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STATUS OF WIPP COMPLIANCE WITH EPA 40 CFR 191, DECEMBER 1990*

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INTRODUCTION

The United States Department of Energy (DOE) is developing the Waste Isolation Pilot Plant (WIPP), located in southeastern New Mexico, for disposal of transuranic wastes generated by defense programs. The DOE must first demonstrate compliance with the Environmental Protection Agency's (EPA) *Environmental Standards for the Management and Disposal of Spent Nuclear Fuel, High-Level and Transuranic Radioactive Wastes* (40 CFR Part 191),[1] hereafter called the Standard. The Standard was vacated by a Federal Court of Appeals in 1987 and is undergoing revision; by agreement with the State of New Mexico the DOE will continue to evaluate repository performance with respect to the Standard as first promulgated until a new version is available.[2]

The Containment Requirements in Subpart B of the Standard set limits on the probability that cumulative radionuclide releases to the accessible environment during the 10,000 years following decommissioning of the repository will exceed certain limits. To comply with these requirements, performance assessments must construct a modeling system that can adequately simulate all realistic future states of the repository that might result in radionuclide releases. Because the regulatory limits are probabilistic, performance assessments must accurately reflect variability and uncertainty within all factors that contribute to the simulation, including variability in material properties, probabilities of future human actions, and uncertainties inherent in the conceptual and numerical models that simulate reality.

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This paper describes conceptual and numerical improvements in the performance-assessment methodology made during 1990, and summarizes the present status of WIPP performance assessment. All results to date are preliminary, and cannot be used to determine compliance or non-compliance. The DOE anticipates determining compliance after evaluating a final performance assessment in 1994.

DESCRIPTION OF WORK

Preliminary analyses indicate that compliance with the Standard appears certain as long as the repository remains undisturbed.[3] These analyses will be repeated when better models and an expanded database permit more accurate simulations. Because present predictions indicate that no radionuclides whatsoever will be released from the undisturbed repository to the accessible environment within 10,000 years, it is unlikely that revised predictions will cast doubt on compliance with those sections of the Standard that regulate undisturbed performance.

Performance assessments presently concentrate on inadvertent human intrusion, which has been recognized as the only event likely to lead to radionuclide releases in excess of regulatory limits. Figure 1 illustrates a representative intrusion scenario, in which a borehole penetrates both the repository and a hypothetical pressurized brine reservoir in the Castile Formation underlying the Salado Formation that hosts the repository. Radionuclides could be released during drilling, when cuttings and material eroded from the borehole wall are carried to the ground surface by circulating drilling fluid. Radionuclides could also reach the accessible environment, as defined by the Standard, in the subsurface, following lateral transport in groundwater in the Culebra Dolomite Member of the Rustler Formation overlying the repository. Intrusion scenarios are also considered in which a brine reservoir is not present or not penetrated. Formally evaluating compliance will require considering all realistic scenarios,[4] including those involving multiple intrusions. Final probabilities for scenarios have not yet been estimated.

Research emphasizes identifying those aspects of the database and modeling systems where uncertainties and variabilities have the greatest potential to influence compliance. Uncertainty and sensitivity analyses use the Latin Hypercube Sampling technique followed by stepwise regression analysis.[5] In other sensitivity analyses, specific parameter groups are assigned fixed values corresponding to extreme and median values and all other parameters in the database are sampled probabilistically over the full range of possible values. Results are assembled into complementary cumulative distribution function (CCDF) plots of probability versus 10,000-year cumulative radionuclide release, as recommended in the guidance to the Standard. The technique isolates effects of variations in parameter groups (conceptual models) on predicted performance. Priorities can then be set for future model and database research.

The process is iterative. Computational problems have been simplified by the development of CAMCON (Compliance Assessment Methodology CONtroller),[6] a software controller that links modeling programs for various components. CAMCON enables multiple Monte Carlo simulations that apply the entire modeling system to specific questions. As problems are resolved, new models and data are incorporated into the system for subsequent simulations. Biannual, preliminary performance assessments build toward the final compliance evaluation. Simulations prior to 1994 may not be comprehensive, but each preliminary assessment should resolve particular problems and improve the capability of the system to accurately and credibly predict repository performance.

RESULTS

Before the Standard was available, WIPP performance was predicted deterministically with fixed, conservative values for selected parameters.[7] Research for these calculations developed much of the present database and provided valuable guidance for subsequent probabilistic performance-assessment modeling.

