Protection Standards for Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes (40 CFR 191, Subpart B)*. Detailed information about the technical basis for the preliminary comparison is contained in Volume 2. The reference data base and values for input parameters used in the modeling system are contained in Volume 3. Uncertainty and sensitivity analyses related to 40 CFR 191B are contained in Volume 4. Volume 5 contains uncertainty and sensitivity analyses of gas and brine migration for undisturbed performance. Finally, guidance derived from the entire 1992 performance assessment is presented in Volume 6.

Results of the 1992 performance assessment are preliminary, and are not suitable for final comparison with 40 CFR 191, Subpart B. Portions of the modeling system and the data base remain incomplete, and the level of confidence in the performance estimates is not sufficient for a defensible compliance evaluation. Results are, however, suitable for providing guidance to the WIPP Project.

All results are conditional on the models and data used, and are presented for preliminary comparison to the Containment Requirements of 40 CFR 191, Subpart B as mean complimentary cumulative distribution functions (CCDFs) displaying estimated probabilistic releases of radionuclides to the accessible environment. Results compare three conceptual models for radionuclide transport in the Culebra Dolomite Member of the Rustler Formation and two approaches to estimating the probability of inadvertent human intrusion into the WIPP by exploratory drilling. The representation for disposal-system performance believed to be most realistic includes intrusion probabilities based on expert-panel judgement and dual-porosity transport with chemical retardation. For intrusions occurring 1000 years after decommissioning, the mean CCDF for this representation lies more than one order of magnitude below the EPA limits. Using the same approach to intrusion probabilities used in the 1991 performance assessment (i.e., not taking expert judgement into account and basing the probability model on the maximum intrusion probability indicated in Appendix B of 40 CFR 191, Subpart B) significantly increases the probability of releases, regardless of the model used for subsurface transport. Assuming the higher intrusion probabilities and dual-porosity transport without chemical retardation, the mean CCDF is approximately one order of magnitude below the EPA limits. For the higher intrusion probabilities and single-

porosity, fracture-only transport, the mean CCDF is less than one order of magnitude below the EPA limits."

Stormont, J.C., Howard, C.L., and Daemen, J.J.K. 1991. In Situ Measurements of Rock Salt Permeability Changes Due to a Nearby Excavation. SAND90-3134. Sandia National Laboratories, Albuquerque, NM.

ABSTRACT;

" The Small-Scale Mine-By was an in situ experiment to measure changes in brine and gas permeability of rock salt as a result of nearby excavation. A series of small-volume pressurize brine- and gas-filled test intervals were established 8 m beneath the floor of Room L1 in the WIPP underground. The test intervals were isolated in the bottom of the 4.8-cm diameter monitoring boreholes with inflatable rubber packers, and are initially pressurized to about 2 MPa.. Both brine- and gas-filled test intervals were located 1.25, 1.5, 2, 3, and 4 r from the center of a planned large-diameter hole, where r is the radius of the large-diameter hole. Prior to the drilling of the large-diameter borehole, the responses of both the brine- and gas-filled test intervals were consistent with the formation modeled as a very low permeability, low porosity porous medium with a significant pore (brine) pressure and no measurable gas permeability. The drilling of the mine-by borehole created a zone of dilated, partially saturated rock out to about 1.5 r. The formation pressure increases from near zero at 1.5 r to the pre-excavation value at 4 r. Injection tests reveal a gradient of brine permeabilities from 5 x $10^{-18}$ $m^2$ at 1.25 r to about the pre-excavation value ($10^{-21}m^2$) by 3 r. Gas-injection tests reveal measurable gas permeability is limited to within 1.5 r."

Stormont, J.C., Peterson, E.W., and Lagus, P.L. 1987. Summary and Observations about WIPP Facility Horizon Flow Measurements through 1986. SAND87-0176. Sandia National Laboratories, Albuquerque, NM.

ABSTRACT;

" Numerous gas flow measurements have been made at the Waste Isolation Pilot Plant (WIPP) facility horizon from 1984 through 1986. Almost all tests have been constant-pressure or pressure-decay tests from single boreholes drilled in the underground excavations. Results indicate that beyond about 2 m from an excavation, both halite and interbeds (anhydrite and clay layers) allowed very low gas flows, and calculated permeabilities are below 1 microdarcy. In regions within 2 m of an excavation, very high flow rates were measured in the interbeds immediately above and below an excavation when the test hole was drilled from near the center of the excavation. The halite also permits substantially greater gas flow within about 1 m of the excavations. Limited tracer measurements reveal that flow paths in both the halite and interbeds in the near field region are significantly larger than those in the presumed undisturbed condition. The gas flow measurements are consistent with the development of a (perhaps partially-saturated) dilitant zone (increased porosity) around the excavations. Considerable uncertainty is associated with permeabilities calculated from these flow measurements, due to unknowns of rock saturation, entry pressure effects, flow homogeneity, etc.