Early probabilistic analyses, designed to demonstrate the methodology that would ultimately be used for compliance evaluation, resulted in CCDF plots that were weighted combinations of selected scenarios (Figure 2).[3] These plots are not suitable for determining compliance. Probabilities assigned to the various scenarios were preliminary, the database was incomplete, and models for several components were inadequate or unavailable. Two useful conclusions could be drawn from the results. First, the database and models available at that time were not adequate for determining compliance of the "reference design" disposal system following human intrusion. Second, the calculations indicated that, if necessary, modifications that restrict the flow of brine through the waste can effectively improve predicted performance. Future analyses will assess potential benefits from specific modifications, and results will be used to assist in determining the need, if any, for modifications to the present design of the disposal system.

More recent probabilistic analyses reflect changes in the database and models (Figure 3). The database was expanded to include an updated waste inventory and the results of new research. Direct releases at the ground surface, which in the past had been approximated using a fixed value, were calculated probabilistically using a helical flow model for erosion and transport of waste by circulating drilling fluid that permits simulating the effects of variations in waste shear strength. Flow and radionuclide transport within the Culebra Dolomite Member were simulated with the two-dimensional code SWIFT II[8] for ground-water flow, instead of the earlier one-dimensional model, and included effects of retardation in clays. Integrated cumulative releases are shown for a subsurface accessible environment defined at a radius of 2.5 km (an approximation of the land-withdrawal boundary for the WIPP), instead of the 5 km boundary used previously. The Standard defines the boundary of the subsurface accessible environment only to be "no more than" 5 km from the waste panel.[1]

Results show a reduction in cumulative releases, largely because of radionuclide retardation by clays. Comparison of the CCDF plots calculated with and without radionuclide releases at the ground surface during drilling indicates that direct releases have a significant

effect on the high probability, low summed normalized release, portion of the curve. As with the earlier plots, the EPA containment requirements are shown merely as reference points. These preliminary plots are not suitable for determining compliance, and the shift in curve location should be interpreted primarily as an indicator of the sensitivity of the system to refinements in modeling and changes in the database.

Analyses in progress emphasize uncertainties related to conceptual and numerical models. Specifically, flow in the Culebra Dolomite Member is modeled over regional and local domains, with boundary conditions for the local domain defined by regional simulations. The SWIFT II ground-water flow code has been replaced by SECO, designed in part to facilitate local area simulations within a larger regional grid.[9] Both single-porosity fracture flow and dual-porosity fracture-plus-matrix flow are considered. The two-dimensional finite element code STAFF2D[10] simulates radionuclide transport. Boundary conditions of the regional grid are varied to approximate variable recharge related to possible future climate changes and to incorporate uncertainties along the low-flux eastern and southern boundaries. Uncertainty in the transmissivity field is managed with simple zonal fields derived directly from either the well data or a kriged and subjectively calibrated transmissivity field.[11] Future modeling systems will incorporate geostatistical techniques for including residual uncertainty directly into the modeling system.

CONCLUSIONS

Performance-assessment work for the WIPP currently concentrates on improving the modeling system, expanding the database, and improving capability to predict repository performance. All results to date are preliminary, and final evaluation of compliance with the Standard is not anticipated until 1994.

Performance assessment for the WIPP is the first attempt to show compliance with the Standard for a real site. Although some aspects of WIPP performance are specific to

transuranic waste and do not apply to high-level waste repositories, the basic methodology for constructing credible probabilistic assessments can be used for all facilities that must comply with the Standard. Problems presently confronting the WIPP performance assessment, including uncertainties in conceptual and numerical models and an incomplete database, will be encountered in all performance-assessment efforts.

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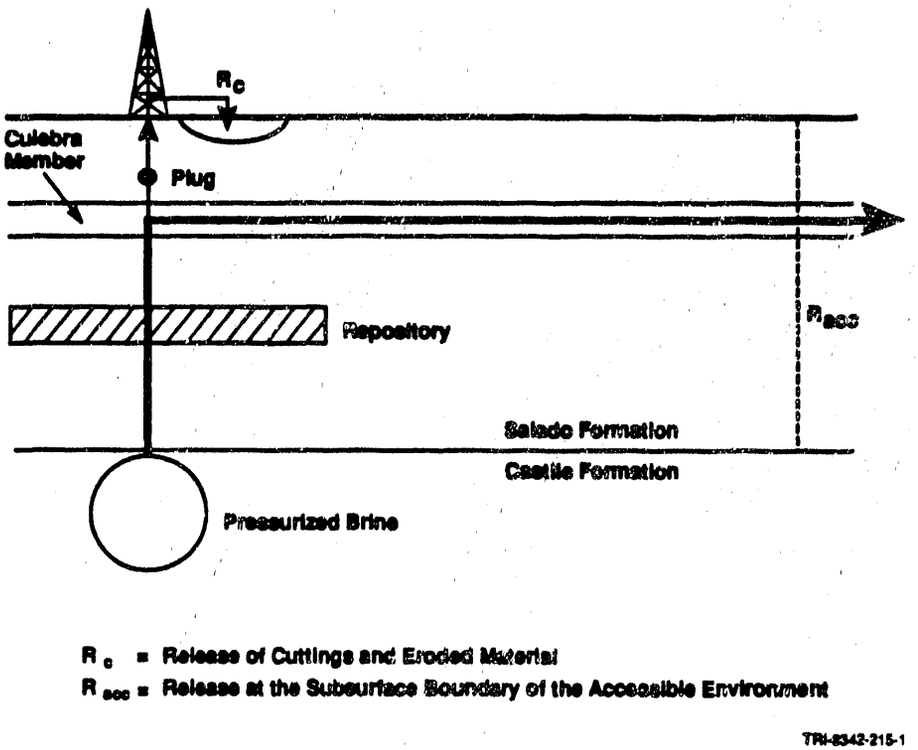

FIG. 1. Conceptual model for representative borehole intrusion scenario. Arrows indicate assumed direction and relative magnitude of flow.[3]