Observations based on these gas flow measurements will aid in understanding the behavior and response of rocks surrounding the WIPP Facility excavations. The implications of these measurements for seal design are useful, particularly in assessing the degree of seal bypass to expect in adjacent rock. Results suggest that seal be emplaced as soon as possible after excavation and in as narrow drifts as possible to minimize potential bypass. These data are also useful in separate studies of brine influx and gas generation/dissipation. Future measurements will focus on the development and extent of the disturbed zone, and on obtaining data which will make conversion of flow data to intrinsic permeabilities more defensible."

Stormont, J.C. 1991. "Gas Flow Measurements as Index Tests for the Disturbed Rock Zone," Memorandum to Distribution, Sandia National Laboratories, Albuquerque, NM.

NOTE: The above listed document was not available for inclusion in the Reference Expansion as of the printing date. Page changes will be provided as the above document becomes available for inclusion.

Stormont, J.C., 1988. Preliminary Seal Design Evaluation for the Waste Isolation Pilot Plant. SAND87-3083. Sandia National Laboratories, Albuquerque, NM.

ABSTRACT

" This report presents a preliminary evaluation of design concepts for the eventual sealing of the shafts, drifts, and boreholes at the Waste Isolation Pilot Plant Facility. The purpose of the seal systems is to limit the flow of water into, through, and out of the repository. . . ."

Westinghouse Electric Corporation. 1995. Conceptual Design for Operational Phase Panel Closure System. DOE/WIPP-Draft-2057. Closure and Post Closure Plans. Westinghouse Electric Corporation, Waste Isolation Division, Carlsbad, NM.

EXECUTIVE SUMMARY, p ES-i;

" The Waste Isolation Pilot Plant (WIPP), a U.S. Department of Energy (DOE) research facility located near Carlsbad, New Mexico, was established to demonstrate the safe disposal of defense-generated transuranic (TRU) waste. The WIPP repository is approximately 2,150 feet (ft) (655 meters [m]) below the surface in bedded salt. The WIPP facility includes a northern experimental area, a shaft-pillar area, and a waste-disposal area. The waste disposal area is comprised of panels, each of which consists of seven rooms and two access panel entries (Figure ES-1).

Following completion of waste emplacement in each panel, ventilation will be established in the next panel to be used and the panel containing the waste will be closed. The DOE will seek approval for 'partial closure' of each of the panels as they are sequentially filled with waste on a panel-by-panel basis. Partial closure is the process of rendering a part of the underground repository inactive and closed according to the approved facility closure plans.

The plan covers administrative procedures deemed necessary by the U. S. Environmental Protection Agency (EPA) to provide assurance that individual panel closures are being achieved according to the New Mexico Administrative Code (NMAC) Resource Conservation and Recovery Act (RCRA) permit and as a condition of this permit. The partial closure plan will address requirements for future monitoring that are deemed necessary for the post closure period.

A review of existing literature on panel closure systems including the applicable design criteria for closure systems during the anticipated operational life of the facility of 35 years, was conducted. The literature review included panel barrier concepts and field testing as developed by the ONWI high-level waste program, the SNL WIPP Repository Sealing Program, and other panel barrier concepts. This information was reviewed because of it's application to showing compliance to quantitative flow standards during underground operations. The results of the literature review were presented to summarize previous panel barrier designs, and their application to WIPP. In addition, information on the disturbed rock zone (DRZ) (extent and permeability enhancement), potential fracturing of the Anhydrite MB139, and interface zone properties directly relevant to developing a conceptual design for panel closure systems is presented.

This report considers engineering designs such that the migration mass flow rate of hazardous constituents at the WIPP point of compliance will not exceed the environmental migration mass flow rate limit established for specific volatile organic compounds (VOCs) during the operational period. The performance criteria considers the point of compliance for the release of VOCs as the 16-section land withdrawal boundary. . . ."

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