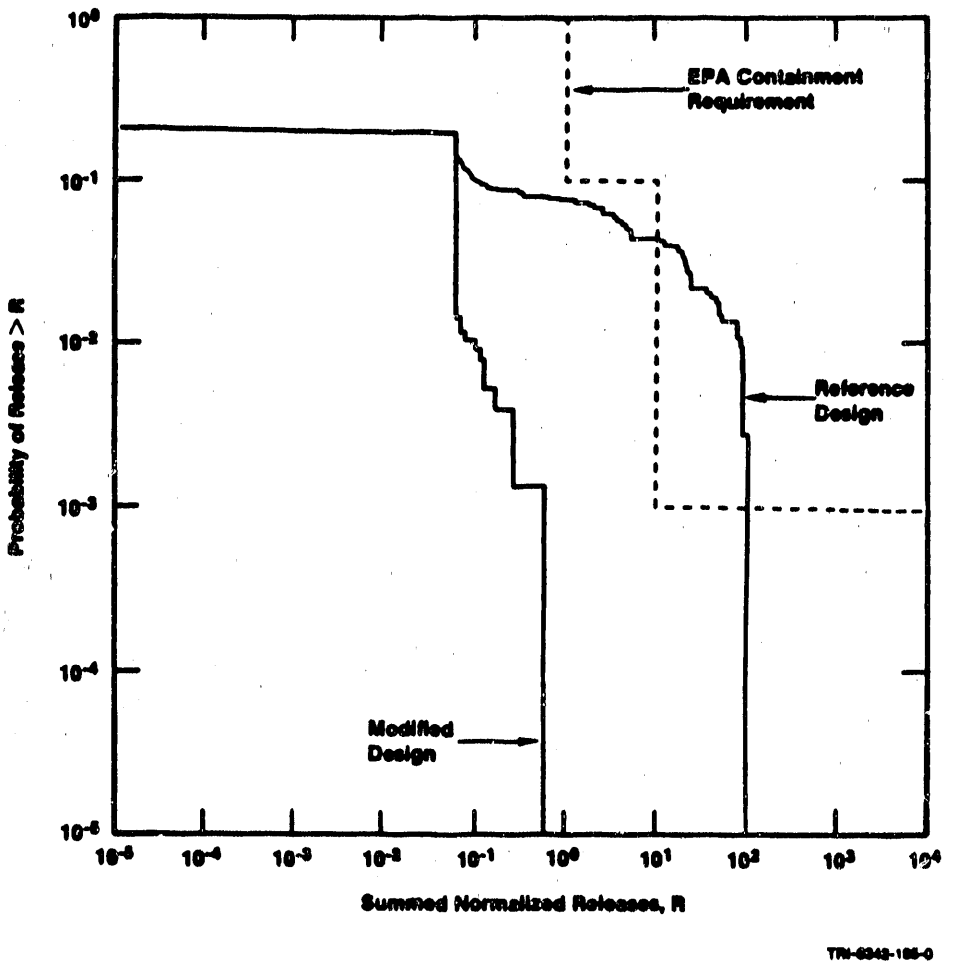

FIG. 2. Two 1989 methodology demonstration CCDFs, each constructed from 50 simulations per scenario for seven scenarios (an undisturbed base case and six borehole intrusion scenarios).[3] Shift in curve location shows the potential effect of modifying waste form to reduce porosity and permeability. Calculations were made using preliminary models, an incomplete database, and preliminary scenario probabilities, and cannot be used to determine regulatory compliance.

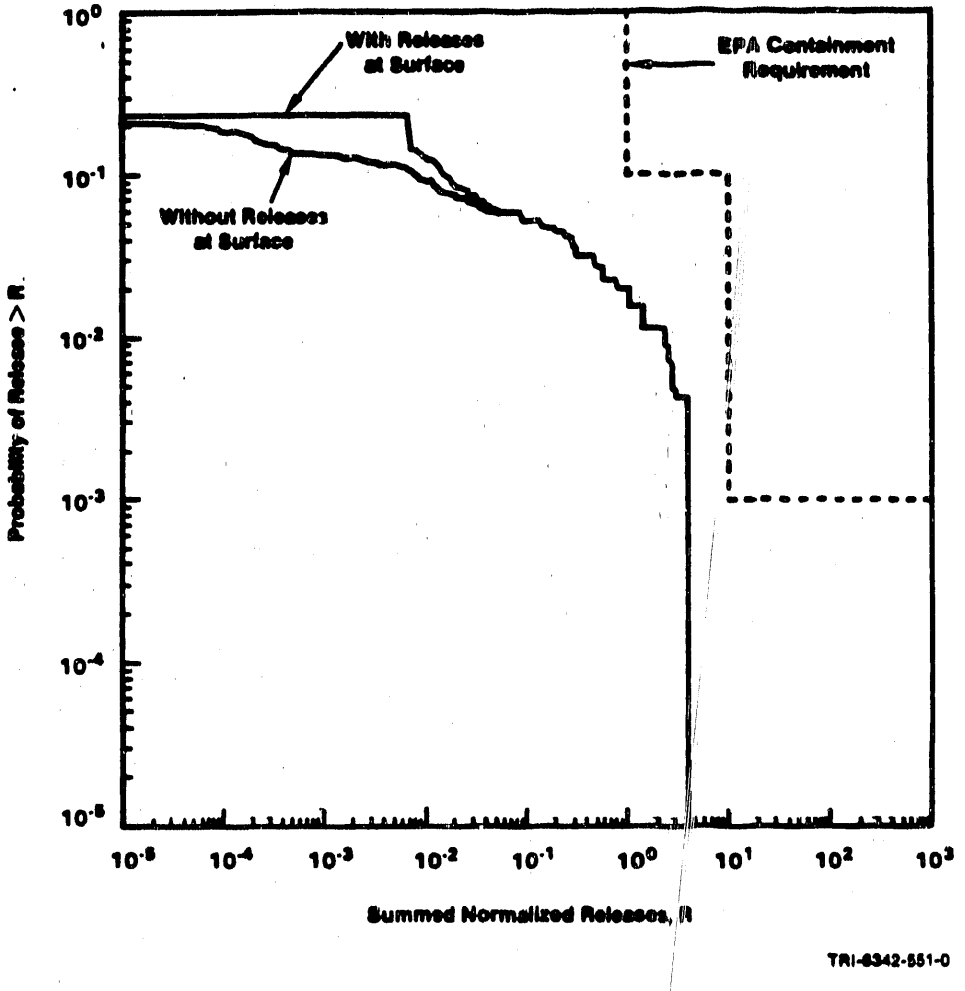

FIG. 3. Two 1990 preliminary performance assessment CCDFs showing predicted performance of the repository assuming present reference design. Curves are constructed from 50 simulations per scenario for four scenarios (an undisturbed base case and three representative borehole intrusion scenarios). Curves show relative importance of direct releases at the ground surface during drilling. Curves reflect improvements in models and database over earlier simulations, but results are still preliminary and cannot be used to determine regulatory compliance.

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